OFFICE OF RIVER PROTECTION
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

AUG 14 2015

15-ECD-0038

Ms. Jane A. Hedges, Program Manager
Nuclear Waste Program
Washington State
Department of Ecology
3100 Port of Benton Blvd.
Richland, Washington 99354

Ms. Hedges:

SUBMITTAL OF DANGEROUS WASTE DESIGN PACKAGE LAW-025, REV. 0, FOR THE LOW-ACTIVITY WASTE FACILITY THERMAL CATALYTIC OXIDIZER/SELECTIVE CATALYTIC REDUCER

Reference: WA7890008967, "Dangerous Waste Portion of the Hanford Facility Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste, Part III, Operating Unit 10, 'Waste Treatment and Immobilization Plant.'"

This letter transmits the Low-Activity Waste (LAW) Facility dangerous waste permit (DWP) design package, Thermal Catalytic Oxidizer (TCO)/Selective Catalytic Reducer, LAW-025, Rev. 0 (Attachment 1). This permit design package provides design information for the LAW Miscellaneous Unit made up of the TCO, the NOx Selective Catalytic Reducer (SCR), the Electric Heater, and the Heat Exchanger that are collectively known as TCO/SCR and located on LVP-SKID-00002. The TCO/SCR is part of the LAW secondary offgas/vessel vent process melter offgas system.

Attachment 1 also provides the design information that is necessary for the Washington State Department of Ecology (Ecology) to confirm the structures, systems, and components that are described in the permit package. This will comply with the Reference and will allow Ecology to permit the installation of the LVP-SKID-00002.

This permit design package submittal is certified coincident with issuance of the integrity assessment report contained in the package. Permit-affecting design changes not included in or occurring after issuance of the final integrity assessment report will be processed in accordance with DWP requirements for permit modifications. The installation of equipment and components will be done in accordance with permit packages that are approved and incorporated into the DWP by Ecology.

Attachment 2 provides the U.S. Department of Energy, Office of River Protection and Bechtel National, Inc.'s certifications.

Ecology has reviewed the package and comments have been dispositioned.

If you have any questions, please contact me, or your staff may contact Gae M. Neath, Environmental Compliance Division, (509) 376-7828.

Kevin W. Smith, Manager
Office of River Protection

ECD:GMN

Attachments: (2)

cc w/attachs:
B.L. Curn, BNI
B.G. Erlandson, BNI
S. Greagor, BNI
M. McCullough, BNI
S.K. Murdock, BNI
D.C. Robertson, BNI
Administrative Record (WTP H-0-8)
BNI Correspondence
Environmental Portal, LMSI

cc w/o attachs:
J. Cox, CTUIR
S.G. Harris, CTUIR
S.L. Dahl, Ecology
D. McDonald, Ecology
G.P. Bohnee, NPT
K. Niles, Oregon Energy
E.D. MacAlister, RL
R. Jim, YN

cc electronic:
J. Cantu, Ecology (2 hard copies)
A.S. Carlson, Ecology (6 hard copies, Public Review)
T.Z. Gao, Ecology
M.E. Jones, Ecology
J.K. Perry, MSA
A.C. McKarns, RL
D.J. Sommer, SCS

Attachment 1
15-ECD-0038
(1725 Pages)

Dangerous Waste Permit Package LAW-025, Rev. 0,
Thermal Catalytic Oxidizer/Selective Catalytic Reducer

DANGEROUS WASTE PERMIT PACKAGE, THERMAL CATALYTIC OXIDIZER/SELECTIVE CATALYTIC REDUCER, LAW-025, REVISION 0, DESCRIPTION

LAW-025, Rev. 0, "Miscellaneous Unit for LAW Facility LVP System (Thermal Catalytic Oxidizer, NOx Selective Catalytic Reducer, Electric Heater, and Heat Exchanger located on LVP-SKID-00002)"

The low-activity waste (LAW) vitrification facility permit package LAW-025 addresses design of the thermal catalytic oxidizer, NOx selective catalytic reducer, electric heater, and heat exchanger skid miscellaneous unit system which is part of the LAW secondary offgas/vessel vent process system (LVP). The skid, LVP-SKID-00002, is located in room L-304F at elevation 48 ft.

In the LVP system, melter offgas is combined with vessel vent offgas and heated in the melter offgas HEPA preheaters to raise the offgas above the dew point. The heated offgas then passes through HEPA filters to remove particulates. The offgas is next treated to remove mercury, iodine, and acid gasses (primarily hydrogen chloride and hydrogen fluoride) by activated carbon adsorption units.

The offgas then passes through a recuperative heat exchanger, electric heater, catalytic oxidation unit, and catalytic reduction unit (LVP-SKID-00002). The catalytic oxidation unit oxidizes volatile organic compounds and carbon monoxide into water and carbon dioxide. The heat recovery exchange first raises the offgas temperature using the hot offgas from the catalyst beds. The electric heater is used to supplement the heat exchanger during start-up and when operating with low NOx concentrations. The heated offgas is passed through the VOC catalyst to oxidize VOCs and carbon monoxide to carbon dioxide and water vapor and reduces oxides of nitrogen to nitrogen and water using ammonia. This reduction reaction is exothermic, and significantly increases the offgas temperatures. The outgoing hot offgas is then cooled down in the heat exchanger that concurrently serves as the heating media for the incoming offgas.

The cooled offgas is then directed through the LAW melter offgas caustic scrubber for final cooling and to remove residual acid gasses (primarily sulfur oxides and carbon dioxide) and to provide offgas cooling. Effluent from the LAW melter offgas caustic scrubber is recirculated through the LAW caustic collection tank (LVP-TK-00001). Exhausters (also termed blowers or fans) provide the motive force for the offgas. The treated offgas is discharged to the atmosphere through the LAW stack.

Permit package LAW-025, Rev. 0, includes:

- An assessment report signed by an independent qualified registered professional engineer (IQRPE) certifying that the TCO/SCR is adequately designed and will not collapse, rupture, or fail as provided in WAC-173-303-640(2)(c)
- General Arrangement Plan
- Piping and Instrumentation Diagram
- Mechanical drawings for the thermal catalytic oxidizer/reducer with heat exchanger and electric heater
- Engineering specification for pressure vessel design and fabrication

- Engineering specification for the thermal catalytic oxidizers/reducer with heat exchanger and electric heater
- Engineering specification for pressure vessel design and fabrication
- Mechanical data sheet for the LAW catalytic oxidizer/reducer (with heat exchanger and electric heater)
- Corrosion evaluations for the:
  - Catalytic oxidizer heat recovery exchanger
  - Catalytic oxidizer electric heater
  - Thermal catalytic oxidizer
  - NOx selective catalytic reducer

The following documents are provided for incorporation into the Administrative record:

- Mass and energy balance document
- Prevention of hydrogen accumulation documentation

The following components of this package are already included in the Dangerous Waste Permit, the Administrative Record, or are provided with other permit packages, as listed in the Table of Contents:

- A process flow diagram for the LVP system
- Process flow diagram change notices for the LVP system
- Engineering specifications for:
  - Positive material identification (PMI)
  - Seismic qualification criteria for pressure vessels
- A document describing secondary containment design
- A revised document describing the LAW vitrification offgas system bypass analysis
- A document describing the installation of tank systems and miscellaneous unit systems
- A system description for LOP and LVP: LAW Melter Offgas
- System description change notices
- Material and energy balance documents
- A document describing the control of toxic vapors and emissions from WTP tank systems and miscellaneous treatment unit systems

Design Package No. LAW-025, Rev. 0 CCN 277127
Miscellaneous Unit for LAW Facility LVP System
(Thermal Catalytic Oxidizer, Selective Catalytic Reducer, Electric Heater, and Heat Exchanger Skid)
Table of Contents

July 9, 2015

For Incorporation into the Permit

Engineering Document	Document Number	Revision	Permit Conditions	Included	Remarks
IQRPE Independent Assessment Report	24590-CM-HC4-HXYG-00240-02-00012	00A	III.10.H.5.c.i	Y	Incorporate into Appendix 9.11
Permit Drawings					
LAW Vitrification Building General Arrangement Plan at El. 48 ft – 0 in.	24590-LAW-P1-P01T-00005	5	III.10.H.5.c.ii	Y	Incorporate into Appendix 9.4
Process Flow Diagram - LAW Vitrification Secondary Offgas Treatment (System LVP)	24590-LAW-M5-V17T-00011	5	III.10.H.5.c.ii	N	In Appendix 9.1
PFD Drawing Change Notices	24590-LAW-M5N-V17T-00012 24590-LAW-M5N-V17T-00019 24590-LAW-M5N-V17T-00023 24590-LAW-M5N-V17T-00029	N/A	III.10.H.5.c.ii	N	In Appendix 9.1
Piping & Instrumentation Diagram P&ID - LAW - LAW Secondary Offgas/Vessel Vent Process System SCO/SCR Skid	24590-LAW-M6-LVP-00005002	2	III.10.H.5.c.ii	Y	Incorporate into Appendix 9.2
Mechanical Drawings LAW Thermal Catalytic Oxidizer - TCO General Arrangement	24590-CD-POC-MBT0-00007-01-00353, Sheet 1 of 4 24590-CD-POC-MBT0-00007-01-00353, Sheet 2 of 4 24590-CD-POC-MBT0-00007-01-00353, Sheet 3 of 4 24590-CD-POC-MBT0-00007-01-00353, Sheet 4of 4	00C 00C 00C 00C	III.10.H.5.c.ii	Y	Incorporate into Appendix 9.6

Design Package No. LAW-025, Rev. 0 CCN 277127
Miscellaneous Unit for LAW Facility LVP System
(Thermal Catalytic Oxidizer, Selective Catalytic Reducer, Electric Heater, and Heat Exchanger Skid)
Table of Contents

For Incorporation into the Permit

Engineering Document	Document Number	Revision	Permit Conditions	Included	Remarks
Engineering Specifications					
Engineering Specification for LAW Thermal Catalytic Oxidizers/Reducers (with Heat Exchanger and Electric Heater)	24590-LAW-3PS-MBTV-T0001	4	III.10.H.5.c.ii III.10.H.5.c.iii	Y	Incorporate into Appendix 9.7
SDDR for code year reference for ASME Section VIII B & PVC listed in Engineering Specification for LAW TCO/SCR	24590-WTP-SDDR-MS-15-00017	N/A	III.10.H.5.c.ii III.10.H.5.c.iii	N	Provided to Ecology in CCN275838
SDDR for thermowell testing for the LAW TCO/SCR	24590-WTP-SDDR-MS-15-00030	N/A	III.10.H.5.c.ii III.10.H.5.c.iii	N	Provided to Ecology in CCN 275847
Engineering Specification for Positive Material Identification (PMI) for Shop Fabrication	24590-WTP-3PS-G000-T0002	9	III.10.H.5.c.ii III.10.H.5.c.iii	N	In Appendix 7.7
Engineering Specification for Pressure Vessel Design and Fabrication	24590-WTP-3PS-MV00-T0001	5	III.10.H.5.c.ii III.10.H.5.c.iii	Y	Incorporate into Appendix 7.7
Engineering Specification for Seismic Qualification Criteria for Pressure Vessels	24590-WTP-3PS-MV00-T0002	3	III.10.H.5.c.ii III.10.H.5.c.iii	N	In Appendix 7.7
Mechanical Data Sheet and other Permit documentation					
Mechanical Data Sheet - LAW Catalytic Oxidizer/Reducer	24590-LAW-MKD-LVP-00012	14	III.10.H.5.c.ii III.10.H.5.c.iii	Y	Incorporate into Appendix 9.6
Secondary Containment Design	24590-WTP-PER-CSA-02-001	10	III.10.H.5.c.ii III.10.H.5.c.iii	N	In Appendix 7.5
Underground Pipe Protection	Not applicable	-	III.10.H.5.c.iv	N	There are no underground pipes in the LAW facility El. 3 ft and above
Corrosion Evaluations and other Permit documentation					
LVP-HX-00001 - Catalytic Oxidizer Heat Recovery Exchanger	24590-LAW-N1D-LVP-00005	3	III.10.H.5.c.v	Y	Incorporate into Appendix 9.9

Design Package No. LAW-025, Rev. 0 CCN 277127
Miscellaneous Unit for LAW Facility LVP System
(Thermal Catalytic Oxidizer, Selective Catalytic Reducer, Electric Heater, and Heat Exchanger Skid)
Table of Contents

For Incorporation into the Permit

Engineering Document	Document Number	Revision	Permit Conditions	Included	Remarks
LVP-HTR-00002 - Catalytic Oxidizer Electric Heater	24590-LAW-N1D-LVP-00006	3		Y	Incorporate into Appendix 9.9
LVP-SCO-00001 - Thermal Catalytic Oxidizer	24590-LAW-N1D-LVP-00007	4		Y	Incorporate into Appendix 9.9
LVP_SCR-00001 - NOx Selective Catalytic. Oxidizer	24590-LAW-N1D-LVP-00008	3		Y	Incorporate into Appendix 9.9
LAW Vitrification Offgas System Bypass Analysis	24590-LAW-PER-PR-03-001	2	III.10.H.5.c.ix	N	In Appendix 9.18
Installation of Tank Systems and Miscellaneous Unit Systems	24590-WTP-PER-CON-02-001	6	III.10.H.5.c.x	N	In Appendix 7.12

For Incorporation into the Administrative Record

Engineering Document	Document Number	Revision	Permit Condition	Included	Remarks
Structural Support Calculations for Off Spec, Non-Standard or Field Fabricated Miscellaneous Treatment Subsystems	Not Applicable - See Remarks	-	III.10.H.5.c.iii	N	There are no Off Spec, Non-Standard or Field Fabricated Miscellaneous Treatment in the LAW facility
System Description for the Law Primary Offgas (LOP) and Secondary Offgas/Vessel Vent (LVP) Systems	24590-LAW-3YD-LOP-00001	3	III.10.H.5.c.vii	N	In Administrative Record
System Description Change Notices against the Law Primary Offgas (LOP) and Secondary Offgas/Vessel Vent (LVP) Systems	24590-LAW-3YN-LOP-00011		III.10.H.5.c.vii	N	Provided to Ecology in CCN 233560
	24590-LAW-3YN-LOP-00012		III.10.H.5.c.vii	N	Provided to Ecology in CCN 241650
	24590-LAW-3YN-LOP-00013		III.10.H.5.c.vii	N	Provided to Ecology in CCN 241672
	24590-LAW-3YN-LOP-00015		III.10.H.5.c.vii	N	Provided to Ecology in CCN 261722

Mass and Energy Balance					Incorporate into Administrative Record
Flowsheet Bases, Assumptions, and Requirements	24590-WTP-RPT-PT-02-005	7	III.10.H.5.c.viii	Y	Incorporate into Administrative Record
2010 WTP Material Balance and Steady State Flowsheet Assessment, Deliverable 2.7	24590-WTP-RPT-PET-10-022	0		N	In Administrative Record (CCN 241137)
Steady-State (AES) Model Run Report for 2010 Material Balance and Process Flowsheet Analysis Assessment Report	24590-WTP-MRR-PET-10-010	0		N	In Administrative Record (CCN 241137)
Control of Toxic Vapors and Emissions from WTP Tank Systems and Miscellaneous Treatment Unit Systems	24590-WTP-PER-PR-03-002	3	III.10.H.5.c.xi	N	In Administrative Record (CCN 161097)
Prevention of Hydrogen Accumulation	LAW Miscellaneous Treatment Unit Hydrogen Accumulation Document for the DWP Administrative Record (CCN 280210)	N/A	III.10.H.5.c.xii	Y	Incorporate into Administrative Record

ISSUED BY
RPP-WTP PDC

R11727186

AREVA

AFS-15-0238

June 29, 2015

Ms. Tess Klatt
Subcontract Administrator
Bechtel National, Inc.
2435 Stevens Center Place
Richland, Washington 99354

Dear Ms. Klatt:

BECHTEL NATIONAL, INC. CONTRACT NO. 24590-CM-HC4-HXYG-00240 IQRPE STRUCTURAL INTEGRITY ASSESSMENT REPORT FOR LAW LVP THERMAL CATALYTIC OXIDIZER/REDUCER (TCO Unit) (IA-3013146-000)

The integrity assessment of the subject LAW LVP Thermal Catalytic Oxidizer/Reducer (TCO Unit) has been completed per the contract requirements and is enclosed for your use. The assessment found that the design is sufficient to ensure that the LAW LVP Thermal Catalytic Oxidizer/Reducer (TCO Unit) is adequately designed and has sufficient structural strength, compatibility with the waste(s) to be processed/stored/treated, and corrosion protection to ensure that it will not collapse, rupture, or fail.

If you have any questions, please contact Tarlok Hundal at (509) 371-1975, or via email at tarlok.hundal@areva.com.

Sincerely,

Elizabeth W. Smith, C.P.M
Contract Administrator
AREVA Federal Services LLC
Richland Office

Enclosure (1)

LP

cc: D. C. Pfluger, MS5-I w/enclosure (2)

24590-CM-HC4-HXYG-00240-02-00012 Rev. 00A

IQRPE STRUCTURAL INTEGRITY ASSESSMENT REPORT
FOR
LAW LVP THERMAL CATALYTIC OXIDIZER/REDUCER (TCO Unit)

Please note that source, special nuclear and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the U.S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts; that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

IQRPE STRUCTURAL INTEGRITY ASSESSMENT REPORT
FOR
LAW LVP THERMAL CATALYTIC OXIDIZER/REDUCER (TCO Unit)

"I, Tarlok Singh Hundal, have reviewed and certified a portion of the design of a new tank system or component located at the Hanford Waste Treatment Plant, owned/operated by Department of Energy, Office of River Protection, Richland, Washington. My duties were independent review of the current design for the LAW LVP Thermal Catalytic Oxidizer/Reducer (TCO Unit), as required by the Washington Administrative Code, *Dangerous Waste Regulations*, Section WAC-173-303-640(3) (a) through (g) applicable components."

"I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment."

The documentation reviewed indicates that the design fully satisfies the requirements of the WAC.

The attached review is twelve (12) pages numbered one (1) through eleven (12).

T S Hundal
Signature

6/29/2015
Date

Scope	Scope of this Integrity Assessment	The scope of this integrity assessment includes LAW Catalytic Oxidizer/Reducer Miscelleneous Units, collectively known as Thermal Catalytic/Oxidizer (TCO Unit). This TCO Unit houses four subcomponents namely VOC Catalyst Oxidizer (LVP-SCO-00001), Selective Catalyst Reducer (LVP-SCR-00001), Electric Heater (LVP-HTR-00002), and Heat Recovery Exchanger (LVP-HX-00001). The TCO Unit associated with the LVP system is shown on the Process Flow Diagram 24590-LAW-M5-V17T-00011. The LAW LVP system receives melter offgas from the Primary Offgas System (LOP) and its primary safety function is to ensure containment of hazardous gases within the system. The offgas stream has potentially high levels of Oxides of Nitrogen (NO_x) and Volatile Organic Compounds (VOCs). The LAW TCO unit's catalysts remove VOCs and NO_x compounds from the offgas, before further processing in caustic scrubber and exhausters prior to release via discharge stack. The TCO Unit is mounted on a skid (LVP-SKID-00002) located in Room L-0304F at Floor Elevation 48'-0" of the LAW facility as shown on General Arrangement Plan drawing 24590-LAW-P1-P01T-00005.
	Summary of Assessment	For each item of "Information Assessed" (i.e., Criteria) on the following pages, the documents listed under "Source of Information" were reviewed and found to furnish adequate design requirements and controls to ensure that the design fully satisfies the requirements of Washington Administrative Code (WAC), Chapter 173-303 WAC, *Dangerous Waste Regulations*, Section WAC-173-303-640 (3) (a) through (g) applicable elements of the *Tank Systems*.

References	Material Requisition, Specifications, and Plant Drawings	Material Requisition (MR): 24590-QL-MRA-MBT0-00007, Rev. 3, Oxidizers, Thermal Catalytic LAW. Specifications: The following Specifications with their respective revision and Specification Change Notices (SCNs) are listed in the above listed MR, except as marked with asterisk *: 24590-LAW-3PS-MBTV-T0001, Engineering Specification for LAW Thermal Catalytic Oxidizer/Reducer; 24590-WTP-3PS-MV00-T0001, Engineering Specification for Pressure Vessel Design and Fabrication; *24590-WTP-3PS-MV00-T0002, Engineering Specification for Seismic Qualification Criteria for Pressure Vessels; *24590-WTP-3PS-MV00-T0003, Engineering Specification for Fatigue Analysis of Pressure Vessels; 24590-WTP-3PS-MVB2-T0001, Engineering Specification for Welding of Pressure Vessels, Heat Exchangers, and Boilers; 24590-WTP-3PS-G000-T0002, Engineering Specification for Positive Material Identification (PMI) for Shop Fabrication; 24590-WTP-3PS-G000-T0003, Engineering Specification for Packaging, Handling, and Storage Requirements; *24590-WTP-3PS-FB01-T0001, Engineering Specification for Structural Design Loads for Seismic Category III & IV Equipment and Tanks; 24590-WTP-3PS-SS00-T0001, Engineering Specification for Welding of Structural Carbon Steel; 24590-WTP-3PS-SS00-T0002, Engineering Specification for Welding of Structural Stainless Steel and Welding of Structural Carbon Steel to Structural Stainless Steel. Plant Drawings: 24590-LAW-P1-P01T-00005, Rev. 5, LAW Vitrification Building General Arrangement Plan at El. 48'-0"; 24590-LAW-DD-S13T-00306, Rev. 9, LAW Vitrification Building Carbon Bed Adsorbers and Catalytic Oxidizer/Reducer Equipment Anchorage @ El. 48'-0"; 24590-LAW-DD-S13T-00313, Rev. 0, LAW Vitrification Building Thermal Catalytic Oxidizer/Reducer Anchor Bolt Schedule at El. 48'-0"; 24590-LAW-DD-S13T-00314, Rev. 0, LAW Vitrification Building Catalytic Oxidizer/Reducer Equipment Anchorage @ El. (+) 47'-0"; 24590-LAW-M5-V17T-00011, Rev. 5, Process Flow Diagram LAW Vit Secondary Offgas Treatment (System LVP), including DCN #s 24590-LAW-M5N-V17T-00012, -00019, -00023, and -00029; 24590-LAW-M6-LVP-00005001, Rev. 2, P&ID- LAW Secondary Offgas/Vessel Vent Process System Amonia Dilution Skid; 24590-LAW-M6-LVP-00005002, Rev. 2, P&ID- LAW Secondary Offgas/Vessel Vent Process System SCO/SCR Skid; 24590-LAW-P1-P23T-00051, Rev. 4, LAW Vitrification Building Equipment Location Plan El. 48'-0"/Area 4; 24590-LAW-P1-P23T-00052, Rev. 5, LAW Vitrification Building Equipment Location Plan El. 48'-0"/Area 5; 24590-LAW-DB-S13T-00135, Rev. 9, LAW Vitrification Building Main Building Partial Conc Forming Plan Zone 5 @ El. (+) 48'-0"; 24590-LAW-SS-S15T-00028, Rev. 6, LAW Vitrification Building Main Building Structural Steel Partial Floor Framing Plan Zone 5 @ TOS El. (+) 47'-0".

References (cont'd)	Vendor Fabrication Drawings	Vendor Fabrication Drawings (*Bechtel Status Code 1 and 2 Drawings): 24590-CD-POC-MBT0-00007-01-00182, Rev. 00F, LAW Thermal Catalytic Oxidizer-VOC SCO Housing Weldment, Sht. 1-2; 24590-CD-POC-MBT0-00007-01-00237, Rev. 00E, LAW Thermal Catalytic Oxidizer-VOC-SCO Front Weldment; 24590-CD-POC-MBT0-00007-01-00238, Rev. 00H, LAW Thermal Catalytic Oxidizer-Mechanism General Assembly; 24590-CD-POC-MBT0-00007-01-00239, Rev. 00H, LAW Thermal Catalytic Oxidizer-VOC SCO General Assembly, Sht. 1-3; 24590-CD-POC-MBT0-00007-01-00240, Rev. 00H, LAW Thermal Catalytic Oxidizer-NOX Housing Weldment, Sht. 1-2; 24590-CD-POC-MBT0-00007-01-00253, Rev. 00J, LAW Thermal Catalytic Oxidizer-NOX Front Weldment; 24590-CD-POC-MBT0-00007-01-00254, Rev. 00F, LAW Thermal Catalytic Oxidizer-NOX General Assembly, Sht. 1-3; 24590-CD-POC-MBT0-00007-01-00255, Rev. 00F, LAW Thermal Catalytic Oxidizer-Heat Exchanger Weldment, Sht. 1-2; 24590-CD-POC-MBT0-00007-01-00279, Rev. 00E, LAW Thermal Catalytic Oxidizer-Heat Exchanger General Assembly, Sht. 1-3; 24590-CD-POC-MBT0-00007-01-00281, Rev. 00D, LAW Thermal Catalytic Oxidizer-Heater Housing Weldment; 24590-CD-POC-MBT0-00007-01-00282, Rev. 00C, LAW Thermal Catalytic Oxidizer-Heater Inlet Duct Weldment; 24590-CD-POC-MBT0-00007-01-00283, Rev. 00C, LAW Thermal Catalytic Oxidizer-Heater Outlet Duct Weldment; 24590-CD-POC-MBT0-00007-01-00315, Rev. 00C, LAW Thermal Catalytic Oxidizer-Heater Front Weldment; 24590-CD-POC-MBT0-00007-01-00325, Rev. 00F, LAW Thermal Catalytic Oxidizer-Heater General Assembly, Sht. 1-3; 24590-CD-POC-MBT0-00007-01-00326, Rev. 00D, LAW Thermal Catalytic Oxidizer-Heater Inlet Duct General Assembly, Sht. 1-2; 24590-CD-POC-MBT0-00007-01-00327, Rev. 00E, LAW Thermal Catalytic Oxidizer-Heater Outlet Duct General Assembly, Sht. 1-3; 24590-CD-POC-MBT0-00007-01-00328, Rev. 00F, LAW Thermal Catalytic Oxidizer-VOC Inlet Weldment; 24590-CD-POC-MBT0-00007-01-00348, Rev. 00C, LAW Thermal Catalytic Oxidizer-VOC SCO Base Frame Weldment; 24590-CD-POC-MBT0-00007-01-00351, Rev. 00F, LAW Thermal Catalytic Oxidizer-NH3-NOX Base Frame Weldment; 24590-CD-POC-MBT0-00007-01-00352, Rev. 00C, LAW Thermal Catalytic Oxidizer-Heat Exchanger Base Frame Weldment; 24590-CD-POC-MBT0-00007-01-00353, Rev. 00C, LAW Thermal Catalytic Oxidizer-TCO General Arrangement, Sht. 1-4; 24590-CD-POC-MBT0-00007-01-00354, Rev. 00D, LAW Thermal Catalytic Oxidizer-LAW TCO Final Assembly, Sht. 1-4; 24590-CD-POC-MBT0-00007-01-00357, Rev. 00G, LAW Thermal Catalytic Oxidizer-Heat Exchanger Inlet/Outlet Weldment; 24590-CD-POC-MBT0-00007-01-00386, Rev. 00D, LAW Thermal Catalytic Oxidizer-TCO General Assembly, Sht. 1-2; 24590-CD-POC-MBT0-00007-01-00387, Rev. 00D, LAW Thermal Catalytic Oxidizer-Heat Exchanger Inlet/Outlet General Assembly; 24590-CD-POC-MBT0-00007-01-00388, Rev. 00C, LAW Thermal Catalytic Oxidizer-Heat Exchanger Inlet-Outlet Machined; 24590-CD-POC-MBT0-00007-01-00389, Rev. 00C, LAW Thermal Catalytic Oxidizer-Heater Housing Machined; 24590-CD-POC-MBT0-00007-01-00390, Rev. 00D, LAW Thermal Catalytic Oxidizer-Heater Inlet Duct Machined; 24590-CD-POC-MBT0-00007-01-00391, Rev. 00D, LAW Thermal Catalytic Oxidizer-Heater Outlet Duct Machined; 24590-CD-POC-MBT0-00007-01-00397, Rev. 00B, LAW Thermal Catalytic Oxidizer-TCO Field Installation, Sht. 1-9; 24590-CD-POC-MBT0-00007-01-00401, Rev. 00D, LAW Thermal Catalytic Oxidizer-Shipping Drawings, Sht. 1-4. * Bechtel Status Code 1 Drawing is an "as fabricated vendor drawing" approved/accepted by Bechtel. Bechtel Status Code 2 Drawing is an "as fabricated vendor drawing" approved (with comments)/accepted by Bechtel.

References (cont'd)	Mechanical Data Sheet, Corrosion Evaluation, and System Description	Mechanical Data Sheet (MDS): 24590-LAW-MKD-LVP-00012, Rev. 13, LAW Catalytic Oxidizer/Reducer (LVP-SKID-00002/00003). Corrosion Evaluation: 24590-LAW-N1D-LVP-00005, Rev. 3, LAW Catalytic Oxidizer Heat Recovery Exchanger (LVP-HX-00001); 24590-LAW-N1D-LVP-00006, Rev. 3, LAW Catalytic Oxidizer Electric Heater (LVP-HTR-00002); 24590-LAW-N1D-LVP-00007, Rev. 4, LAW Thermal Catalytic Oxidizer (LVP-SCO-00001); 24590-LAW-N1D-LVP-00008, Rev. 3, LAW NOx Selective Catalytic Reducer (LVP-SCR-00001). System Description: 24590-LAW-3YD-LOP-00001, Rev. 3, System Description for the LAW Primary Offgas (LOP) and Secondary Offgas/Vessel Vent (LVP) Systems, including SDCN # 00011, 00012, 00013, and 00015.

	Information Assessed	Source of Information	Assessment
Design	Plant Item design standards are appropriate and adequate for the vessel have intended use.	Material Requisition, Specifications, Drawings, and Mechanical Data Sheet listed above under References; ASME Boiler and Pressure Vessel Code (B&PV), Section VIII, Division 1 & 2, Rules for Construction of Pressure Vessels, American Society of Mechanical Engineers; ASME B31.3 Code, Process Piping, American Society of Mechanical Engineers; AISC N690, American National Standard-Nuclear Facilities-Steel Safety Related Structures for Design, Fabrication, and Erection, American Society of Steel Construction; AISC M016, Manual of Steel Construction, ASD 9th Edition, American Society of Steel Construction; AWS 1.1, Structural Welding Code-Steel, American Welding Society; AWS 1.6, Structural Welding Code-Stainless Steel; American Welding Society; UBC 1997, Uniform Building Code. 24590-WTP-DC-ST-01-001, Rev. 13, Structural Design Criteria; ASTM Standards, American Society for Testing and Materials.	The LAW TCO Unit is considered as a vessel. The TCO Unit is also interchangeably termed herein as Plant Item or Miscellaneous Unit. The Engineering Specifications, Material Requisition, and Mechanical Data Sheet documents require that the TCO Unit housing and its components design, fabrication, and installation be per applicable codes, standards, and design criteria listed in the Source of Information column herein. The unit will be without the National Board of Registration ASME Code stamp. Supplementary requirements for the TCO Unit are specified in the listed referenced engineering specifications. The supplementary requirements include structural design requirements, fatigue, seismic, and thermal analyses, positive material identification, fabrication tolerances, welding procedures, welder qualifications and testing records, NDE inspections and records, packaging, handling, and storage requirements. The TCO Unit is identified as Safety Significant (SS), Quality Level (Q), and Seismic Category (SC-III) in the Mechanical Data Sheet. The Vendor Fabrication drawings show that the TCO Unit is approximately 43 ft (L) x 10 ft (W) x 13 ft (H). The drawings reviewed show that TCO Unit housing and its numerous components are built with various grades of stainless steel material (mainly type 347). The TCO Unit is adequately insulated to maintain the surface temperature below 140 °F for protection of the workers and below 150 °F for support steel and concrete elements as required per Engineering Specification for TCO Unit and Structural Design Criteria, respectively. The TCO Unit is mounted on an ASTM A992 carbon steel frame skid. The design requirements specified in the aforementioned codes, standards, and specifications are appropriate and adequate for the intended use of the TCO Unit.

	Information Assessed	Source of Information	Assessment
Design (cont'd)	If a non-standard Plant Item is to be used, the design calculations demonstrate sound engineering principles of construction.	Material Requisition, Mechanical Data Sheet, Specifications, and Drawings listed above under References; ASME Boiler and Pressure Vessel Code (B&PV), Section VIII, Division 1 & 2, Rules for Construction of Pressure Vessels, American Society of Mechanical Engineers; ASME B31.3 Code, Process Piping, American Society of Mechanical Engineers; AISC N690, American National Standard-Nuclear Facilities-Steel Safety Related Structures for Design, Fabrication, and Erection, American Society of Steel Construction; AISC M016, Manual of Steel Construction, ASD 9th Edition, American Society of Steel Construction; AWS 1.1, Structural Welding Code-Steel, American Welding Society; AWS 1.6, Structural Welding Code-Stainless Steel; American Welding Society; UBC 1997, Uniform Building Code. 24590-WTP-DC-ST-01-001, Rev. 13, Structural Design Criteria; ASTM Standards, American Society for Testing and Materials. 24590-LAW-MVC-LVP-00004, Rev. A, LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS, including ECCN # 24590-LAW-MVE-LVP-00001.	The LAW LVP TCO Unit is a non-standard offgas treatment assembly that is shop fabricated. The referenced Material Requisition, Mechanical Data Sheet, and Specifications require that the TCO Unit be designed, fabricated, inspected, tested, and installed per the applicable codes, standards, and design criteria listed in the Source of Information column herein. Review of the TCO Stress Analysis and drawings show that appropriate applicable load cases and combinations thereof were used utilizing sound engineering principles for the design and construction of the TCO Unit. Furthermore, approval and acceptance of the vendor fabrication drawings by Bechtel National Inc. (BNI), is an added assurance that all applicable requirements stated in aforementioned documents (including daughter documents) for the TCO Unit have been met.

	Information Assessed	Source of Information	Assessment
Design (cont'd)	Plant Item has adequate strength, after consideration of the corrosion allowance, to withstand the operating pressure, operating temperature, and seismic loads.	Material Requisition, Specifications, Mechanical Data Sheet, and Corrosion Evaluation listed above under References; ASME Boiler and Pressure Vessel Code (B&PV), Section VIII, Division 1 & 2, Rules for Construction of Pressure Vessels, American Society of Mechanical Engineers; ASME B31.3 Code, Process Piping, American Society of Mechanical Engineers; AISC N690, American National Standard-Nuclear Facilities-Steel Safety Related Structures for Design, Fabrication, and Erection, American Society of Steel Construction; AISC M016, Manual of Steel Construction, ASD 9th Edition, American Society of Steel Construction; AWS 1.1, Structural Welding Code-Steel, American Welding Society; AWS 1.6, Structural Welding Code-Stainless Steel; American Welding Society; UBC 1997, Uniform Building Code; 24590-WTP-DC-ST-01-001, Rev. 13, Structural Design Criteria; ASTM Standards, American Society for Testing and Materials. 24590-LAW-MVC-LVP-00004, Rev. A, LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS, including ECCN # 24590-LAW-MVE-LVP-00001.	The Engineering Specification for LAW TCO Unit and Mechanical Data Sheet documents require that the TCO Unit housing including all related components and appurtenances be designed and fabricated in accordance with the applicable sections of codes, standards, and design criteria listed in the Source of Information column herein. These codes and standards require specific consideration of operating pressures, temperatures, corrosion allowance, and seismic loads in the design process. Supplementary requirements are specified in the referenced engineering specifications. The supplementary requirements include structural design, fatigue and thermal analyses, positive material identification, fabrication tolerances, acceptable welding procedures, welder qualifications and testing records, NDE inspections and records, and packaging, handling, and storage requirements for the TCO Unit. The Mechanical Data Sheet identifies the operating pressure and temperature ranges and seismic category for the TCO Unit. Corrosion allowance of 0.010" is recommended for the TCO Unit as identified in the Corrosion Evaluation and Mechanical Data Sheet documents. The Engineering Specification for Seismic Design of Pressure Vessels specifies requirements for the seismic design. The Stress Analysis with ANSYS document reviewed shows that the applicable design and loading parameters were appropriately considered in the design process and the TCO Unit has adequate strength to sustain them during its design life.

	Information Assessed	Source of Information	Assessment
Foundation	Plant Item foundation will maintain the load of a full unit.	Material Requisition, Specifications, and Mechanical Data Sheet listed above under references; ASME Boiler and Pressure Vessel Code (B&PV), Section VIII, Division 1 & 2, Rules for Construction of Pressure Vessels, American Society of Mechanical Engineers; AISC N690, American National Standard-Nuclear Facilities-Steel Safety Related Structures for Design, Fabrication, and Erection, American Society of Steel Construction; AISC M016, Manual of Steel Construction, ASD 9th Edition, American Society of Steel Construction; AWS 1.1, Structural Welding Code-Steel, American Welding Society; AWS 1.6, Structural Welding Code-Stainless Steel; American Welding Society; UBC 1997, Uniform Building Code; 24590-WTP-DC-ST-01-001, Rev. 13, Structural Design Criteria; 24590-WTP-DB-ENG-01-001, Rev. 2, Basis of Design; 24590-LAW-MVC-LVP-00004, Rev. A, LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS, including ECCN # 24590-LAW-MVE-LVP-00001; 24590-LAW-DDC-S13T-00055, Rev. 1A, LAW Thermal Catalytic Oxidizer/Reducer Anchorage, including ECCN # 24590-LAW-DDE-S13T-00075 and -00076.	The Engineering Specifications, Material Requisition, and Mechanical Data Sheet documents require that the TCO Unit housing support be designed per applicable requirements of the codes, standards, and design criteria listed in Source of Information column herein. The requirements in the aforementioned codes and standards have adequate structural design requirements to ensure proper support for the TCO Unit. The Basis of Design document requires that the supports and foundations shall be designed adequately to sustain all applicable loads including the full weight of the unit. The review of Stress Analysis and Anchorage calculation documents shows that the supporting frame of the TCO Unit housing has been designed adequately to handle the applicable loads. However, it should be noted that the evaluation of the TCO Unit housing foundation (concrete floor slab @ Elev. 48'-0") is not in the scope of this report. It is covered under a separate integrity assessment report.

	Information Assessed	Source of Information	Assessment
Foundation (cont'd)	If in an area subject to flooding, the Plant Item is anchored.	Drawings, Specifications, and Mechanical Data Sheet listed above under References; 24590-LAW-MVC-LVP-00004, Rev. A, LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS, including ECCN # 24590-LAW-MVE-LVP-00001; 24590-LAW-DDC-S13T-00055, Rev. 1A, LAW Thermal Catalytic Oxidizer/Reducer Anchorage, including ECCN # 24590-LAW-DDE-S13T-00075 and -00076.	As shown on the referenced drawings, the TCO Unit is located at floor Elevation 48'-0" of the LAW facility. The Specification for Pressure Vessel Design and Fabrication requires that supports and anchors shall be designed to secure the buoyant unit in case the unit is empty and submerged to the level indicated in the Mechanical Data Sheet. The Mechanical Data Sheet indicates design basis event flood height of 0.92 ft (11") in Room L-0304F. It is noted that the drawings show that the TCO Unit housing is mounted on a steel frame skid. This skid is made up of multiple 6" H x 4" W tube steel transverse support members placed on two W8 (8" H) longitudinal sections, adding up to 14" height dimension above the floor slab that makes the bottom of TCO Unit more than the aforementioned flood height of 0.92 ft (11"). Therefore, as noted in the Mechanical Data Sheet, it precludes submergence of the TCO Unit's sensitive components and hence, it is not subject to buoyant forces for anchorage consideration. However, the TCO Unit is attached to skid (LVP-SKID-00002) frame which in turn is welded to the surface plates. And the surface plates are anchored to the floor slab with thru bolts to sustain other applicable design loads including seismic forces as shown in the reviewed listed Stress Analysis and Anchorage documents and related drawings.
	Plant Item system will withstand the effects of frost heave.	Drawings listed above under References; 24590-WTP-DC-ST-01-001, Rev. 13, Structural Design Criteria.	The Structural Design Criteria document requires that all structural foundations extend into the surrounding soil below the 30 inch frost line in order to preclude frost heave. As shown on the referenced drawings, the TCO Unit installed in the LAW facility at floor Elevation 48'-0" which is not subject to frost heave, hence, the TCO Unit is not subjected to any frost heave effects.

	Information Assessed	Source of Information	Assessment
Waste Characteristics	Characteristics of the waste to be stored or treated have been identified (ignitable, reactive, toxic, specific gravity, vapor pressure, flash point, storage temperature)	System Description, Mechanical Data Sheet, and Corrosion Evaluation listed above under References; 24590-WTP-PER-PR-03-002, Rev. 3, Control of Toxic Vapors and Emissions from WTP Tank Systems and Miscellaneous Unit Systems; 24590-WTP-M4C-V11T-00004, Rev. C, Calculation of Hydrogen Generation Rates and Times to Lower Flammability Limit for WTP. 24590-LAW-M4C-LOP-00001, Rev. 3, LAW Melter Offgas System Design Basis Flowsheets, including ECCN # 00003 and 00009; CCN 280210, LAW Miscellaneous Treatment Unit Hydrogen Accumulation Documentation for the DWP Administrative Record.	The Mechanical Data Sheet presents the operating temperatures and pressures for the TCO Unit. The Corrosion Evaluation documents address the chemical composition of the offgas in order to select appropriate TCO Unit materials and specify the corrosion allowance. The System Description document identifies the offgas being handled by the TCO Unit as hazardous, but not as ignitable or flammable. The main function of the TCO Unit is to prevent the escape of toxic and hazardous gas vapors to the environment from the LAW offgas system. The TCO Unit design is required to provide an intact housing pressure boundary during normal and abnormal operations and during and after design level seismic events. Waste characteristics that are hazardous, such as ignitability, reactivity, and toxicity are appropriately addressed in the Control of Toxic Vapors and Emissions, Calculation of Hydrogen Generation Rates, Melter Offgas System Design Basis Flowsheets, and CCN 280210 documents. The System Description and the Control of Toxic Vapors and Emissions documents describe that the LAW TCO Unit remove volatile organic compounds (VOCs) and nitrogen oxides (NO_x) compounds from the LAW offgas LVP exhaust system. Review of the Calculation for Hydrogen Generation Rates, Melter Offgas System Design Basis Flowsheets, and CCN 280210 documents show that this miscellaneous TCO Unit does not pose any hydrogen generation or accumulation hazard.
	Plant Item is designed to store or treat the wastes with the characteristics defined above and any treatment reagents.	Corrosion Evaluation, Mechanical Data Sheet, and System Description listed above under References.	The Corrosion Evaluation documents and the Mechanical Data Sheet adequately demonstrate incorporation of identified waste characteristics into the TCO Unit design. Normal and abnormal operating conditions are discussed in the System Description document. The offgas passing thru the SCR catalyst unit is injected with ammonia vapors and C3 air from the ammonia/air dilution skid (LVP-SKID-00003) housing the dilution fans (LVP-FAN-00001/00002) and a mixing chamber.

	Information Assessed	Source of Information	Assessment
Compatibility	The waste types are compatible with each other.	System Description and Drawings listed above under References.	The System Description document and Process Flow Diagram drawings show LVP system exhausters draw gases from melters through TCO Unit to remove VOC and NO_x compounds from the offgas constituents. The System Description document lists various administrative controls in place, which are adequate to ensure that no waste type compatibility issues exist in handling or processing the offgas constituents.
Compatibility	Plant Item material and protective coatings ensure the vessel structure is adequately protected from the corrosive effects of the waste stream and external environments (expected to not leak or fail for the design life of the system).	Corrosion Evaluation, Mechanical Data Sheet, Material Requisition, System Description, and Specifications listed above under References.	The material selection process included internal corrosion considerations relevant to the operating conditions of the TCO Unit. Based upon those considerations, various grades of stainless steel material were chosen for the TCO Unit components for compounds in direct contact with the offgas stream as documented in the Corrosion Evaluation documents for this equipment. The material selection is listed on the Mechanical Data Sheet under materials of construction. These material selections and corrosion allowance value of 0.010" were based upon a design life of 40 years per System Description document. As the TCO Unit operates in generally dry and actively ventilated conditions, therefore, external corrosion is not considered to be an issue. In order to prevent release of any gases leak testing and acceptance required per Material Requisition document will ensure pressure boundary integrity of the TCO Unit and that it will provide the intended service during its design life.
Corrosion Allowance	Corrosion allowance is adequate for the intended service life of the Plant Item.	Corrosion Evaluation, Mechanical Data Sheet, and System Description listed above under References.	The Corrosion Evaluation documents and Mechanical Data Sheet specify a corrosion allowance value of 0.010" for all TCO Unit components. This corrosion allowance value is appropriate as the equipment operates under dry-air conditions and no condensation is expected. These recommendations are based upon stainless steel material characteristics and an intended design service life of 40 years as listed in System Description and Mechanical Data Sheet.

	Information Assessed	Source of Information	Assessment
Pressure Controls	Pressure controls (vents and relief valves) are adequately designed to ensure pressure relief if normal operating pressures in the Plant Item are exceeded.	System Description listed above under References.	The System Description document provides a discussion of Normal and Off-Normal operations of the LAW Secondary Offgas System. The installation of pressure monitors and controls instrumentation in the LVP system ensure to prevent over pressurization of the TCO Unit. The functionality of the TCO Unit and differential pressure monitoring instrument including periodic checking of the bypass valve interlock and actuator is performed to prevent any restrictions in the path of the offgas flow and hence prevention of over pressurization of any TCO Unit components.

Master Distribution Schedule for WTP Project Subcontract Management Group

SUBMITTAL TRANSMITTAL:	☒ First Submittal	☐ Re-Submittal	☐ QVRP Package	☐ RFI
☒ No Review Required	☐ No Review Required Re-Submittal	☐ Submittal Supplement		
CORRESPONDENCE:	☐ With Attachment	☐ W/O Attachment (letter only)	☐ RFI	
☐ Fax as Original (Letter Only)	☐ Fax as Original (With Attachment)			
☐ Pre-Award/Award Package	☐ Executed Change Order Package			
☐ Executed Amendment Package	☐ Back Charge	☐ Closeout Package		

Subcontract Number:	24590-CM-HC4-HXYG-00240
Subcontract Title:	Tank Integrity Design Assessments
Subcontractor Name:	AREVA Federal Services, LLC
Subcontract Administrator:	Tess Klatt

PDC Document Number	Rev	Document Title	Rev
24590-CM-HC4-HXYG-00240-02-00012	00A	IQRPE Structural Integrity Assessment Report For LAW LVP Thermal Catalytic Oxidizer/Reducer (TCO Unit) (IA-3013146-000)	
Associated GRCN # _____			

DUE BACK TO SUBCONTRACT ADMINISTRATOR NO LATER THAN: N/A

INCOMING DISTRIBUTION

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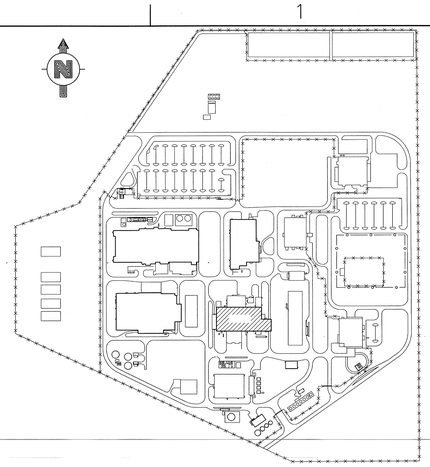
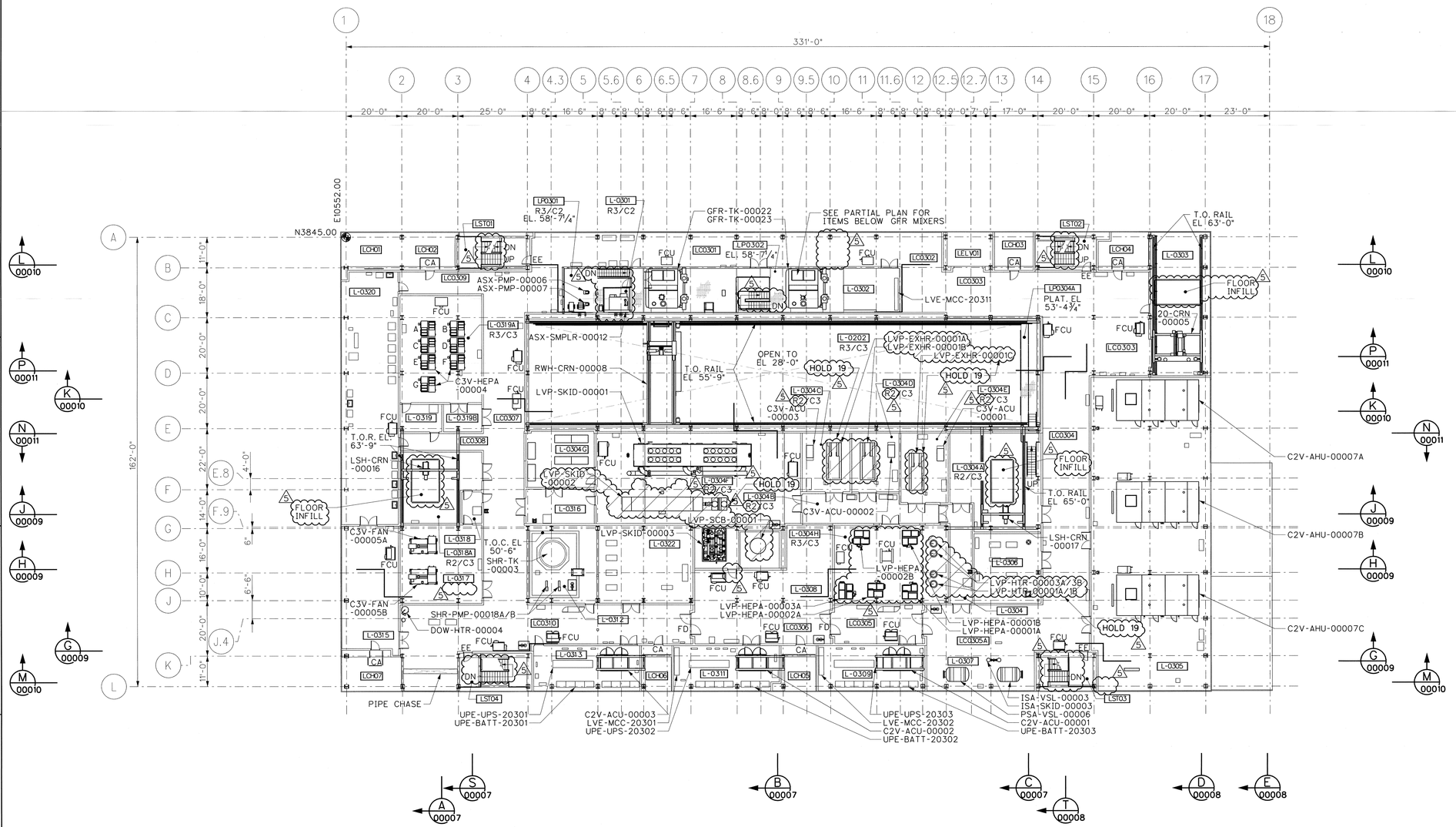
Barry Curn	X						
Dan Robertson	X						
Bret Peck	X						
Tricia Akers	X						

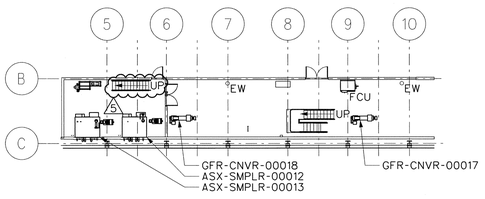


KEY PLAN

PLAN AT EL 48'-0"



PARTIAL PLAN AT EL 48'-0"



NOTES:

1. FOR GENERAL NOTES, SEE 24590-LAW-P1-P01T-00001.
2. CONTENTS OF THIS DOCUMENT ARE DANGEROUS WASTE PERMIT AFFECTING.
5. 3. SEE REVISION 4 OF THIS DRAWING FOR REVISION HISTORY.
4. THE RADIATION/CONTAMINATION CLASSIFICATIONS DEPICTED ON THE DRAWING ARE FOR DESIGN PURPOSES ONLY AND DO NOT NECESSARILY INDICATE THE ACTUAL RADIOLOGICAL CLASSIFICATION DURING RADIOACTIVE OPERATIONS.
5. ROOMS ARE OFFICIALLY IDENTIFIED BY ROOM NUMBERS ONLY. ROOM NUMBERS ARE ESTABLISHED AND CONTROLLED ON GENERAL ARRANGEMENT DRAWINGS. ONLY ROOM NUMBERS ARE NEEDED TO IDENTIFY ROOMS ON ENGINEERING DISCIPLINE DOCUMENTS. WHILE ROOM NUMBERS ARE CONTROLLED, THE MOST COMMON NAME OF ROOMS ASSOCIATED WITH EACH ROOM NUMBER ARE SHOWN FOR REFERENCE ONLY ON ARCHITECTURAL FLOOR PLANS.
5. 6. REVISED TO INCORPORATE THE FOLLOWING:

   24590-LAW-A1N-A10T-00073: ADDED DOOR TO LC0306.

   24590-LAW-P1N-P01T-00036: REVISED FLOOR HATCHES. FURTHER REVISED FLOOR HATCHES TO REPLACE COILING DOORS AND STEEL PLATES WITH FLOOR INFILL.

   24590-LAW-P1N-P01T-00058: REVISED RAD/CON CLASSIFCATION IN L-0317 TO R2/C2.

   24590-WTP-FC-C-13-0292: REVISED PARTITION WALL AT C/5-6.

   REVISED RAD/CON CLASSIFCATIONS IN L-0304B/C/D/E/F TO R2/C3.

   RELOCATED LVP-HEPA-00001A/B, LVP-HEPA-00002A/B AND LVP-HEPA-00003A.

   REVISED PARTITION WALL AT COLUMN LINE L/15.

   DELETED PARTITION WALL AND DOOR NEAR COLUMN LINE B/10.

   REMOVED MINOR EQUIPMENT TAGS.

   REMOVED GIRTS AND CROSS-BRACING FOR CLARITY.

   REVISED STAIRS FOR CLARITY.

   DELETED HOLD 17 FROM THIS DRAWING. SEE EQUIPMENT LOCATION DRAWINGS FOR C&I EQUIPMENT HOLD.

   ADDED HOLD 19.

   ADDED NOTE 6. REVISED NOTE 3.

   ADDED "DESIGN CHANGES INCORPORATED BY REFERENCE" BLOCK.

DESIGN CHANGES INCORPORATED BY REFERENCE	
DOCUMENT NO	DOCUMENT NO
24590-WTP-FC-C-12-0325	

HOLDS:

17. DELETED
19. PENDING DWP APPROVAL.

LEGEND:

CA	CONTROLLED ACCESS
EE	EMERGENCY EXIT
FCU	FAN COIL UNIT
FD	FIRE DOOR
L-XXXX	ROOM, CELL, (VAULT) OR TUNNEL
LCXXXX	
LMXXXX	MEZZANINE
LPXXXX	ROOM PLATFORM
LPCXXXX	CORRIDOR PLATFORM
LCHXX	CHASE
LELVXX	ELEVATOR
LSTXX	STAIR
	EQUIPMENT LAYDOWN AREA
	CONCRETE
	CHECKERED PLATE
	GRATING
	EMERGENCY EYEWASH
	LADDER
	EMERGENCY SHOWER/EYEWASH
	FLOOR PENETRATION

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA) are regulated at the U. S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts that pursuant to AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

REVISION HISTORY

REV	DESCRIPTION	ORG	CHKD	RVWD	APVD	DATE
5	REVISED TO INCORPORATE CHANGES IN NOTE 6	JTC	JB	KM	[illegible]	14OCT13
4	REVISED TO INCORPORATE CHANGES IN NOTE 3	CMS	RLS	JKL	PAP	11/16/11
3	REVISED TO INCORPORATE CHANGES IN NOTE 3	TH	CMS	JM	JC/AR	11/1/06
0	ISSUED FOR DESIGN - SUPERSEDES DWG-W375LV-PL00046, REV D	TH	CMS	PR	CJW	11/25/03

ISSUED BY RPP-WTP PDC		
BY	DATE	
ISSUE STAMP		

PROJECT No.	24590	
SITE	HANFORD	
AREA	200E	
BUILDING No.	20	

	BY	DATE
ORIGINATOR	TIMOTHY E. HAWKINS	11/25/03
CHECKER	CRAIG M. SALERNO	11/25/03
APPROVER	C. J. WINKLER	11/25/03
REVIEWER	PHIL REICHERT	11/25/03

CONTENT APPLICABLE TO ALARA? [X] YES [ ] NO
ADR NO. 24590-LAW-ADR-PL-03-006 REV: 1
ENAS SCREENING REQUIRED? [X] YES [ ] NO ENAS INITIAL IF YES DEK

BECHTEL

RIVER PROTECTION PROJECT
WASTE TREATMENT PLANT
2435 STEVENS CENTER PLACE
RICHLAND, WA 99354

CONTRACT No: DE-AC27-01RV14136

LAW VITRIFICATION BUILDING GENERAL ARRANGEMENT PLAN AT EL. 48'-0"

SCALE: 1/16"=1'-0"

24590-LAW-P1-P01T-00005 REV 5

SCREENING IS REQUIRED FOR DRAWING TYPES IDENTIFIED IN 24590-WTP-GPP-SREG-002

"E" SIZE - 44x34
COMPUTER GENERATED - MANUAL DESIGN CHANGES NOT PERMITTED

R11613176

9/26/2013 1:49:29 PM

C:\Work\Icenter\dms06392\24590LAWP01T00005.DGN

FORM E_SDN.DGN 02/2009

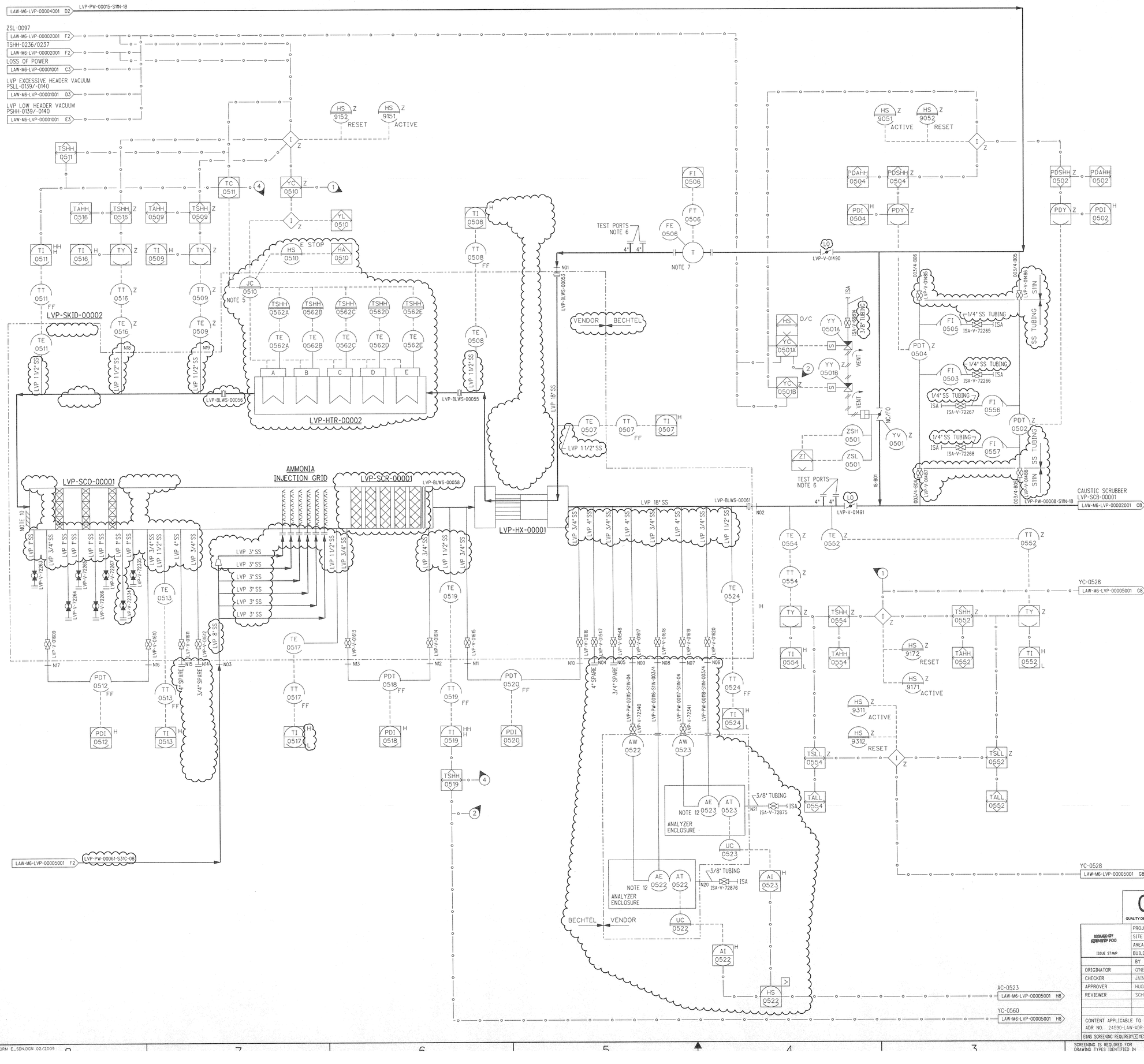
LVP-SKID-00002 LAW CATALYTIC OXIDIZER/ REDUCER SKID – 3000 1CFM –

LVP-SCO-00001 THERMAL CATALYTIC OXIDIZER – 3000 SCFM –

LVP-HTR-00002 CATALYTIC OXIDIZER ELECTRIC HEATER A-E 310 KW TOTAL

LVP-SCR-00001 NOx SELECTIVE CATALYTIC REDUCER 4000 SCFM –

LVP-HX-00001 CATALYTIC OXIDIZER HEAT RECOVERY UNIT – –



NOTES:

1. SEE DRAWINGS 24590-WTP-M6-50-00001 THROUGH 24590-WTP-M6-50-00008 FOR GENERAL NOTES, SYMBOLS AND LEGEND, AND GENERAL SLOPE REQUIREMENTS.
2. CONTENTS OF THIS DOCUMENT ARE DANGEROUS WASTE PERMIT AFFECTING.
3. THE PRESSURE BOUNDARY FOR ALL COMPONENTS ON THIS DRAWING IS QUALITY LEVEL Q AND SEISMIC CATEGORY SC-III, UNLESS OTHERWISE NOTED.
4. DELETED
5. FIVE HEATER BANKS ARE CONTROLLED FROM ICN VIA VENDOR CONTROL PANEL LVP-PNL-00003.
6. TEST PORTS ARE TO BE INSTALLED AT THE SAME AXIAL POSITION. ONE PORT SHOULD BE AS CLOSE TO VERTICAL (TOP) AS POSSIBLE. THE OTHER SHOULD BE 90° OPPOSED. TEST PORTS SHALL BE PLACED A MINIMUM OF TWO (2) INSIDE PIPE DIAMETERS FROM UPSTREAM FLOW DISTURBANCES AND A MINIMUM OF ONE-HALF (1/2) INSIDE PIPE DIAMETER FROM DOWNSTREAM DISTURBANCES. WHERE PRACTICAL, THESE STRAIGHT RUN DISTANCES SHOULD BE DOUBLED.
7. FLOW ELEMENT SHALL BE LOCATED A MINIMUM OF TEN INSIDE PIPE DIAMETERS FROM UPSTREAM AND DOWNSTREAM FLOW DISTURBANCES TO ENSURE STRAIGHT PIPE FLOW DISTRIBUTION THROUGH THE DEVICE. TEST PORTS ARE NOT REGARDED TO CREATE FLOW DISTURBANCES.
8. JUNCTION BOX LVP-JB-00012 (NON-SAFETY) TO BE INSTALLED ON TOO SKID.
9. THIS DRAWING IS CONVERTED FROM A SINGLE SHEET TO MULTI-SHEET DRAWINGS AND IN PART SUPERSEDES 24590-LAW-M6-LVP-00005 REV 2. THIS DRAWING INCLUDES INFORMATION FROM 24590-LAW-M6N-LVP-00054, -00057, -00060, -000066, -00069, AND 24590-QL-MRA-MBT0-00007-T0003.
10. INSULATION PER 24590-WTP-SDDR-MS-14-00002.
11. REVISION 1: INCORPORATED 24590-LAW-M6N-LVP-00083, -00088, AND -00091. REVISED/ADDED VALVES, BELLOWS, NOZZLES, NOTES, AND INSTRUMENTATION.
12. INSTRUMENTS AE-0522 AND AE-0523 MEASURE NH3 LEVELS.
13. REVISION 2: INCORPORATED 24590-LAW-M6N-LVP-00074. REVISED/DELETED/ADDED NOTES, HOSES, CAP, VALVES, BELLOWS, LINE MATERIALS, VENDOR/BECHTEL BOUNDARY, FLANGES, AND INSTRUMENTATION.

HOLD OPEN ITEMS:

NONE

REFERENCES:

1. 24590-LAW-3YD-LOP-00001, SYSTEM DESCRIPTION FOR THE LAW PRIMARY OFFGAS (LOP) AND SECONDARY OFFGAS/VESSEL VENT (LVP) SYSTEMS.

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REV	DESCRIPTION	ORG	CHKD	RVWD	APVD	DATE
2	REVISED PER NOTE 13	DMB	MAO	MAO	MAO	8/22/14
1	REVISED PER NOTE 11	RP	RM	SK/SS	KH/PD	06/26/13
0	ISSUED FOR CONSTRUCTION, SEE NOTE 9	MO	SJ	SS	TH/DM	11-22-11

REVISION HISTORY

Q QUALITY DESIGNATOR

ISSUED BY 24590-WTP PDC ISSUE STAMP

PROJECT No.	24590	
SITE	HANFORD	
AREA	200E	
BUILDING No.	20	
	BY	DATE
ORIGINATOR	O'NEILL, MICHAEL	11-18-11
CHECKER	JAIN, SATISH	11-18-11
APPROVER	HUGHES, T / MILDON, D.	11-22-11
REVIEWER	SCHMUDE, STEVEN	11-18-11

CONTENT APPLICABLE TO ALARA? [X] YES [ ] NO
ADR NO. 24590-LAW-ADR-M-02-023 REV: 4
EMS SCREENING REQUIRED? [X] YES [ ] NO EMS INITIAL IF YES

SCREENING IS REQUIRED FOR DRAWING TYPES IDENTIFIED IN

BECHTEL

RIVER PROTECTION PROJECT
WASTE TREATMENT PLANT
2435 STEVENS CENTER PLACE
RICHLAND, WA 99354

CONTRACT No: DE-AC27-01RV14136

P&ID - LAW LAW SECONDARY OFFGAS/VESSEL VENT PROCESS SYSTEM SCO/SCR SKID

SCALE: NONE

24590-LAW-M6-LVP-00005002 REV 2

E- SIZE - 44x34 COMPUTER GENERATED - MANUAL

R1163784

8/22/2014 7:43:00 AM

PLOTTED BY: gpockes C:\Work\gpockes\dms03838\LAWML_LVP00005002.dgn

FORM E_SDN.DGN 02/2009

REVISIONS					
REV.	DESCRIPTION	REV BY:	CHKD BY:	APPROVED BY:	DATE
A	ADDED NOTES FOR INSULATING BLANKETS AROUND ALL PIPE, NOTES FOR GROUNDING LUGS, SHOWN TEMPERATURE ELEMENTS AND THERMOWELL NAMES, UPDATED CONDUIT ROUTING TO GO TO BOX & ELECTRICAL CONDUIT FACE, REMOVED LVP-NOSE-00032 THRU -00037 FROM END VIEW SHT 1, ADDED REFERENCE DIMENSIONS, UPDATED AMMONIA INJECTION MANIFOLD DESIGN & DIMENSIONS, REMOVED NOTES & MADE CATALYST MODULES VISIBLE SHT 2, ADDED NOTE 2 SHT 4	PV	RP	DWP	10/22/2014
B	ADDED COG & RELATED DIMENSIONS, ADDED APPROXIMATE WEIGHT, CORRECTED CATALYST MODULES NOTES (ELEVATION VIEW SHEET 2), UPDATED VIEWS TO REFLECT SUBASSEMBLY DESIGN UPDATES, ADDED NOTE 3 (SHEET 1)	PV	RP	MP	2/3/2015

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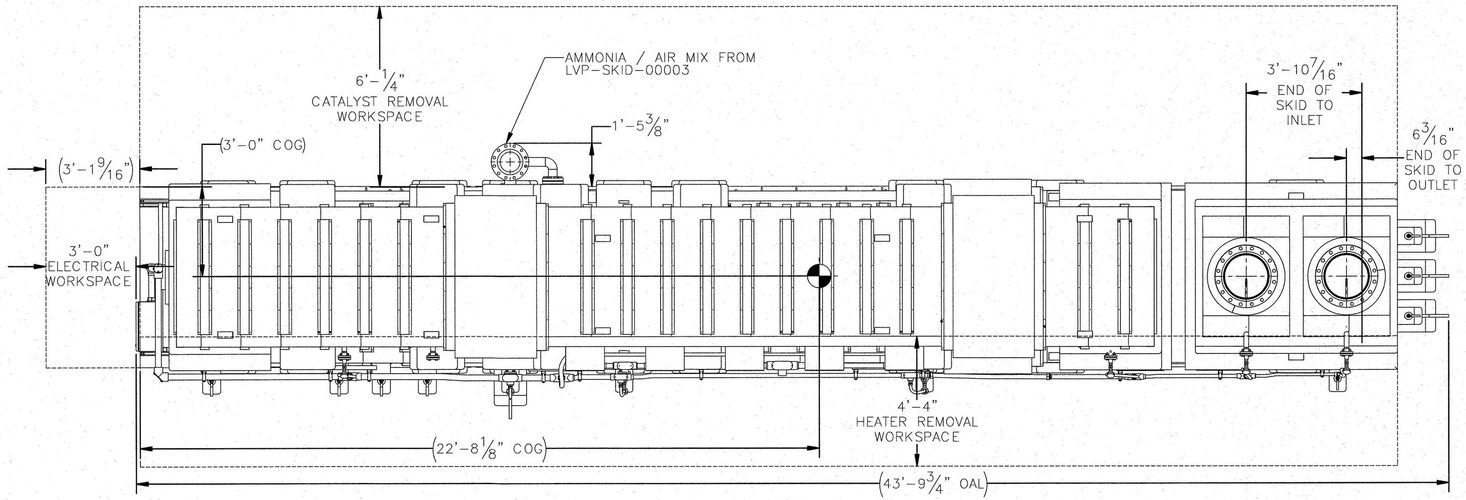
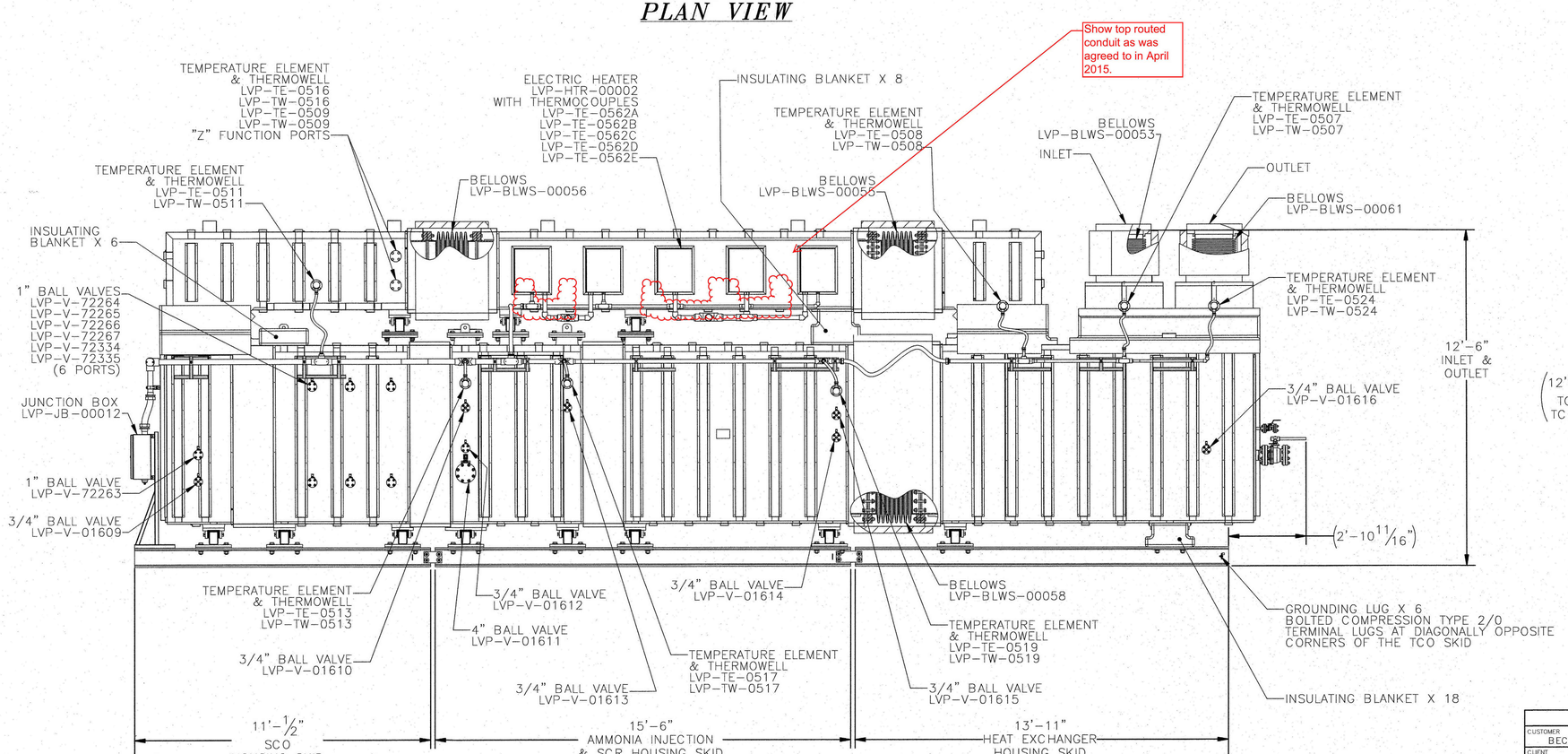
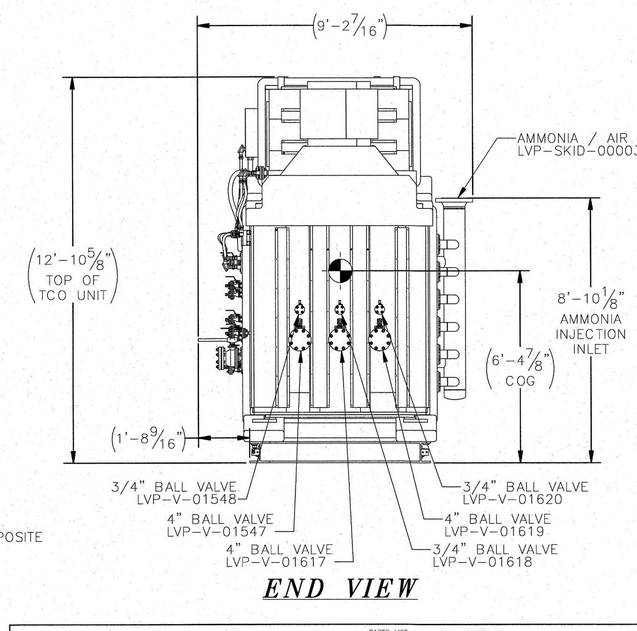
CONDUITS PROVIDED ARE NOT LARGE ENOUGH TO ACCOMMODATE INCOMING POWER CABLES TO THE HEATERS. THE CURRENT BNI DESIGN REQUIRES 5 - 2" CONDUITS RUN EXPOSED, ONE TO EACH HEATER TERMINAL BOX. EACH CONDUIT HAS TWO 3C#6+GND CABLES. IT WOULD BE PREFERABLE TO COME IN THROUGH THE TOP OF THE TERMINAL BOXES.



PLAN VIEW



ELEVATION VIEW



END VIEW

NOTES:

1. REFERENCE DRAWING 913040-060-001 FOR P&ID
2. SEE SHT 4 FOR ADDITIONAL NOTES
3. SEE 913040-DAT-015 FOR BALL VALVE INSULATION BLANKET TAG NUMBERS

APPROXIMATE WEIGHT: 122665 LBS

PARTS LIST

CUSTOMER: BECHTEL NATIONAL INC.	CONTRACT NO.: 24590-CD-POC-MBT0-00007
CLIENT: DOE-ORP	EQUIPMENT NO.: 24590-LAW-MX-LVP-SKID-00002
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DEBURR SHARP EDGES	PROJECT LOCATION: WASHINGTON STATE, 200 EAST AREA OF THE HANFORD SITE
TOLERANCES ARE: FRACTIONS ±1/2 DECIMALS .X ± .2 .XX ± .12 .XXX ± .062 ANGLES ± 2°	EQUIPMENT SERVICE: LVP OFFGAS SYSTEM
MATERIAL	APPROVALS / DATE: DRAWN NS 2/10/2014; CHECKED RP 2/25/2014; APPROVED MP 2/25/2014; DO NOT SCALE DRAWING

HONEX
P.O. BOX 70 Lafayette, CO. 80026
Fax: 303-666-5560 Phone: 303-666-5550

HANFORD TANK WASTE TREATMENT AND IMMOBILIZATION PLANT (WTP)

LAW THERMAL CATALYTIC OXIDIZER

TCO GENERAL ARRANGEMENT

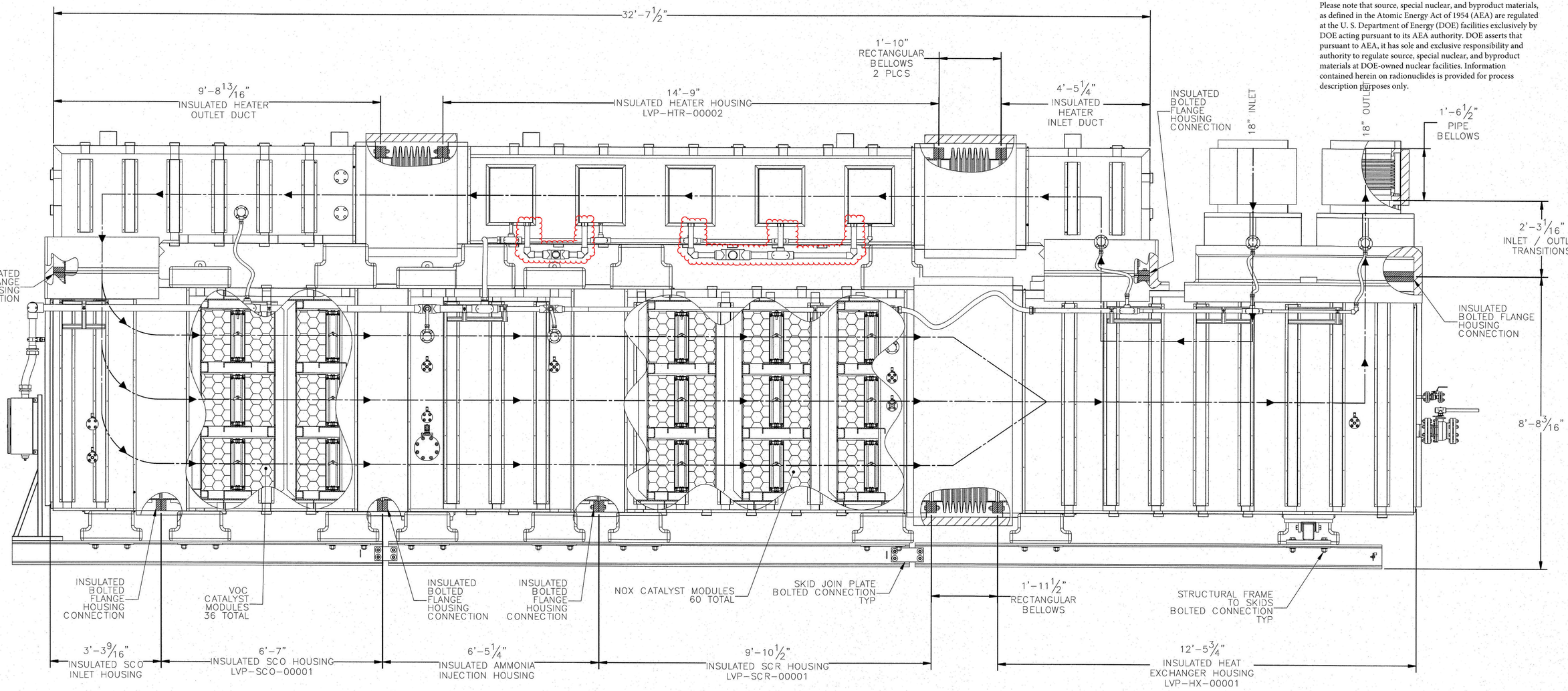
PRODUCTION ORDER NO.	SIZE	DWG. NO.	REV.
913040	D	913040-010-001	B

SCALE: NONE | CATEGORY NO: | SHEET 1 of 4

24590-CD-POC-MBT0-00007-01-00353 00C
received 2015-03-12
R80012650

REVISIONS					
REV.	DESCRIPTION	REV BY:	CHKD BY:	APPROVED BY:	DATE
A	ADDED NOTES FOR INSULATING BLANKETS AROUND ALL FEET, NOTES FOR GROUNDING LUG, SHIM NOTE ON PG. 4, UPDATED SHT 2 TO SHOW BASE FRAMES, UPDATED CONDUIT, UPDATED JUNCTION BOX & ELECTRICAL WORKSPACE, REMOVED LVP-NOSE-00002 THRU -00007 FROM END VIEW SHT 1, ADDED REFERENCE DIMENSIONS, UPDATED AMMONIA INJECTION MANIFOLD DESIGN & DIMENSIONS, REMOVED NOTES & MADE CATALYST MODULES VISIBLE SHT 2, ADDED NOTE 2 SHT 4	PV	RP	DWP	10/22/2014
B	ADDED COG & RELATED DIMENSIONS, ADDED APPROXIMATE WEIGHT, CORRECTED CATALYST MODULES NOTES (ELEVATION VIEW SHEET 2), UPDATED VIEWS TO REFLECT SUBASSEMBLY DESIGN UPDATES, ADDED NOTE 3 (SHEET 1)	PV	RP	MP	3/3/2015

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA) are regulated at the U. S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts that pursuant to AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

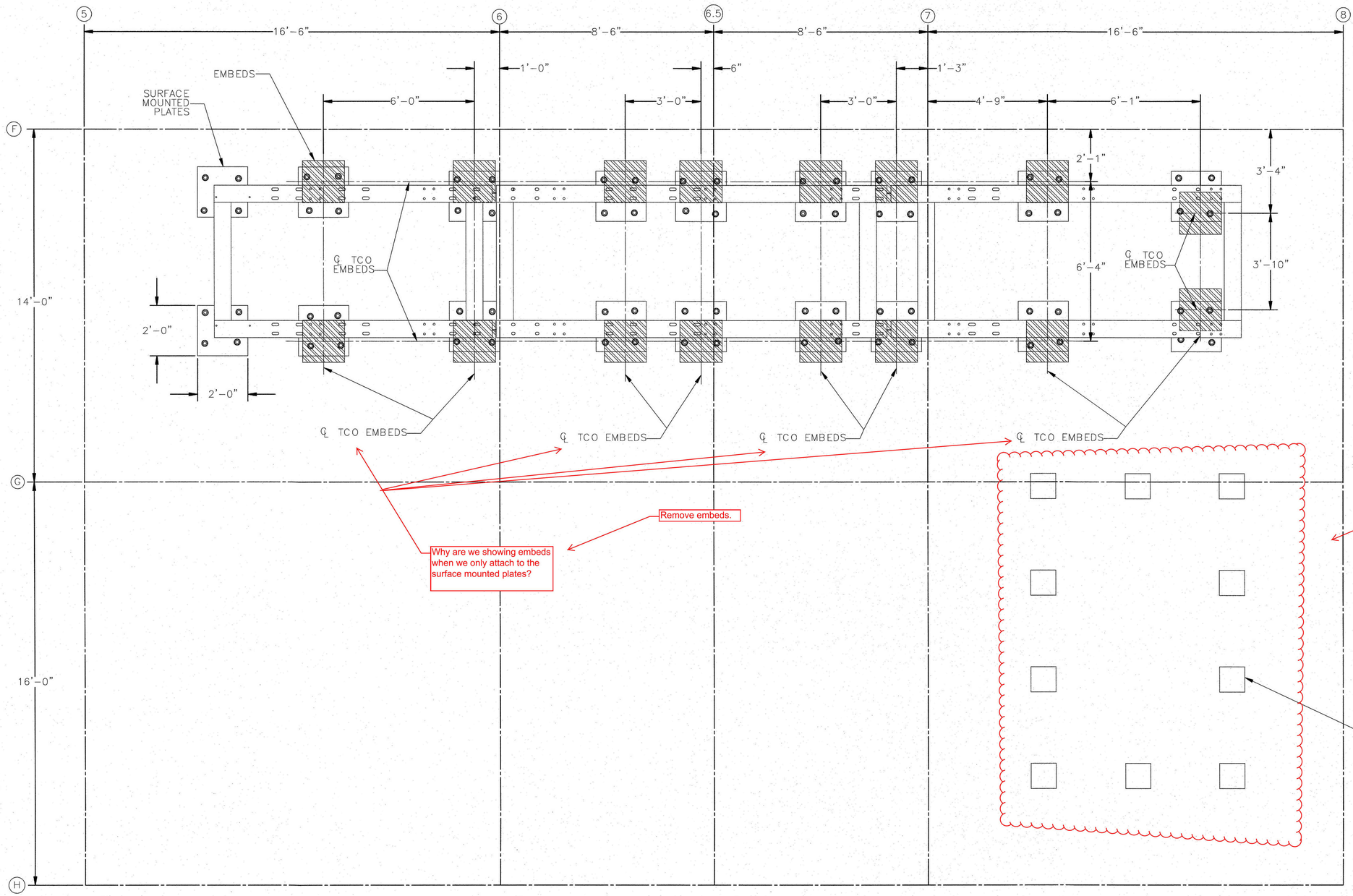


ELEVATION VIEW

PARTS LIST

CUSTOMER: BECHTEL NATIONAL INC.	CONTRACT NO.: 24590-CD-POC-MBTO-00007	IONEX P.O. BOX 70, Lafayette, CO. 80026 Fax: 303-666-5560 Phone: 303-666-5550
CLIENT: DOE-ORP	EQUIPMENT NO.: 24590-LAW-MX-LVP-SKID-00002	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DEBURR SHARP EDGES TOLERANCES ARE: FRACTIONS ±1/2 DECIMALS .X ± .2, .XX ± .12, .XXX ± .062 ANGLES ± 2°	PROJECT LOCATION: WASHINGTON STATE, 200 EAST AREA OF THE HANFORD SITE	HANFORD TANK WASTE TREATMENT AND IMMOBILIZATION PLANT (WTP) ***LAW THERMAL CATALYTIC OXIDIZER*** ***TCO GENERAL ARRANGEMENT***
	EQUIPMENT SERVICE: LVP OFFGAS SYSTEM	
MATERIAL	APPROVALS / DATE DRAWN: NS 2/10/2014 CHECKED: RP 2/25/2014 APPROVED: MP 2/25/2014	PRODUCTION ORDER NO.: 913040 · SIZE: D · DWG. NO.: 913040-010-001 · REV.: B
DO NOT SCALE DRAWING		SCALE: NONE · CATEGORY NO: · SHEET 2 of 4

REVISIONS					
REV.	DESCRIPTION	REV BY:	CHKD BY:	APPROVED BY:	DATE
A	ADDED NOTES FOR INSULATING BLANKETS AROUND ALL FEET, NOTES FOR GROUNDING LUG, SHIM NOTE ON FIG. 4, UPDATED SHT 3 TO SHOW BASE FRAMES, UPDATED CONDUIT, UPDATED JUNCTION BOX & ELECTRICAL WORKSPACE, REMOVED LVP-HOSE-00002 THRU -00037 FROM END VIEW SHT 1, ADDED REFERENCE DIMENSIONS, UPDATED AMMONIA INJECTION MANIFOLD DESIGN & DIMENSIONS, REMOVED NOTES & MADE CATALYST MODULES VISIBLE SHT 2, ADDED NOTE 2 SHT 4	PV	RP	DWP	10/22/2014
B	ADDED COG & RELATED DIMENSIONS, ADDED APPROXIMATE WEIGHT, CORRECTED CATALYST MODULES NOTES (ELEVATION VIEW SHEET 2), UPDATED VIEWS TO REFLECT SUBASSEMBLY DESIGN UPDATES, ADDED NOTE 3 (SHEET 1)	PV	RP	WP	3/3/2015



N

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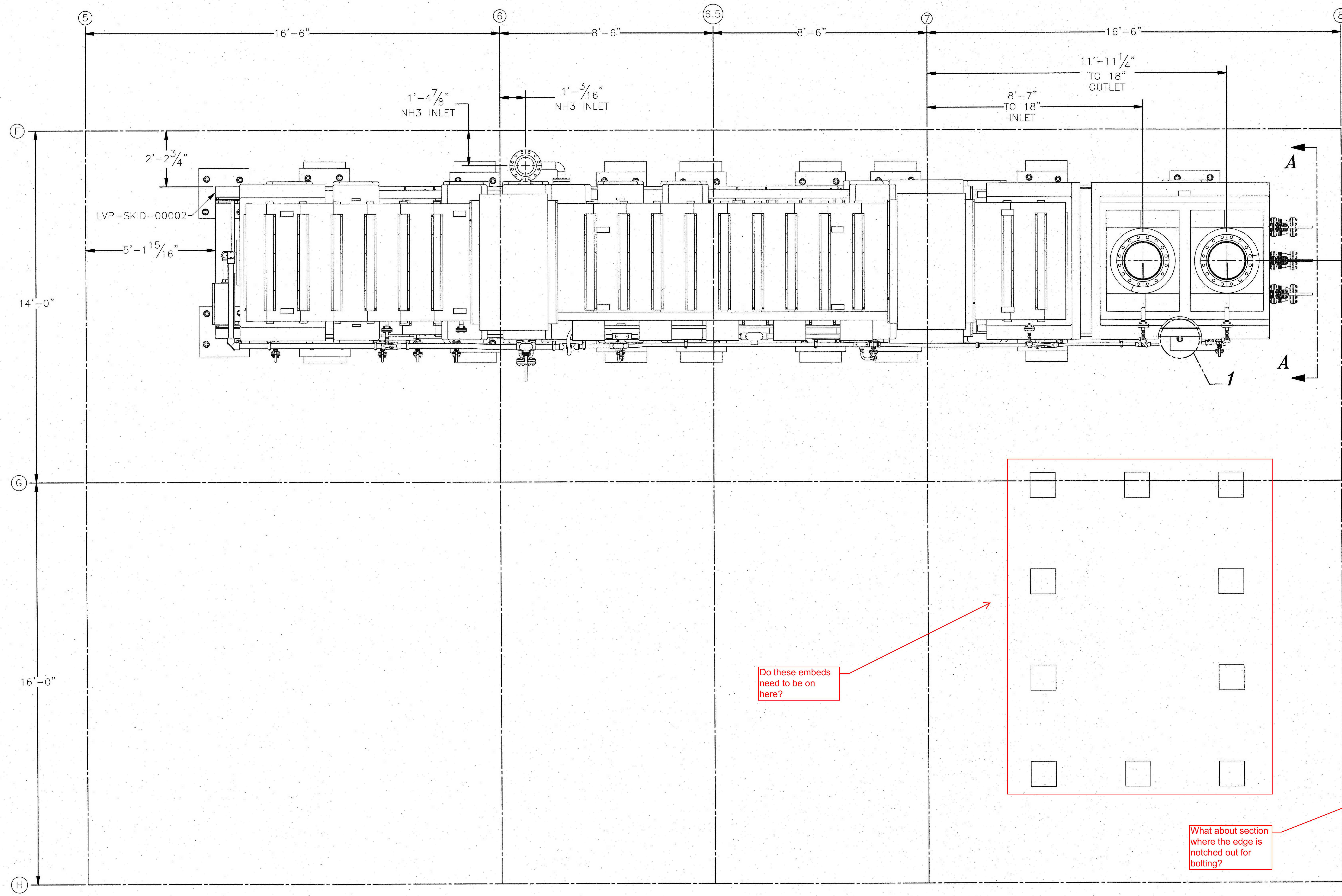
EMBED LOCATIONS/ROOM LAYOUT PLAN VIEW

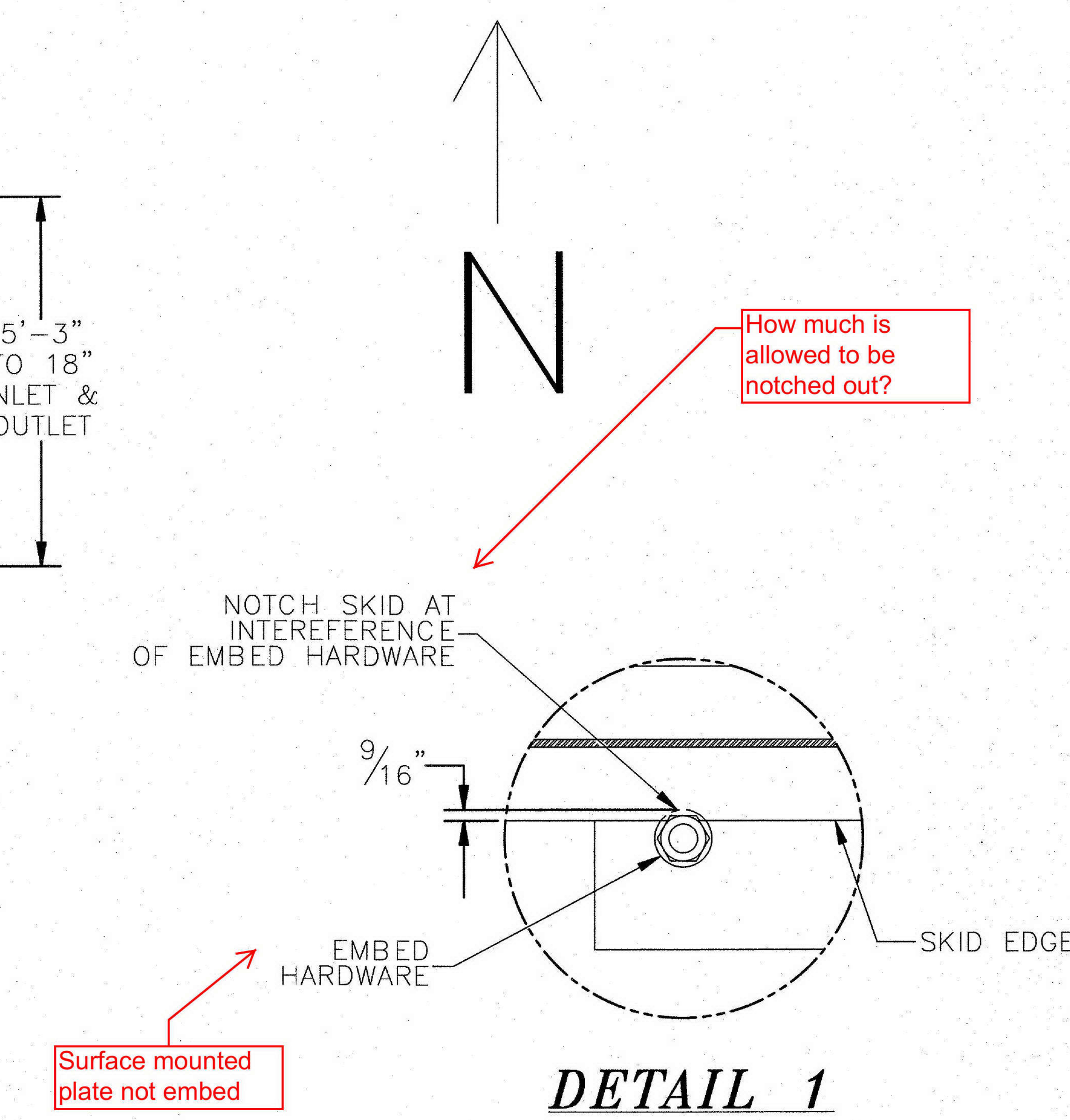
(REF BNI DWG 24590-LAW-DB-S13T-00135)
(REF BNI DWG 24590-LAW-DD-S13T-00306)
(REF BNI DWG 24590-LAW-DD-S13T-00313)
(REF BNI DWG 24590-BOF-DD-S13T-00001)

PARTS LIST

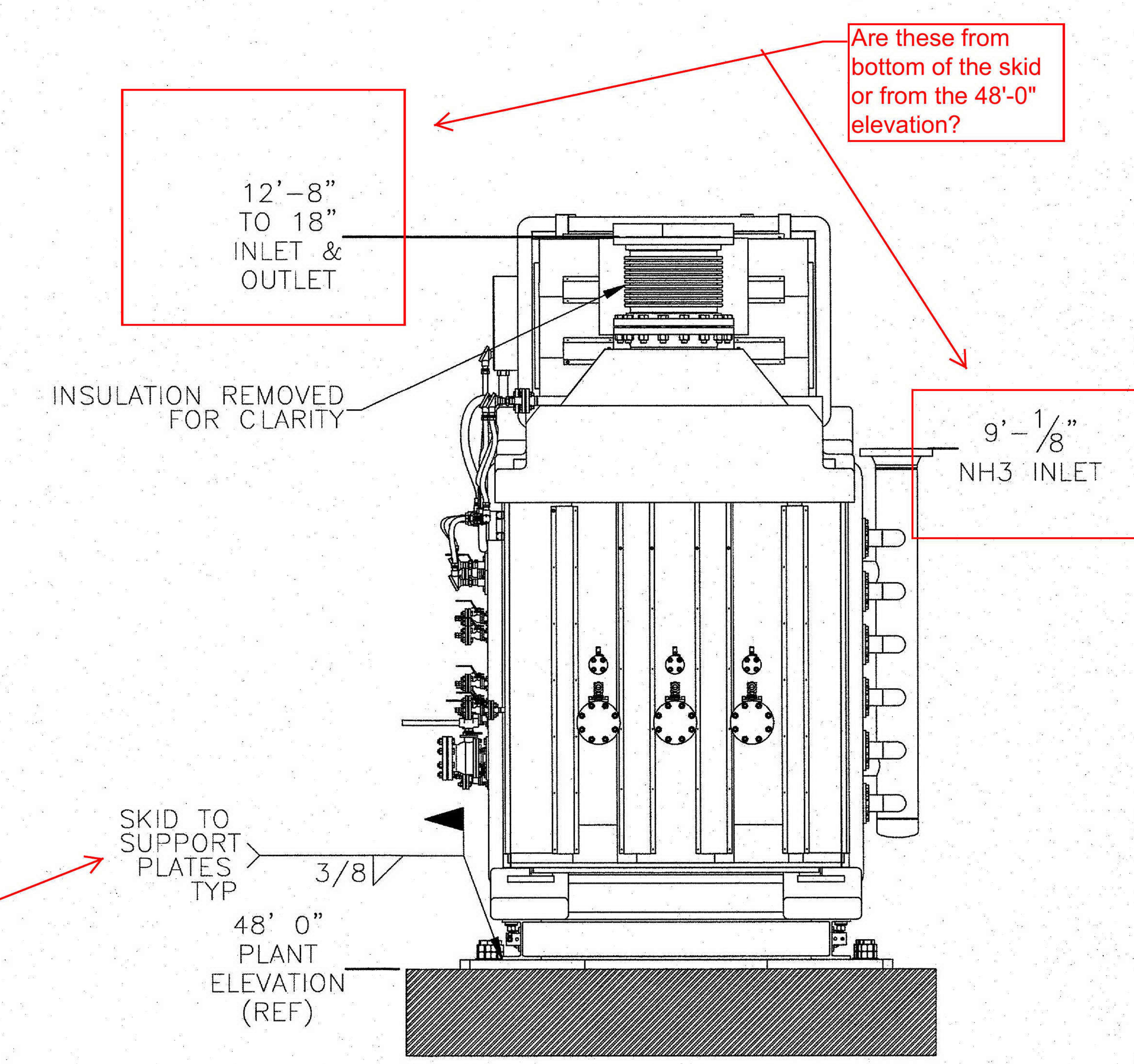
CUSTOMER: BECHTEL NATIONAL INC.	CONTRACT NO.: 24590-CD-POC-MBTO-00007	ONEX P.O. BOX 70, Lafayette, CO. 80026 Fax: 303-666-5560 Phone: 303-666-5550
CLIENT: DOE-ORP	EQUIPMENT NO.: 24590-LAW-MX-LVP-SKID-00002	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DEBURR SHARP EDGES TOLERANCES ARE: FRACTIONS ±1/2 DECIMALS .X ± .2 .XX ± .12 .XXX ± .062 ANGLES ± 2°	PROJECT LOCATION: WASHINGTON STATE, 200 EAST AREA OF THE HANFORD SITE EQUIPMENT SERVICE: LVP OFFGAS SYSTEM	HANFORD TANK WASTE TREATMENT AND IMMOBILIZATION PLANT (WTP) ***LAW THERMAL CATALYTIC OXIDIZER*** ***TCO GENERAL ARRANGEMENT***
MATERIAL	APPROVALS / DATE DRAWN: NS 2/10/2014 CHECKED: RP 2/25/2014 APPROVED: MP 2/25/2014 DO NOT SCALE DRAWING	PRODUCTION ORDER NO.: 913040 SIZE: D DWG. NO.: 913040-010-001 REV.: B SCALE: NONE CATEGORY NO.: SHEET 3 of 4

REV.	DESCRIPTION	REV BY:	CHKD BY:	APPROVED BY:	DATE
A	ADDED NOTES FOR INSULATING BLANKETS AROUND ALL FEET, NOTES FOR GROUNDING LUG, SHIM NOTE ON PG. 4, UPDATED SHT 3 TO SHOW BASE FRAMES, UPDATED CONDUIT, UPDATED JUNCTION BOX & ELECTRICAL WORKSPACE, REMOVED LVP-HOSE-00032 THRU -00037 FROM END VIEW SHT 1, ADDED REFERENCE DIMENSIONS, UPDATED AMMONIA INJECTION MANIFOLD DESIGN & DIMENSIONS, REMOVED NOTES & MADE CATALYST MODULES VISIBLE SHT 2, ADDED NOTE 2 SHT 4	PV	RP	DWP	10/22/2014
B	ADDED COG & RELATED DIMENSIONS, ADDED APPROXIMATE WEIGHT, CORRECTED CATALYST MODULES NOTES (ELEVATION VIEW SHEET 2), UPDATED VIEWS TO REFLECT SUBASSEMBLY DESIGN UPDATES, ADDED NOTE 3 (SHEET 1)	PV	RP	DWP	3/3/2015





DETAIL 1



SECTION A-A

TCO UNIT LAYOUT ON EMBEDS PLAN VIEW

(REF BNI DWG 24590-LAW-PI-P23T-00052)
(REF BNI DWG 24590-LAW-DD-S13T-00306)

Should be "P1" not "PI"

REF BNI DWG 24590-LAW-P1-P23T-00051

NOTES:

1. LEVEL AND PLUMB LAW TCO. SHIM UNDER THE LAW SUPPORT FRAME AS REQUIRED. WTP CONSTRUCTION TO USE WTP PROVIDED QUALITY LEVEL Q CARBON SHIM STOCK.
2. REMOVE PAINT AS NECESSARY TO ACHIEVE FIELD WELD OF SKID TO SURFACE MOUNTED PLATES

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PARTS LIST

CUSTOMER: BECHTEL NATIONAL INC.	CONTRACT NO.: 24590-CD-POC-MBT0-00007
CLIENT: DOE-ORP	EQUIPMENT NO.: 24590-LAW-MX-LVP-SKID-00002
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DEBURR SHARP EDGES	PROJECT LOCATION: WASHINGTON STATE, 200 EAST AREA OF THE HANFORD SITE
TOLERANCES ARE: FRACTIONS ±1/2; DECIMALS .X ± .2, .XX ± .12, .XXX ± .062; ANGLES ± 2°	EQUIPMENT SERVICE: LVP OFFGAS SYSTEM
MATERIAL	

IONEX
P.O. BOX 70
Lafayette, CO. 80026
Fax: 303-666-5560
Phone: 303-666-5550

APPROVALS		DATE
DRAWN	NS	2/10/2014
CHECKED	RP	2/25/2014
APPROVED	MP	2/25/2014

DO NOT SCALE DRAWING

HANFORD TANK WASTE TREATMENT AND IMMOBILIZATION PLANT (WTP)

LAW THERMAL CATALYTIC OXIDIZER

TCO GENERAL ARRANGEMENT

PRODUCTION ORDER NO.	SIZE	DWG. NO.	REV.
913040	D	913040-010-001	B

SCALE NONE | CATEGORY NO: | SHEET 4 of 4

RIVER PROTECTION PROJECT – WASTE TREATMENT PLANT

ENGINEERING SPECIFICATION

FOR

LAW Thermal Catalytic Oxidizer/Reducer

Content applicable to ALARA? ☒ Yes ☐ No

ADR No.
24590-LAW-ADR-M-02-023

Rev
4

Specification changes retroactive? ☐ Yes ☒ No
☐ N/A (alpha revision or revision 0)

NOTE: Contents of this document are Dangerous Waste Permit affecting.

Quality Level
Q
DOE Contract No. DE-AC27-01RV14136

REV	DATE	BY	CHECK	AUTHORIZATION	AUTHORIZATION	APPROVER
4	5/5/2015	D Rickettson	Jim Marsh	N/A	N/A	~~S Kretzschmar~~ P. RAJAGOPALAN AL 5/5/15
3	10/21/14	D Rickettson	G Goolsby	N/A	N/A	S Kretzschmar
2	07/01/13	J Marsh	D Rickettson	N/A	N/A	O Omel
1	04/26/10	D Nelson	N Whitcomb	N/A	N/A	J Roth
0	03/01/10	D Nelson	N Whitcomb	N/A	N/A	J Roth

SPECIFICATION No.
24590-LAW-3PS-MBTV-T0001

Rev
4

Revision History

Revision	Reason for Revision	Q Specification Revision Only Margin Reduced?		CM Only
		YES	NO	N/A
0	Issued for purchase	N/A	N/A	N/A
1	This revision removes the full complement of NQA-1 requirements and substitutes a Quality Requirements Specification customized specifically for the LAW TCO procurement. This revision also reflects the removal of IEEE-323 environmental qualification requirements for LAW SS equipment. No revision bars were used for this revision. Issued for purchase.	☐	☒	☐
2	Incorporates TCN's 24590-QL-MRA-MBT0-00007-T0002, 4, 6, 7, 8, and 9. Incorporates SDDR's 24590-WTP-SDDR-MS-11-00054, 11-00200, 11-00298, 11-00299, 12-00094, 12-00110, 12-00167, 12-00168, 12-00173, 13-00001, 13-00006, 13-00015, 13-00023. On 04/10/13 the Supplier for the LAW TCO went out of business. The following specification sections were revised to address finishing the LAW TCO by the Completion Supplier. •Add section 1.2.15, defined work scope for the Completion Supplier •Add section 1.3.12, defined work scope for WTP. WTP will be responsible for seismic, thermal, ASME B 31.3 and ASME VIII calculations. •Revised the specification throughout changing "Supplier" to "Completion Supplier" where appropriate. • Revised the specification throughout deleting submittal requirements for seismic, thermal, ASME B 31.3 and ASME VIII analysis. •Add section 4.5, Defined Government Furnished Material (GFE) requirements for the Completion Supplier. •Rewrite section 5.1.4, defined ammonia gas pipe line connection requirements for the Completion Supplier. •Rewrite section 6.1.4, revised testing of rectangular flanges for Completion Supplier. •Delete section 10.2.7.1, contents on this section moved to new section 4.5. •editorial revision to Attachment JQ07, section 3.4.5.2.1, added ASTM A276, 316L, as required by TCN8 •Attachment JQ07 - Deleted the safety software requirements, added the cable separation requirements. •Added attachment 13 LAW design Status 06/26/13, for the Completion Supplier.	☐	☒	☐
3	Incorporated TCN's 24590-QL-MRA-MBT0-00007-T0010, and 11. Incorporated SDDR's 24590-WTP-SDDR-MS-13-00074, 14-00002, 14-00003, 14-00004, 14-00042, 14-00048, 14-00049, 14-00050, 14-00061, 14-00062 and 14-00064. Incorporated technical notes from MR, 24590-QL-MRA-MBT0-00007. The Completion Supplier and WTP were unable to qualify the majority of the partially fabricated TCO and ammonia air dilution skid for reuse. The options that allowed the Completion Supplier to refurbish the partially fabricated TCO and ammonia air dilution were removed. This	☐	☒	☐

		Q Specification Revision Only Margin Reduced?		CM Only
	general specification revision aligns the specification with the current fabrication plan. Aligning the specification with the current fabrication plan and incorporating previously approved changes (TCNs, SDDR & technical notes) does not reduce margin. Justification for margin statement. Margin was evaluated on the previously reviewed and approved changes. Fabrication options do not include margin, so deletion of fabrication options do not impact margin. Fabrication plans do not include margin, so margin is not impacted. Revision bars were not used for this general specification revision.			
4	Incorporated SDDR's 24590-WTP-SDDR-MS-14-00066, 14-00068, 14-00069, 14-00074, 14-00076, 14-00091, 15-00010, 15-00012, 15-00017, 15-00018, 15-00021, 15-00022, 15-00023 and 15-00025. Incorporated EIEs, 24590-LAW-EIE-MS-14-0079 & 14-0088. Strike out and or Revision bars were used to denote changes.	☐	☒	☐

Notice

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the US Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

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Attachments

Attachment JQ07 - ***Instrumentation for Packaged Systems***
Attachment EKP0 - ***Electrical Requirements for Packaged Systems***
Attachment NN00 - ***Thermal Insulation for Mechanical Systems***
Attachment PS02 - ***Shop Fabrication of Piping***
Attachment AFPS - ***Shop Applied Special Protective Coatings for Steel Items and Equipment***
Attachment EEQ - ***LAW TCO EEQ Guidance***

1. **24590-WTP-SRD-ESH-01-001-02, pages C.34-1 thru C.34-5, tailoring of ANSI-K61.1**
2. **24590-WTP-SRD-ESH-01-001-02, pages C.26-1 thru C.26-7, tailoring of ASME-B31.3**
3. **Deleted**
4. **LAW Skid Interface Connections**
5. **Connection for Non-Routine Sample Extraction**
6. **Connection for Sample Extraction-Permanent Typical**
7. **Certificate of Analysis for BASF Catalysts, LLC (VOCat 300S)**
8. **LAW TCO & Ammonia/Air Dilution Skid Embed As-Built Elevations**
9. **Deleted**
10. **Deleted**
11. **Sample Certificate of Conformance**
12. **Deleted**
13. **Deleted**

1 Scope

1.1 Project Description and Location

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is a complex of waste treatment facilities where the Department of Energy's (DOE) Hanford site tank waste will be pretreated and immobilized into stable glass form via vitrification. The WTP Contractor will design, build, and start up the WTP pretreatment and vitrification facilities for the US Department of Energy's (DOE) Office of River Protection (ORP). The waste treatment facilities will pre-treat and immobilize the Low-Activity Waste (LAW) and High-Level Waste (HLW) currently stored in underground storage tanks at the Hanford Site.

The Hanford Site occupies an area of about 560 square miles and is located along the Columbia River, north of the city of Richland. The WTP Facility will be constructed at the East End of the 200 East Area of the Hanford Site. Benton, Franklin, and Grant counties surround the Hanford Site.

1.2 Equipment, Material, and Services Required

This specification provides the requirements for the design, materials selection, appurtenances selection, quality control, quality assurance, inspection, fabrication, testing and labeling of an LAW Thermal Catalytic Oxidizer/Reducer (TCO) and the associated Ammonia/Air Dilution Skid.

The scope of work for the Completion Supplier includes work specifically defined in this specification and its addenda and attachments. Work shall include, but is not limited to, the following:

1.2.1 Low-Activity Waste Off-Gas Equipment: To include a Thermal Catalytic Oxidizer/Reducer Skid, LVP-SKID-00002, Ammonia/Air Dilution Skid, LVP-SKID-00003, and Ammonia-Air Dilution fan control panel (LVP-PNL-00003).

1.2.2 Deleted

1.2.3 Provide Material Test Reports (MTRs), welding procedures, removable insulation installation procedures, surface preparation and coating procedures, testing procedures, testing results, inspection results, and all other procedures and documentation required per this specification and its addenda and attachments.

1.2.4 Provide transportation, storage, and installation instructions for the Thermal Catalytic Oxidizer/Reducer and the Ammonia/Air Dilution Skid per manufacturer's recommendation and this specification.

1.2.5 Provide packaging and prepare the Thermal Catalytic Oxidizer/Reducers Skid, the Ammonia/Air Dilution Skid, control panels, gaskets, special tools (if required), and catalyst bed for shipment to the WTP site. Packaging shall be sufficient to allow indoor storage for a period of up to 12 months at the WTP site, without Buyer action except routine inspection. Environmental conditions for storage are found in Section 7.4 of this specification.

1.2.6 Provide special tools required for installation and maintenance.

1.2.7 Provide Material Safety Data Sheets (MSDSs) for the catalyst cartridges and any other potentially hazardous chemicals or materials which will be delivered to the Buyer.

1.2.8 Deleted

1.2.9 Procure and install thermal insulation. Provide installation procedures for removable insulation.

1.2.10 Deleted

1.2.11 Provide shop painting of carbon steel surfaces.

1.2.12 Deleted

1.2.13 Provide junction boxes to accommodate wiring to remote-mounted Completion Supplier control panel. The Completion Supplier shall provide wiring schedule, diagrams, and documentation to facilitate installation of wiring from equipment to remote control panel.

1.2.14 Deleted

1.3 Work by Others

Specific activities and materials excluded from the scope of this specification include:

1.3.1 Shipping to WTP jobsite

1.3.2 Material unloading and storage at jobsite

1.3.3 Installation labor

1.3.4 Foundation embeds and Surface Mounted Plates

1.3.5 Ammonia vapor supply to skid connection

1.3.6 Electric power supply

1.3.7 Off skid external wiring

1.3.8 External connection to the Buyer's instrumentation and controls

1.3.9 Containment Tent, portable High Efficiency Particulate Air (HEPA) filter exhauster

1.3.10 Grounding cable

1.3.11 Z Instruments, TE-0509 with thermowell, TE-0516 with thermowell, FE-0530, FE-0531, FE-0540, FE-0541, YV-0528 and YV-0538

1.3.12 WTP will provide the Seismic, Thermal, ASME Section VIII, and the ASME B31.3 piping analyses for the Thermal Catalytic Oxidizer/ Reducer skid and the associated Ammonia / Air Dilution skid.

1.4 Acronyms and Abbreviations

ADS	Ammonia Dilution Skid
AHJ	Authority Having Jurisdiction
AI	Analog Input
AISC	American Institute of Steel Construction
AO	Analog Output
ANSI	American National Standards Institute
ASD	Adjustable Speed Drive
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
AWS	American Welding Society
C&I	Control & Instrumentation

CM	Commercial
MTR	Material Test Report
COA	Certificate of Analysis
COTS	Commercial-Off-The-Shelf
DBE	Design Basis Event
DCS	Distributed Control System
DD	Device Description
DO	Digital Output
DRE	Destruction and Removal Efficiency
EJMA	Expansion Joint Manufactures Association
FT	Functional Test
FF	Foundation® Fieldbus
FMEA	Failure Mode and Effects Analysis
FTF	Filter Test Facility
GFE	Government Furnished Equipment
HEPA	High Efficiency Particulate Air
HLW	High Level Waste
ICN	Integrated Control Network
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input / Output
ISA	Instrument Service Air
LAW	Low Activity Waste
MACT	Maximum Achievable Control Technology
MDS	Mechanical Data Sheet
MR	Material Requisition
MSDS	Material Safety Data Sheet
MTBF	Mean-Time Between Failure
NACE	National Association of Corrosion Engineers
NDE	Non-Destructive Examination
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NMCF	Non-Modifiable Configurable Firmware
NOx	Oxides of Nitrogen
NRTL	Nationally Recognized Testing Laboratory
P&ID	Piping and Instrumentation Diagram
PCJ	Process Control System
PLC	Programmable Logic controller
PMI	Positive Material Identification
PPE	Personnel Protection Equipment
PPJ	Programmable Protection System
PQR	Procedure Qualification Record
PSA	Process Service Air
QAP	Quality Assurance Program
Q	Quality
QL	Quality Level
RFQ	Request for Quote
RPP	River Protection Project
RTD	Resistance Temperature Device

SBS	Submerged Bed Scrubber
SC	Seismic Category
SCO	Selective Catalytic Oxidation
SCR	Selective Catalytic Reduction
SDDR	Supplier Deviation Disposition Request
SIS	Safety Instrumented System
SS	Safety Significant
SSCs	Systems, Structures, and Components
SVOCs	Semi-Volatile Organic Compounds
TCO	Thermal Catalytic Oxidizer/Reducer
UL	Underwriters Laboratories, Inc.
VOCs	Volatile Organic Compounds
VSL	Vitreous State Laboratory
WAC	Washington Administrative Code
WESP	Wet Electro Static Precipitator
WPS	Welding Procedure Specification
WTP	Hanford Tank Waste Treatment and Immobilization Plant

1.5 Definitions

The equipment covered by this specification will be used in the WTP, where the following definitions are applicable:

Quality Level (QL): The quality level identifies the quality requirements to be applied to the equipment. The identified quality levels are Q (Quality), and CM (Commercial).

Seismic Category (SC): Specific requirements for each seismic category are defined in the reference document, Sections 2.3.21 of this specification.

Thermal Catalytic Oxidizer/Reducer Expert: One who has extensive knowledge regarding the characteristics and application of Thermal Catalytic Oxidizer/Reducer.

Cabinet: It is used interchangeably with the word "enclosure" within this specification.

Enclosure: A surrounding case constructed to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection to the enclosed equipment against specific environmental conditions. An enclosure generally does not have any operational interface accessible from the exterior.

Panel: A type of enclosure that provides some kind of operational interface accessible from the exterior, without having to open the enclosure.

Rack: An open frame construction of angle, strut, channel, pipe, etc., designed to support the mounting of four or more instruments.

Non-Modifiable Configurable Firmware: The combination of commercial off the shelf hardware device, computer instructions, and data that resides as read-only software on that device. Non-Modifiable Configurable Firmware precludes modifications by the Buyer's staff, but can accept configuration parameters, via a set up process, to achieve specific functionality to meet the Buyer's requirements, provided features or capabilities such as advanced "scripting" or "coding" are not utilized. Non-modifiable configurable firmware can be adequately verified by testing the component of which it is an integral part.

1.6 Safety/Quality Classifications

1.6.1 Refer to the MDS in Section 2 of the MR for Safety Class, Quality Level, and Seismic Category classifications related to the LAW Thermal Catalytic Oxidizer/Reducer and the Ammonia/Air Dilution skid.

2 Applicable Documents

2.1 General

2.1.1 Work shall be done in accordance with the referenced codes, standards, and documents listed below, which are an integral part of this specification.

2.1.2 When specific chapters, sections, parts, or paragraphs are listed following a code, industry standard, or reference document, only those chapters, sections, parts, or paragraphs of the document are applicable and shall be applied. For the codes and standards listed in Section 2, the specific revision or effective date identified shall be followed. If a date or revision is not identified, the latest issue, including addenda, at the time of quotation, shall apply.

2.2 Industry Standards

2.2.1 Deleted

2.2.2 ASME B31.3 – 1996, *Process Piping Code*, as tailored in Appendix C of 24590-WTP-SRD-ESH-01-001-02, *Safety Requirements Document Vol. II* (see Attachment 2)

2.2.3 ASME B & PVC, Section VIII-2004, Division 1: *Rules for Construction of Pressure Vessels*

2.2.4 ASME Y14.100, *Engineering Drawing Practices*

2.2.5 ASTM – E84-08, *Surface Burning Characteristics of Building Materials*

2.2.6 Deleted

2.2.7 AWS D1.6-1999, *Structural Welding Code, Stainless Steel*

2.2.8 NEMA 250-2003, *Enclosures for Electrical Equipment (1,000 Volts Maximum)*

2.2.9 NFPA 70 – 1999, *National Electrical Code*

2.2.10 NFPA 497-1997, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

2.2.11 UL 467-2007, *Standard for Safety Grounding and Bonding Equipment*

2.2.12 UL 508-2007, *Standard for Safety Electric Industrial Control Equipment*

2.2.13 UL 508A-2007, *Standard for Industrial Control Panels*

2.2.14 ANSI K61.1 - 1999, *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*, as tailored in Appendix C of 24590-WTP-SRD-ESH-01-001-02, *Safety Requirements Document Vol. II* (see Attachment 1)

2.2.15 ASME AG-1 1997 with ASME AG-1a-2000 Addenda, Code on Nuclear Air & Gas Treatment

2.2.16 Deleted

2.2.17 ASME PTC-10-1997, Performance Test Codes on Compressors and Exhausters

2.2.18 ABMA 9-1990, Load Ratings and Fatigue Life for Ball Bearings

2.2.19 ABMA 11-1990, Load Ratings and Fatigue Life for Roller Bearings

2.2.20 ISO 3744-1995, Acoustics - Determination of Sound Power Levels of Noise Sources Using Sound Pressure - Engineering Method in an Essentially Free Field over a Reflecting Plane

2.2.21 ISO 1940-1:2003, Mechanical Vibration - Balance Quality Requirements for Rotors In a Constant (Rigid) State-Part 1: Specification and Verification of Balance Tolerances

2.2.22 NEMA MG 1-1998, Motors and Generators

2.2.23 AMCA-210-1999, Laboratory Methods of Testing Fans for Aerodynamic Performance Rating

2.2.24 AWS D1.1-2000, *Structural Welding Code – Steel*

2.2.25 EJMA Ninth Edition with 2011 Addenda

2.2.26 29 CFR 1910, *Occupational Safety and Health Standards for General Industry*

2.2.27 1997 UBC, *Uniform Building Code*

2.2.28 ASME B16.10-2009, Face-to-Face and End-to-End Dimensions of Valves

2.3 Reference Documents/Drawings

2.3.1 24590-WTP-3PS-EVV1-T0001, *Engineering Specification for Low Voltage Adjustable Speed Drives*

2.3.2 Deleted

2.3.3 24590-WTP-3PS-G000-T0001, *Engineering Specification for Supplier Quality Assurance Program Requirements*

2.3.4 24590-WTP-3PS-G000-T0002, *Engineering Specification for Positive Material Identification (PMI) for Shop Fabrication*

2.3.5 24590-WTP-3PS-G000-T0003, *Engineering Specification for Packaging, Handling and Storage Requirements*

2.3.6 Deleted

2.3.7 Deleted

2.3.8 24590-WTP-3PS-JQ00-T0004, *Engineering Specification for Management of Supplier Software*

2.3.9 24590-WTP-3PS-JXXE-T0003, *Engineering Specification for Commercial C&I Enclosures, Panels, Cabinets, and Racks*

2.3.10 *Deleted*

2.3.11 24590-WTP-3PS-MKH0-T0009, *Engineering Specification for Standard Nuclear Grade High Efficiency Particulate Air (HEPA) Filters (For ASME AG-1 Compliant Filters)*

2.3.12 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication*

2.3.13 Deleted

2.3.14 24590-WTP-3PS-MVB2-T0001, *Engineering Specification for Welding of Pressure Vessel, Heat Exchangers and Boilers*

2.3.15 24590-WTP-3PS-NWP0-T0001, *Engineering Specification for General Welding and NDE Requirements for Supplier Fabricated Piping*

2.3.16 24590-WTP-3PS-SS00-T0001, *Engineering Specification for Welding of Structural Carbon Steel*

2.3.17 24590-WTP-3PS-SS00-T0002, *Engineering Specification for Welding of Structural Stainless Steel and Welding of Structural Carbon Steel to Structural Stainless Steel*

2.3.18 24590-101-TSA-W000-0009-195-00002, *Report - Small Scale Melter Testing for Allyl Alcohol Method Verification*

2.3.19 24590-WTP-LIST-CON-08-0001, *Restricted Materials List WTP Safety Assurance*

2.3.20 24590-LAW-M6-LVP-00005002, *P&ID - LAW Secondary Offgas / Vessel Vent Process System SCO / SCR Skid*

2.3.21 24590-LAW-MKD-LVP-00012, *24590-LAW-MX-LVP-SKID-00002 and 24590-LAW-MX-LVP-SKID-00003 - LAW Catalytic Oxidizer / Reducer*

2.3.22 24590-WTP-3PS-PB01-T0001, *Technical Supply Conditions for Pipe, Fittings, and Flanges*

2.3.23 Deleted

2.3.24 24590-LAW-M6-LVP-00005001, *P&ID - LAW Secondary Offgas / Vessel Vent Process System Ammonia Dilution Skid*

2.3.25 **24590-WTP-3PS-MUMI-T0002, Low Voltage Induction Motors**

3 Design Requirements

3.1 General

3.1.1 The Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution unit is designed to selectively and primarily remove Volatile Organic Compounds (VOCs) and Oxides of Nitrogen (NO_X) from the offgas generated by the LAW melters.

3.1.2 The Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution unit shall be designed per this specification, the applicable documents listed in Section 2 of this specification, and the MDSs in Section 2 of the MR.

3.1.3 The WTP facility is designed for a minimum service life of 40 years. Structural and pressure boundary components related to the Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution units shall be engineered with a design life of 40 years. The Recuperative Heat Exchanger shall have a minimum service life of 15 years. Catalyst used in the Thermal Catalytic Oxidizer/Reducer shall have a minimum design life of one year. Other key mechanical components, such as the Electric Heaters, and fans shall have a minimum service life of five years with periodic maintenance.

3.1.4 Operation of the Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution units shall be continuous for one year. Refer to MDSs in Section 2 of the MR for thermal cyclic conditions. All instruments in section 3.1.14 with a "Z" suffix have been removed from the Completion Supplier's scope.

3.1.5 Deleted

3.1.6 The maximum pressure drops across the Thermal Catalytic Oxidizer/Reducer shall be in accordance with the requirements of the MDSs.

3.1.7 The following requirements shall be met (responsibility of the Buyer):

- Pressure boundary shall be designed in accordance with the requirements of ASME B&PVC, Section VIII, Div. 1 and BUYER specification 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication.* Code stamp is not required
- Non-Destructive Examination (NDE) requirements for the pressure boundary shall be in accordance with the Buyer specification 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication.* See additional requirements for Design Level 2 (L-2) Vessels, Section 6.3
- Seismic analysis shall be per the Buyer's specification 24590-WTP-3PS-MV00-T0002, *Engineering Specification for Seismic qualification Criteria for Pressure Vessels*
- The structure supporting the pressure boundary shall be designed per BUYER specification 24590-WTP-3PS-MV00-T0002, Section 7.2.2, *Engineering Specification for Seismic Qualification Criteria for Pressure Vessels*

3.1.8 Penetrations in the pressure boundary (i.e. access doors, sample ports, etc.) shall be designed and reinforced in accordance with the requirements of ASME B&PVC, Section VIII, Div. 1, and the Buyer's specification 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication.*

3.1.9 Deleted

3.1.10 Deleted

3.1.11 Deleted

3.1.12 Circular expansion joints / bellows shall be designed and manufactured in accordance with ASME B31.3 and the Expansion Joint Manufacturers Association (EJMA) standard. The 18 inch diameter bellows shall be designed for a design pressure of +15 psig / full vacuum. The design temperature for the 18 inch bellows shall be 500F. The 18 inch diameter bellows shall be designed for 100 cycles. Square or rectangular joints not specifically addressed by the Boiler & Pressure Vessel Code, ASME Section VIII, Division 1, shall meet the requirements within the latest version of the Expansion Joint Manufactures Association (EJMA) Standard. The bellows design shall meet all the design conditions and design life of the equipment. Stainless steel expansion bellows shall not be annealed after forming.

3.1.13 The Buyer will design the outlet piping for sample nozzles located downstream of the recuperative heat exchanger required for ammonia control. The Completion Supplier shall supply Expansion joints for both the offgas process inlet and outlet connections. Expansion joints shall be one ply ~~or greater~~.

Analysis Condition, Movements	(Combined)	Required or Not Required

Compression Design	1.000 inch	Required
Lateral Design	0.5000 inch	Required
Angular Design	2 degrees	Required
Torsion	0.3 degrees	Optional, not a contract requirement

3.1.14 The following are the Safety Significant functions of the LAW Thermal Catalytic Oxidizer/Reducer and the Ammonia/Air Dilution units. An instrument has a "Z" suffix if it serves an active safety function. All instruments with a "Z" suffix have been removed from the Completion Supplier's scope. (Note: Only root components are listed below. See P&IDs 24590-LAW-M6-LVP-00005001 and 24590-LAW-M6-LVP-00005002 for the remaining components):

a) Confinement of Melter Offgas: TCO housing, piping, and appurtenances shall be designed to maintain melter offgas confinement during normal operation, and during and after a seismic category III DBE. Structural failure of internals shall not breach confinement boundary.

b) Confinement of Ammonia: The ammonia and air dilution supply piping, valves, and appurtenances shall maintain confinement of ammonia during normal operation, and during and after a seismic category III DBE.

c) Electric Heater Shutdown Safety Scenarios to safely shut down electric heaters before, during and after a seismic category III DBE:

- Electric Heaters shall shut down upon detection of high heater outlet temperature (TE 0509(Z) & TE 0516(Z)) (by others)
- Electric Heaters shall shut down upon detection of high temperature at outlet of SCO/SCR skid (by others)
- Electric Heaters shall shut down upon detection of Caustic Scrubber bypass valve opening (by others)
- Electric Heaters shall shut down upon detection of high temperature at outlet of the Caustic Scrubber (by others)

d) Ammonia Supply Safety Scenarios to safely control the supply of ammonia before, during and after a seismic category III DBE:

- Close YV 0528(Z) upon detection of low dilution-air flow (by others)
- Close YV 0528(Z) upon detection of low LVP header vacuum (by others)
- Close YV 0528(Z) upon detection of high LVP header vacuum (by others)
- Close YV 0528(Z) upon detection of high ammonia flow (by others)
- Close YV 0528(Z) upon detection of low offgas temperature at the SCO/SCR skid outlet (by others)
- Close YV 0528(Z) upon detection of high offgas temperature exiting the SCO/ SCR skid outlet (by others)

- Close YV 0528(Z) upon detection of high temperature exiting the Caustic Scrubber (by others)
- Close YV 0528(Z) upon detection of the Caustic Scrubber bypass valve not closed (by others)
- Fail-Safe valve YV 0528(Z) fail closed on loss of power or control signal (by others)

e) Ammonia/Air Dilution Safety Scenarios to safely dilute and maintain the SCO/ SCR ammonia concentration below the Lower Flammable Limits (LFL) before, during and after a seismic category III DBE:

- Close YV 0538(Z) upon detection of low LVP header vacuum (by others) below a predetermined setpoint (by others)
- Close YV 0538(Z) upon detection of high LVP header vacuum (by others) above a predetermined setpoint (by others)
- Fail-Safe valve (YV 0538(Z)) fails closed on Loss of power or control signal (by others)

f) SCO/SCR Skid Bypass Valve YV 0501(Z) (by others) Actuation Safety Scenarios to safely handle melter offgas before, during and after a seismic category III DBE:

- Open YV 0501(Z) upon detection of high SCO/SCR differential pressure (by others)
- Open YV 0501(Z) upon detection of high LVP header vacuum (by others)
- Open YV 0501(Z) upon detection of low LVP header vacuum (by others)
- Open YV 0501(Z) upon detection of Caustic Scrubber bypass valve not closed (by others)
- Open YV 0501(Z) upon detection of high temperature exiting the Caustic Scrubber (by others)
- Open YV 0501(Z) upon detection of a loss of normal facility power (by others)
- Fail-safe valve YV 0501(Z) fails open upon loss of power or control signal (by others)

3.2 Offgas Treatment Functional Description of Major Components

Offgas is generated from the vitrification of radioactive waste in Joule heated ceramic melters.

3.2.1 LAW Thermal Catalytic Oxidizer/Selective Catalytic Reduction Unit:

The feed to the LAW Thermal Catalytic Oxidizer/Reducer is primarily melter offgas that has been treated by a Submerged Bed Scrubber (SBS), Wet Electrostatic Precipitator (WESP), HEPA Filters, and an Activated Carbon Bed Adsorber.

3.3 Basic Function

The Thermal Catalytic Oxidizer/Reducer unit shall consist of four primary components; a recuperative heat exchanger, electric heaters, VOC selective catalytic oxidation (SCO) bed, and a NO_X selective catalytic reduction (SCR) bed. The power supply shall be as specified in Section 3.9. The rating of each component shall be determined by the Completion Supplier to meet the performance requirements specified in Section 3.4 of this specification. The

Completion Supplier shall also include ammonia dilution and mixing appurtenances necessary to meet performance requirements of this specification.

3.3.1 Recuperative Heat Exchanger

The recuperative heat exchanger is primarily employed to recover heat from the SCR hot exhaust gas for the Thermal Catalytic Oxidation/Reducer unit. The heat exchanger shall cool down the hot SCR exhaust gas and heat the incoming offgas.

3.3.2 Electric Heaters

The electric heaters are downstream of the recuperative heat exchanger and are employed to heat the offgas feed to the final desired oxidation and reduction temperatures. After startup, the electric heaters shall function as a trim control to raise the offgas temperature to the required oxidizing temperature. Required oxidizing and reduction temperatures shall be per performance criteria specified in Section 3.4 of this specification.

3.3.3 VOC Selective Catalytic Oxidation Unit

The SCO unit, containing oxidation catalyst, is downstream of the Electric Heaters and will oxidize volatile and semi-volatile organic compounds creating water and carbon dioxide. The residence time and number of catalyst beds shall be as specified in Section 3.4 of this specification.

3.3.4 NO_X Selective Catalytic Reduction Unit

The SCR unit, containing reduction catalyst, is downstream of the SCO and shall use ammonia injection to reduce the NO_X to Nitrogen, Oxygen, and water through catalytic reaction with ammonia.

3.3.5 Ammonia/Air Dilution System

The Buyer will supply ammonia gas to the LAW Ammonia/Air Dilution System. The Completion Supplier shall specify dilution air flow rates and pressures if required for the Ammonia/Air Dilution skid. The Completion Supplier shall supply necessary equipment required to meet performance requirements.

3.4 Performance

3.4.1 Refer to the Thermal Catalytic Oxidizer/Reducer MDSs for design data and gas stream properties.

3.4.2 The organic Destruction and Removal Efficiency (DRE) performance shall be based on inlet loadings specified in the MDSs.

3.4.3 The Thermal Catalytic Oxidizer/Reducer shall meet the DRE for Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs) as required in the MDSs as well as residence time and minimum oxidizing temperatures specified.

3.4.4 The NOx SCR unit shall meet the reduction efficiency at less than the specified ammonia slip concentration required in the MDSs.

3.4.5 Detection limits used to verify the Thermal Catalytic Oxidizer/Reducer guaranteed performance shall be based on the Buyer information (MDS General Note 9).

3.4.6 Deleted

3.4.7 The Completion Supplier shall provide the ammonia slip point within the mass balance calculation (excess ammonia beyond that needed for the reaction) for SCR performance.

3.4.8 The ammonia slip exiting the LAW systems shall be specified by the supplier to meet the NOx reduction efficiencies specified in Section 3.4.4 of this specification.

3.4.9 BUYER's residence time, specified in the MDSs, is the minimum for VOC and SVOC destruction.

3.4.10 As specified in the MDSs, concentrations of certain chemical compounds are subject to large step increases and spikes. The Completion Supplier's calculation shall account for these increases and spikes.

3.4.11 The Completion Supplier shall identify if additional NOx analyzers are required outside the boundaries of the Completion Supplier's equipment to meet the specified NO_X reduction efficiency and ammonia slip MDS requirements. The Completion Supplier shall obtain the Buyer's approval for additional NO_X analyzers.

3.5 Design Conditions

3.5.1 Refer to the Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution MDSs in Section 2 of the MR.

3.5.2 The embed plate design location and elevation for the two skids are shown on drawing 24590-LAW-DB-S13T-00135, drawing coordinate (F-6.5 for the TCO skid, G-7.5 for the Ammonia/Air Dilution skid). The design elevation for the top of the embed plates is 48 feet - 0 inches, in plant elevation. The existing embed elevations vary slightly from plate to plate. Attachment 8 lists the embed As-Built elevations.

3.5.3 Deleted

3.5.4 The Buyer's existing embed plates for the TCO skid are coated carbon steel plates, stock code: EBPNS02CD, shown on drawing 24590-BOF-DD-S13T-00001. The Buyer's existing embed plates for the NH3/Air Dilution skid are coated carbon steel plates, stock code: EBPST19CA, shown on drawing 24590-LAW-DD-S13T-00019. The carbon steel embed plates are coated with one layer of inorganic zinc primer. When attachments are welded to the existing embed plates, the Buyer site welding procedures require inorganic zinc primer to be removed within 2- 4 inches of the weld area. Only carbon steel can be welded to the carbon steel embed plates where the inorganic zinc primer has been removed.

3.5.5 Thermal Catalytic Oxidizer / Reducer Skid, LVP-SKID-00002, will be field welded to carbon steel or stainless steel surface mounted plates provided by the Buyer. The Buyer supplied surface mounted plates will be bolted with through bolts and installed with sandwich plates through the facility floor. See the Buyer's drawing 24590-LAW-DD-S13T-00306, Detail 4.

Locate the inlet bellows flange, LVP-BLWS-00053, 12 feet - 6 inches above the base of the Thermal Catalytic Oxidizer / Reducer Skid, LVP-SKID-00002.

Locate the outlet bellows flange, LVP-BLWS-00061, 12 feet - 6 inches above the base of the Thermal Catalytic Oxidizer / Reducer Skid, LVP-SKID-00002.

The Ammonia / Air Dilution Skid, LVP-SKID-00003, will be field welded to carbon steel or stainless steel surface mounted plates provided by the Buyer. The surface mounted plates will be bolted to the facility floor or bolted to the existing embeds. See 24590-LAW-S1-S15T-00147.

3.5.6 The 2 inch thick surface mounted plates shown on drawing 24590-LAW-DD-S13T-00306 have been installed in the LAW facility. Each plate is secured with (4) 1 1/2 inch diameter threaded rods. On the 48' elevation side of the surface mounted plate the threaded rods are

secured with double nuts and washer. During the installation of these surface mounted plates the 1 3/4 inch core drilled holes had to be positioned to miss reinforcing bar. The installed centerline location of the threaded rods with double nuts and washer are shown on drawing, 24590-LAW-DD-S13T-00313. As detailed on this drawing the rods with doubled nuts and washer stick up 3 7/8 inches to 4 1/2 inches above the top of the plate.

3.6 Environmental Conditions

3.6.1 The Thermal Catalytic Oxidizer/Reducer Skid and Ammonia/Air Dilution Skid will be located indoors. Refer to MDSs for specific room environmental design conditions.

3.6.2 Deleted

3.6.3 Deleted

3.6.4 The Completion Supplier shall provide and document Environmental Qualification per the requirements in Attachment EEQ.

3.7 Mechanical Requirements

3.7.1 General

3.7.1.1 Due to access restrictions for installation, the Thermal Catalytic Oxidizer/Reducer unit shall be fabricated in such a manner that will allow delivery in sections that comply with the bounding dimensions specified in MDSs. Each section of the Thermal Catalytic Oxidizer/Reducer shall be skid mounted.

3.7.1.2 The catalyst bed shall be designed for manual removal and replacement. The catalyst bed shall be designed to meet service life requirements outlined in Section 3.1.3 of this specification. The weight of a catalyst module is expected to be 60 to 70 pounds. When weights exceed 50 pounds, lifting beams, catalyst removal tools, or rigs shall be designed and supplied by the Completion Supplier.

3.7.1.3 The Completion Supplier shall provide transitions for connection to the Buyer's piping and gas analyzer instrumentation. All flanges required for connection to the Buyer's piping and gas analyzers shall be raised face flanges and shall be welded to the pipe (no threaded connections allowed). See Attachment 4 (LAW Skid Interface Connections). See also Attachments 5 and 6 (Connection for Non-Routine Sample Extraction and Connection for Sample Extraction - Permanent Typical, respectively) for non-routine and permanent analyzer connection details.

3.7.1.4 Deleted

3.7.1.5 NOT USED

3.7.1.6 Deleted

3.7.1.7 NOT USED

3.7.1.8 A containment tent or series of containments tents will be erected by the Buyer to control the work area for catalyst removal and replacement after permanent installation of the TCO units. The Buyer will supply and set up a portable HEPA filtered exhauster for containment tent ventilation with discharge port monitoring. The TCO unit will be ventilated using the Buyer's permanently installed process fans. Prior to catalyst removal, the TCO unit air will be sampled using a pre-installed sample tap. The air sample will be used to determine the

level of airborne radioactive material inside the TCO unit. After the air samples are taken and deemed acceptable, removal of the catalyst subassembly will proceed.

3.7.1.9 The Completion Supplier shall supply the following for the TCO unit:

One 1-inch air sample tap per TCO unit. Include one 1-inch full port ball valve. The accessible end of the 1-inch ball valve shall include a cap or blind flange. There shall be at least 3 inches of clearance, for tightening bolts, between the insulating jacketing and the underside of the flange.

3.7.1.10 Catalyst removal / installation:

The catalyst bed (s) shall be designed for manual removal and replacement without entering the TCO unit for contact maintenance.

3.7.1.11 To facilitate process troubleshooting and to obtain additional data during testing and operations, the Completion Supplier shall supply the following for each TCO unit:

One sample port between each of the VOC catalyst beds to be used to measure offgas concentrations during non-routine evolutions. Sample ports shall be located to minimize flow disturbance and not interfere with the manipulation of the catalyst access doors. The location shall consider optimum accessibility. However, it is acceptable to locate the sample ports on the top of the TCO. Include ball valve, blind flange, gaskets, and bolts for each sample port. See Attachment 5 (Connection for Non-Routine Sample Extraction) for temporary connection details.

3.7.2 Recuperative Heat Exchanger

3.7.2.1 Unless otherwise specified, the heat exchanger pressure boundary shall be designed in accordance with ASME B&PVC, Section VIII, Div. 1.

3.7.2.2 Deleted

3.7.2.3 Body flanges that allow for total unit replacement

3.7.2.4 Deleted

3.7.2.5 Deleted

3.7.2.6 Bolted connection to skid support frame

3.7.2.7 Heat exchangers shall be designed for full differential pressure, with one side at the design pressure and the other side at atmospheric pressure.

3.7.3 Ammonia/Air Dilution Equipment

3.7.3.1 Design and fabrication of ammonia piping and valves shall be in accordance with ANSI K61.1 and ASME B31.3 (as tailored in Attachment 1 & 2, respectively), and Attachment PS02 *LAW TCO Customized PS02*.

The following items, located on the ammonia dilution skid, shall be labeled as "suitable for ammonia" by the manufacturer of the item or the Completion Supplier; V-01570, YV-0560, PCV-0527, FE-0529, AV-0523, PI-0561, V-01559, V-72275, V-01557, V-01554, and FE-0539.

3.7.3.2 Deleted

3.7.3.3 The Completion Supplier shall supply, test, and deliver HEPA filters and housings for the LAW ammonia dilution system in accordance with MDSs.

3.7.3.4 HEPA filters shall be designed and fabricated in accordance with specification 24590-WTP-3PS-MKH0-T0009, *Engineering Specification for Standard Nuclear Grade High Efficiency Particulate Air (HEPA) Filters (For ASME AG-1 Compliant Filters)*, and MDS listed in Section 2.1 of the Material Requisition.

3.7.3.5 HEPA Filter housings shall be provided in accordance with the MDS listed in Section 2.1 of the Material Requisition. Supplier submittals shall be as follows:

1 Submit procedure for Pressure Decay Test, ASME AG-1 1997 with AG-1a-2000 addenda, Article III-4200 (prepared with guidance given in AG-1 mandatory Appendix TA-III). Perform test on HEPA housings. Test duration shall be 15 minutes.

2 Submit procedure for Structural Capability Test, ASME AG-1 1997 with AG-1a-2000 addenda, TA-3422, (prepared with guidance given in AG-1 mandatory Appendix TA-II). Perform test on HEPA housings.

3 Recommended spare parts for the HEPA housings.

4 Operation and maintenance manuals for the HEPA housings.

3.7.3.6 The Completion Supplier shall supply centrifugal fans for the LAW ammonia/air dilution system. If the Completion Supplier determines airflow cannot be adequately controlled using control valves and that adjustable speed drives (ASD) are required, then the ASDs shall be in accordance with 24590-WTP-3PS-EVV1-T0001, *Engineering Specification for Low Voltage Adjustable Speed Drives*. Centrifugal fan Data Sheets will not be supplied by the Buyer. The Completion Supplier shall create and submit Centrifugal fan Data Sheets outlining performance requirements as specified by the Completion Supplier. Applicable design conditions and mechanical requirements shall be outlined on the Centrifugal fan Data Sheets.

3.7.3.7 Fans shall be capable of performing at the conditions shown on the fan data sheets. Fan performance ratings shall be based on AMCA-210 standard air condition. Materials of construction used shall be compatible with the effluent being handled.

3.7.3.8 Fan/motor assemblies shall be complete with all components and accessories fully assembled, wired, and skid mounted requiring only connection to the Buyer's electrical power and control systems, and interconnecting piping. Fan/motor assemblies shall be self-supporting, capable of carrying the static loads of the fan components and the stress imposed during shipment, installation, and operation.

3.7.3.9 Fans shall be designed and constructed for low leakage. Fans shaft seal(s) shall be low leakage with an external air purge.

3.7.3.10 Bearing rating life shall be established in accordance with ABMA 9 or 11, as applicable.

3.7.3.11 The Completion Supplier shall fill in and submit the "Electrical Data Sheet Low Voltage Induction Motor" contained in specification 24590-WTP-3PS-MUMI-T0002, for Fans LVP-FAN-00001 and LVP-FAN-00002.

3.7.3.12 The Completion Supplier shall fill in and submit the "Electrical Data Sheet Adjustable Speed Drive" contained in specification, 24590-24590-WTP-3PS-EVV1-T0001, for Fans LVP-FAN-00001 and LVP-FAN-00002.

3.7.3.13 Fan sound pressure level shall not exceed 85 dB (A) at 3-feet. If sound power exceeds 85 dB (A) at 3-feet, the Completion Supplier shall obtain the Buyer permission to proceed in the form of an SDDR stating estimated sound power level.

3.7.3.14 To achieve duty / standby configuration for the Buyer, Ammonia Dilutions Fans LVP-FAN 00001 and LVP-FAN-00002 shall be powered on separate 480V power feeds.

3.7.3.15 Electric motors shall be in accordance with NEMA MG-1. Motors shall be totally enclosed fan cooled type, unless motors are small and otherwise environmentally protected. Motor drive combination shall be suitable for operation for the design conditions shown on the Completion Supplier's fan data sheets. Each motor shall have a controller or drive.

3.7.3.16 For the fan, the following shall be submitted for the Buyer's review and information:

3.7.3.16.1 The Completion Supplier's recommended accessibility and maintenance requirements.

3.7.3.16.2 Performance test reports.

3.7.3.16.3 Sound test reports.

3.7.3.16.4 Deleted

3.7.3.17 Deleted

3.8 Loading

3.8.1 The Thermal Catalytic Oxidizer/Reducer (LVP-SKID-00002) and the associated Ammonia/Air Dilution assembly shall be self-supporting, capable of carrying the static loads of components and the stress imposed during shipment, installation, and operation.

3.8.2 Deleted

3.8.3 The Buyer will provide a seismic analysis in accordance with their approved processes and procedures.

3.8.4 Deleted

3.8.5 The Thermal Catalytic Oxidizer/Reducer units shall be designed in accordance with the nozzle load requirements as specified in the MDSs in Section 2 of the MR.

3.9 Electrical Requirements

3.9.1 Electrical components and appurtenances furnished with the Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution units shall conform to the requirements of Attachment EKP0. Electrical components shall also meet applicable sections of NFPA 70-1999 and requirements outlined in NFPA 497-1997.

3.9.2 NOT USED

3.9.3 The Buyer will supply only 480V 3-wire wye-grounded power circuits. These shall connect to terminals in NEMA 4X-enclosed disconnecting devices mounted on the equipment skids. Flexible conduit connections to the skid disconnecting devices shall be used. All fan and heater circuits, and power and control circuits, shall be distributed electrical power from these power disconnecting devices. All branch circuits shall include applicable over-current protection devices. The Completion Supplier shall include in their equipment all motor and heater controllers, including their control circuits and devices. All motors shall be totally enclosed fan cooled type, unless otherwise environmentally protected. If the Completion Supplier's components are rated for a lower voltage, the Completion Supplier shall provide the components necessary to supply the lower voltage and circuit protection devices. All distribution circuits requiring disconnecting means for

maintenance and isolation, including combination controllers, to prevent complete shutdown of the Buyer's power circuits, shall be provided by the Completion Supplier. Electric heaters shall be of the element type and mounted on removable flanged plates for ease of maintenance.

3.9.4 Electrical enclosures shall be NEMA 4X rated.

3.9.5 The Thermal Catalytic Oxidizer/Reducer control panel (LVP-PNL-00003) components shall be UL 508 listed and certified. Control panels as a whole shall be UL 508A labeled.

3.9.6 NOT USED

3.9.7 Provide bolted compression type 2/0 terminal lugs at diagonally opposite corners of the TCO skid and the ammonia dilution skid for connection by the Buyer to the area ground grid. The Buyer uses 2/0 AWG stranded copper for the area ground grid.

3.9.8 The Completion Supplier shall provide total electric load for the Thermal Catalytic Oxidizer/Reducer.

3.9.9 The Completion Supplier shall provide a functional description of the electrical operation of the skids as well as single line, schematic, wiring, layout, and interconnection diagrams. In addition, catalog cut sheets, recommended spare parts, and electrical loads as detailed in Attachment EKP0, Section 9. *Documentation and Submittals.*

3.10 Instrumentation and Control Requirements

3.10.1 Instrumentation and controls furnished with the Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution units shall meet the instrumentation and control requirements as stated in Attachment JQ07. The Buyer shall provide the appropriate ABB control system components (i.e. I/O modules, power supplies) to the Completion Supplier for fabrication into the Completion Supplier's control panel (LVP-PNL-00003) as described in Section 3.4.2 of Attachment JQ07. The Completion Supplier shall provide non-ABB manufactured equipment (fiber optic converters, fiber optic patch cables and plates, terminals, circuit breaker, wiring, etc.) and panel fabrication.

3.10.2 The Completion Supplier shall design the control panel (LVP-PNL-00003) to utilize the ABB control system equipment and provide a panel arrangement drawing with Bill of Material identifying all parts to be provided by the Buyer. The Completion Supplier shall provide an I/O list on the panel arrangement drawing for all instruments. Reference Buyer's P&IDs in Section 2 of the MR for additional information regarding instrument locations and types.

3.10.3 The Completion Supplier shall provide control narrative, logic drawings, termination drawings, and related items as specified in Attachment JQ07 for normal (PCJ). The Buyer shall provide programming for normal operation (PCJ) via software included with the Buyer supplied ABB components. The Buyer shall provide controller, software, and attend and support the functional test of the equipment at the Completion Supplier's facility.

3.10.4 In-line instruments shall be wired to the skid edge. Wiring shall terminate in a junction box. On the LAW TCO the following valves shall end with a Hy-Lok tubing connection: LVP-V-01548, LVP-V-01609, LVP-V-01610, LVP-V-01612, LVP-V-01613, LVP-V-01614, LVP-V-01615, LVP-V-01616, LVP-V-01618, and LVP-V-01620.

On the LAW Ammonia dilution skid the instrument tubing shall run to a bulk head plate. Provide Hy-Lok tubing end connections at the WTP / Completion Supplier interface.

3.10.5 NOT USED

3.10.6 Management of the Completion Supplier software shall be governed by 24590-WTP-3PS-JQ00-T0004, *Engineering Specification for Management of Supplier Software.*

3.11 Lifting Requirements

3.11.1 Lifting lugs shall be installed on the Thermal Catalytic Oxidizer/Reducer and Ammonia/Air Dilution skid packages for lifting and handling. The Completion Supplier shall identify the weight and center of gravity of each package. All lifting points shall be designed in accordance with the requirements of the Buyer specification 24590-WTP-3PS-G000-T0003, *Engineering Specification for Packaging, Handling, and Storage Requirements.*

3.11.2 Lifting eyes or lugs shall be certified to be suitable for the safe, lifting and handling of the equipment without distortion or damage to the components.

3.11.3 Deleted

3.11.4 Lifting lugs must accept standard commercial lifting equipment. Chain blocks or braiding shall not be permitted.

3.11.5 The lifting lugs for the packages must be accessible from the top, without removal of components or covers.

3.11.6 The Buyer will provide calculations for the lift lug design.

3.12 Thermal Analysis Requirements

3.12.1 Deleted

3.12.2 Refer to MDS for thermal analysis technical information and heat loss requirements (i.e. thermal conductivity values, room temperatures, etc.).

3.12.3 The thermal analysis, by the Buyer, will include the effects of stresses resulting from potential variations in temperatures due to startup, normal operation, shutdowns, and thermal cycling of the Thermal Catalytic Oxidizer/Reducer. Analysis shall show that the Thermal Catalytic Oxidizer/Reducer is adequate for the design life specified in Section 3.1.2 of this specification. Analysis shall also establish design temperature of the TCOs.

3.12.4 The thermal analysis, by the Buyer, will include thermal expansion of the Thermal Catalytic Oxidizer/Reducer and resulting nozzle loadings in X, Y, and Z planes with deflections at normal operating conditions and design conditions.

3.12.5 The thermal analysis, by the Buyer, will determine the thickness and extent of insulation required on the sides, ends, top, and bottom of the Thermal Catalytic Oxidizer/Reducer to ensure that the insulation jacket temperature and all exterior uninsulated portions with potential for personnel exposure do not exceed 140 °F at maximum design temperature.

3.12.6 The thermal analysis, by the Buyer, will determine the thickness and extent of insulation required on the bottom of the Thermal Catalytic Oxidizer/Reducer so that the temperature of the concrete does not exceed 150 °F.

3.12.7 Deleted

3.12.8 Deleted

3.12.9 Deleted

3.13 Deleted

3.13.1 Deleted

3.13.2 Deleted

3.13.3 Deleted

3.13.4 Deleted

3.13.5 Deleted

3.14 Accessibility and Maintenance

3.14.1 The Buyer's layout allows for necessary access and space requirements to facilitate maintenance during normal plant operation or scheduled shutdown.

3.14.2 The Completion Supplier's recommended accessibility and maintenance requirements for each piece of equipment shall be included in the Completion Supplier's design and shown on the layout drawings. Layout drawings shall show scaled clearances as dotted areas around and in front of all electrical equipment, components, and control panels. These areas shall be as required in the National Electrical Code.

3.14.3 The Completion Supplier shall provide instructions and frequency of maintenance including lubrication, rotation, heating, and any other type of preventative maintenance that will preserve the equipment until the time it is put into operation, including:

- Up to 12 months indoor storage prior to installation
- Deleted
- Indoor (installed) but not operating preservation maintenance and inspection schedule
- Operating preservation maintenance and inspection schedule

Frequency of inspection and maintenance intervals during operation shall be in accordance with equipment the Completion Supplier's recommendations.

3.14.4 Deleted

3.14.5 Deleted

3.14.6 Deleted

3.14.7 Deleted

3.15 Software Requirements

See Section 3.5 in Attachment JQ07 for specific software requirements.

3.16 Testing and Inspection Requirements

3.16.1 The Completion Supplier shall submit un-priced Purchase Orders with attachments showing flow down of requirements to engineering under document category 33.0, on the G-321-E form. The Completion Supplier is only required to submit the un-priced POs that contain items that will be used in an application that has been designated as "Q" by the Buyer.

3.16.2 The Completion Supplier shall provide fabrication drawings with a Bill of Material. The Bill of Material shall include the WTP Quality Level (Q or CM). The Buyer will determine the WTP Quality level during the drawing review process.

3.16.3 Deleted

3.16.4 Testing and Inspection Requirements for LAW TCO & Ammonia / Air Dilution Skid Components

Testing and inspection requirements are derived from the related CGD plan as developed by the Procurement Engineering Group. For completeness of project records the Completion Supplier shall submit the Inspection, examination and test results to the Buyer via the G-321-E Document Category 33.0.

3.16.4.1 General Requirements for Components Listed in this Section

I. Testing and inspection activities listed herein are derived from the BNI Commercial Grade Dedication plans. In some instances, the tests may be equivalent to tests required in other sections of this specification. If this is the case, a duplication of the test or inspection is not necessary as long as the test or inspection fulfills both requirements. All other tests and inspections listed in this section are strictly for the verification of critical characteristics.

II. Inspect all supplier documentation for compliance with the purchase order requirements and verify that all components in a single line item of the PO have been manufactured and supplied from the same heat/lot of the base material, to the greatest extent possible. If there are different heat/lots for a single line item it may have an impact on the sampling to be performed for testing and inspections. (see VIII below)

III. PMI (OES or XRF), hardness, proof load and/or tensile testing shall be performed by a laboratory that is accredited by one of the following organizations –
-A2LA
-NVLAP
-IAS
-ACLASS
-PJLA
-L-A-B
The specific test must be included in the scope of the current certification/accreditation at the time the test is performed as verified on the accrediting organization's website. The purchase order for testing at an accredited laboratory shall require that tests be performed in accordance with the accredited program. The lab results must contain a statement that the test(s) were performed in accordance with their accredited program. If no labs with this accreditation are available, the Buyer shall be advised of the lab that the Completion Supplier will use with sufficient notice to allow for surveillance activities of the tests by the Buyer's representative. The Completion Supplier is also allowed to perform any or all of these tests after the successful completion of a CG survey in which the capability of the supplier to perform the tests is assessed and found to be acceptable.

IV. The following chemical constituents have been identified as critical to the materials listed below in order to perform their intended safety function –
304/304L SS – Cr, Ni
316/316L SS – Cr, Ni, Mo
347 SS – Cr, Ni, Cb

Incoloy 800 – Ni, Cr
These chemical constituents shall be tested for and individually identified on the test results along with the results of the test.

V. Perform tensile, hardness and proof load testing per ASTM A370. Leeb hardness testing to be performed in accordance with ASTM A956.

VI. Perform chemical verification testing per ASTM A751.

VII. Sampling for tests and inspections found in this section shall be performed per the guidance found in EPRI TR-017218. Accept on 0 defects and reject on 1 or more defects.

VIII. Each individual lot of material shall be sampled as specified below. A lot of material is defined as a single heat or run of material that is cast, extruded, or otherwise formed from a common batch of raw materials.

IX. Pressure testing, hydrostatic or pneumatic, shall be performed in accordance with Buyer approved procedures. The Buyer shall be notified of an impending pressure test to allow for surveillance activities by the Buyer's representative.

X. All inspection, examination, and test results shall be submitted to the Buyer for review within a reasonable time frame after performance of the inspection, examination, or test. The code or standard to which the test or inspection was performed and against which the results were verified shall be listed along with the results of the test, examination, or inspection.

XI. When a service is provided by a 3rd party entity (waterjet cutting, machining, etc.) that has not been evaluated by BNI, traceability of the item/material must be ensured by having a quality representative from the Completion Supplier visit the sub supplier to witness the first operation of the service(cutting, Marking, segregating...). Completion Supplier is to perform additional surveillances depending on the results of the first surveillance and the level of rigor with which the sub-supplier maintains the material traceability.

3.16.4.2 Testing and Inspection Requirements for **Pipe, Fittings and Flanges** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with ASME SA403, SA312 and SA182, SA480, SA961, ASME B16.11, ASME B16.5, ASME B16.9 and data sheets, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection

Inspect each item to confirm that the material marking/identification is in accordance with the applicable ASTM/ASME specification, is clearly readable, and has no indication of re-marking by other parties. For the blank flanges to be used for destructive testing, the following markings shall be present on each flange- heat #, manufacture's name or trademark, material, & size.

Sampling is not permitted.

Dimensional Inspection

Perform dimensional inspection of the pipe, fittings, flanges, and flow conditioner that are to be used in production as follows:

Pipe- Wall thickness at each end of the pipe

Pipe Fittings- Wall thickness at each end

End to End and / or End to Centerline

Flange- Thickness

Bore Diameter

Flow Conditioner- Outside Diameter

Thickness

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

TESTING REQUIREMENTS

Tensile / Yield/Elongation Testing

Perform tensile, yield, and elongation testing of the pipe, fittings, and flanges

Sample per plan found in EPRI TR-017218 Table 2-2, Recommended Destructive Test and Inspection Sampling Plan.

Note: Flow conditioner is excluded from this testing

Chemical Composition Testing/Verification

Perform PMI on the pipe, fittings, flanges, and flow conditioner.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

3.16.4.3 Testing and Inspection Requirements for the **ADS fans** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with Section 3.17.12 of this specification and other purchasing document requirements.

INSPECTION REQUIREMENT

Visual Inspection

Inspect the fans and related documentation as received from the supplier for conformance with the purchasing documents.

Sampling is not permitted.

TESTING REQUIREMENT

Pressure Boundary Integrity Testing/Verification

Perform bubble leak detection test to verify that the housing and flanges are able to withstand the pressures of the air supply line of the ammonia dilution skid. The test will be conducted with the fan off. The acceptance criteria shall be no bubble growth in the flanged and/or gasketed joints

Sampling is not permitted.

3.16.4.4 Testing and Inspection Requirements for **Butterfly Valves** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASTM A351, ASTM A693or ASTM A564, ASME B16.34, API 598 and API 609 as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect each valve to confirm that the valve marking/identification is in accordance with purchasing documents is clearly readable and has no indication of re-marking by other parties.

Sampling is not permitted.

Visual Inspection for Yellow metal

Perform visual inspections of the valves to verify that the disc and stem are not made from yellow metals (copper based alloys).

Sampling is not permitted.

TESTING REQUIREMENT

Chemical Composition Testing/Verification

Perform PMI on the body

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform shell pressure test on all valves per ASME B16.34 Section 7. The performance of this test will use the system design pressure in lieu of the 38 C (100 F) pressure rating. No less than 1.5 times the system design pressure for hydrostatic test, or 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

Sampling is not permitted.

3.16.4.5 Testing and Inspection Requirements for **Ball Valves** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASTM A351 (CF8M), ASME B31.3, B16.34, and API 598, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect each valve to confirm that the valve marking/identification is in accordance with purchasing documents, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

Visual Inspection - Yellow Metal

Perform visual inspections of the valves to verify that the ball and stem are not made from yellow metals (copper based alloys).

Sampling is not permitted.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on all valve bodies and end connections.

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform shell pressure test per ASME B16.34, Section 7. The performance of this test will use the system design pressure in lieu of the 38 C (100 F) pressure rating. No less than 1.5 times the system design pressure for hydrostatic test, or 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

3.16.4.6 Testing and Inspection Requirements for **Pressure Regulator** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASTM A351, ASME B31.3, and B16.34, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect pressure regulator to confirm that the marking/identification is in accordance with purchasing documents, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

~~Visual Inspection for Yellow metal~~

~~Perform visual inspections of the valves to verify that the stem is not made from yellow metals (copper based alloys).~~

~~Sampling is not permitted.~~

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on regulator body.

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform pressure test, the performance of this test will use the system design pressure, no less than 1.5 times the system design pressure for hydrostatic test, or 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

Sampling is not permitted

3.16.4.7 Testing and Inspection Requirements for **Y- Strainer** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASTM A351 and ASME B31.3 Section 345, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect the strainer to confirm that the marking/identification is in accordance with purchasing documents, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on strainer body and bolted cover.

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform pressure test, the performance of this test will use the system design pressure, no less than 1.5 times the system design pressure for hydrostatic test, or 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

Sampling is not permitted.

3.16.4.8 Testing and Inspection Requirements for the **Thermowells** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with purchasing documents, ASME Section VIII, Div. 1, UG-100, and ASME B31.3 Section 345 and other applicable specifications.

INSPECTION REQUIREMENT

Visual Inspection

Inspect the thermowells and related Completion Supplier documentation for compliance with the purchasing documents.

Sampling is not permitted.

Visual Inspection for Yellow metal

Perform visual inspections of the thermowells to verify that the thermowells are not made from yellow metals (copper based alloys)

Sampling is not permitted

TESTING REQUIREMENT

Chemical Composition Testing/Verification

Perform PMI on the flanged thermowells and socket weld thermowells to verify conformance with the applicable material specifications.

Tightened sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test and Inspection Sampling Plan.

Where PMI is destructive, utilize Destructive sampling per EPRI TR-017218 Table 2-2 on per lot basis. Lot is established by single line item per single manufacture or single heat number.

Pressure Boundary Integrity Testing/Verification

Perform pressure test and sensitive leak detection test on the thermowells per ASME B31.3, Section 345.8 (socket weld thermowell) and ASME BPVC Section VIII, Div. 1, UG-100 (flanged thermowells)

Sampling is not permitted.

3.16.4.9 Testing and Inspection Requirements for the **Gaskets** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with purchasing documents and ASME B31.3, B16.20, or ASME Section VIII, as applicable.

INSPECTION REQUIREMENT

Visual Inspection

Inspect the gaskets (for configuration and appearance) and related Completion Supplier documentation for any damage and for compliance with the purchasing documents. For all spiral wound gaskets, verify markings are per ASME B16.20.

Sampling is not permitted.

Dimensional Inspection

Measure the inside and outside diameters of the round gaskets and the thickness and gasket width of the rectangular gaskets to verify conformance the purchasing documents.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan. In this instance a lot is defined as all gaskets purchased on a single line item of the PO.

TESTING REQUIREMENT

Pressure Boundary Integrity Testing/Verification

Perform pressure test and leak detection test on "Q" items with associated gaskets per ASME B31.3, Section 345.8 or ASME Section VIII, UG-100, as applicable.

Sampling is not permitted.

NOTE: Additional gaskets shall be procured to accommodate pressure testing. The test gaskets shall be identical (purchased on the same line item of the PO) to those that will be used in the final skid to be delivered to the WTP.

3.16.4.10 Testing and Inspection Requirements for **Flowmeters** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASTM A182, ASTM A240, ASTM A312, and ASME B31.3, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect each flowmeter to confirm that the marking/identification is in accordance with the drawing, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on all flowmeter pressure boundary piping, and flanges.

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform pressure test, the performance of this test will use the system design pressure, no less than 1.5 times the system design pressure for hydrostatic test, or 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

Sampling is not permitted.

3.16.4.11 Testing and Inspection Requirements for the **Fasteners** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with purchasing documents, ASME/ASTM SA/A193, SA/A194, ASTM A490, A563, F436, ASME B18.2.1, B18.2.2, and B18.21.1, as applicable.

NOTE: This section does not cover fasteners that are supplied with separately purchased items (valve, strainer, etc.).

For sampling washers, a "lot" shall be defined as all items purchased under a single line item of the purchase order

INSPECTION REQUIREMENT

Visual Inspection

Inspect the fasteners to verify compliance with the purchasing documents and to ensure that markings are as specified in the applicable ASTM specification.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

Dimensional Inspection

Measure the following dimensions for compliance with the purchase order requirements and the applicable ASTM and ASME specification

Bolts/Studs - Nominal Diameter

Threads (2A)

Nuts - Thickness

Threads (2B)

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

Washers - Inner Diameter (all types)

- Thickness (flat washers)

- Side length (beveled washers)

Reduced sampling plan per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

TESTING REQUIREMENT

Chemical Composition Testing/Verification

Perform PMI on bolts, studs and nuts.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

Hardness/Tensile/Proof Load Testing

Perform hardness testing on the bolts, studs, and nuts to ensure conformance with the applicable ASTM/ASME specifications and grade:

Tensile testing and / or proof load testing may be used in lieu of hardness testing for the above mentioned items.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan. If tensile tests or proof load tests are performed, sample per EPRI TR-017218 Table 2-2, Recommended Destructive Test, and Inspection Sampling Plan.

Magnet Test

Perform magnet test on washers to verify material compliance with purchasing documents (steel vs. stainless steel).

Reduced sampling plan per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

3.16.4.12 Testing and Inspection Requirements for **Globe Control Valves** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASTM A182, ASTM A351, ASME B31.3, ASME B16.34, and API 598, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect each valve to confirm that the valve marking/identification is in accordance with applicable codes/standards, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

Visual Inspection - Yellow Metal

Perform visual inspections of the valves to verify that the stem and packing nut are not made from yellow metals (copper based alloys).

Sampling is not permitted.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on valve bodies, bonnets and flanged end connections.

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform shell pressure test per ASME B16.34, Section 7. The performance of this test will use the system design pressure in lieu of the 38 C (100 F) pressure rating. No less than 1.5 times the system design pressure for hydrostatic test, or 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

Sampling is not permitted.

3.16.4.13 Testing and Inspection Requirements for **Pressure Gauges** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify conformance with ASME B31.3.

~~**An extra test pressure gauge shall be purchased for each PO line item from the same manufacturing lot with sequential serial numbers as the production gauges. This extra gauge will be destructively tested as detailed below and the remaining gauges will be used on the final production unit.**~~

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect the gauges to confirm that the marking/identification is in accordance with purchasing documents, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

Visual Inspection for Yellow metal

Perform visual inspections of the test pressure gauges to verify that the ~~pressure boundary components~~, socket~~/stem and bourdon tube/bellows, are~~ is not made from yellow metals (copper based alloys).

~~Destructive sampling per EPRI TR-017218 Table 2-2 Recommended Destructive Test, and Inspection Sampling Plan on per lot basis as defined above, utilize the test pressure gauge.~~

Sampling is not permitted

TESTING REQUIREMENTS

Pressure Boundary Integrity Testing/Verification

Perform pressure test, the performance of this test will use the system design pressure, no less than 1.5 times the system design pressure for hydrostatic test, or 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

~~Destructive sampling per EPRI TR-017218 Table 2-2 Recommended Destructive Test, and Inspection Sampling Plan on per lot basis as defined above, utilize the test pressure gauge~~

Sampling is not permitted

3.16.4.14 Testing and Inspection Requirements for **Process Offgas Heaters** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASME SA240, ASME SB515, SB163, SB751, and ASME B&PVC Section VIII-Div. 1, UG-100, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect the heater assembly components at raw material state prior to fabrication to confirm that the manufacturer's marking/identification and configuration is in accordance with purchasing documents and drawings and is clearly readable. (Components to be inspected are the flange plates, thermocouple tubing, and heater tubing)

Sampling is not permitted.

Dimensional Inspection

Measure the following dimensions for compliance with the approved drawings, governing codes/standards, and purchase order requirements –

Flange Plate Thickness – No Sampling Permitted

Flange Plate Width – No Sampling Permitted

Flange Plate Height – No Sampling Permitted

Tube Wall Thickness - Reduced sampling plan per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on the flange plate, filler material (pre-fab, if any), element tube, and thermocouple nipple.

Samples of the materials shall be cut from the original material at the heater supplier's facilities and delivered to the Completion Supplier for testing. Traceability shall be maintained from the parent material to the test pieces. This shall be accomplished by witnessing of the cutting and transfer of information by a representative of the Completion Supplier's quality staff.

One PMI test is to be performed per heat of material.

Pressure Boundary Integrity Testing/Verification

Perform pressure test and leak detection test on the heater per the purchasing document requirements. Leak detection tests are to verify leak tightness of the flanged connections and the heating element to mounting plate joints

Sampling is not permitted.

3.16.4.15 Testing and Inspection Requirements for **Expansion Joints** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASTME SA240, ASME SA182 A479, ASME B31.3, ASME B16.5, ASME B&PVC Section VIII-Div. 1, EJMA, and other PO requirements, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect the Expansion Joints materials in the raw material state prior to fabrication to confirm that the manufacturer's marking/identification is in accordance with purchasing documents and drawings and is clearly readable.

Sampling is not permitted.

Configuration Inspection

Visually inspect each expansion joint to verify the correct number and shape of the convolutions is as specified on the on the purchasing documents, datasheets, and applicable design drawings.

Sampling is not permitted.

Dimensional Inspections

Perform the following dimensional inspections

- Flange Dimensions
    - Rectangular Expansion Joint
        - Inside dimensions
        - Thickness
        - Width
    - Round Expansion Joints
        - Inside Diameter
        - Flange Thickness

Sampling is not permitted

- Bellow Material Thickness

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

Chemical Composition Testing/Verification

Perform PMI on the bellows, flange, and the weld filler material.

Sampling is not permitted.

Samples of the materials (excluding the liner) shall be cut from the original material at the expansion joints supplier's facilities and delivered to the TCO fabricator for testing. Traceability must be maintained from the parent material to the test pieces. This shall be accomplished by witnessing of the cutting and transfer of information by a representative of the TCO fabricator's quality staff.

Pressure Boundary Integrity Testing/Verification

Perform pressure test and leak detection test on all expansion joints per the requirements of the purchasing documents.

Sampling is not permitted.

Weld Integrity Verification

Perform Liquid Penetrant Examination on all pressure retaining welds to verify pressure boundary. (Pressure retaining welds are defined as the longitudinal bellows welds and the bellows to flange welds.)

Sampling is not permitted.

3.16.4.16 Testing and Inspection Requirements for **HEPA Filter Housing** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with the material specification referenced in the purchase order and ASME AG-1-1997 with AG-1A-2000 Addenda, and ASME/ASTM A240, A312, A479, A182, and A276, as applicable.

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INSPECTION REQUIREMENTS

Visual Inspection - Material Markings/Identification

Inspect the housing to confirm that the marking/identification is in accordance with purchasing documents and is clearly readable.

Sampling is not permitted.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

PMI is required to be performed on the filter housing body, housing cover and any pipe and pipe fittings to verify conformance with the applicable codes/standards. PMI on the HEPA housing pressure boundary components was performed by the previous supplier. No further PMI is required by the Completion Supplier as all of the previous results were given a BNI submittal code status 1.

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform pressure decay test(s) on the filter housing assembly per ASME AG-1, Article III-4200, Pressure Decay test.

Sampling is not permitted.

3.16.4.17 Testing and Inspection Requirements for the **HEPA Filters**

The HEPA Filters will be sent directly to WTP from the Filter Test facility. The Completion Supplier will not perform any actions under this section.

3.16.4.18 Testing and Inspection Requirements for the **Structural and Pressure Boundary Steel** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with purchasing documents, ASTM A240, A276, A554, A312, ASME BPV Code Section VIII Division 1, and Section V Article 10.

INSPECTION REQUIREMENT

Visual Inspection

Inspect the pressure boundary and structural steel to confirm that the marking/identification is in accordance with purchasing documents, is clearly readable, and has no indication of re-marking by other parties. Where stainless steel is remarked see "Chemical Composition Comparator test" section below, for carbon steel remarking treat each remarked piece as one lot and perform required testing per lot.

There may be instance where remarking does occur, e.g. only a portion of the complete piece of material is purchased, in which case additional testing is necessary to establish traceability. See "Chemical Composition Comparator Test" section below.

Sampling is not permitted.

Dimensional Inspection

Measure the following dimensions for compliance with the purchase order requirements and the applicable ASTM specification -

Plate and Sheet -	Thickness
Angle -	Thickness
	Leg Height
	Width
Structural Tube -	Wall Thickness
	Width
Flat Bar -	Width
	Thickness
Round Bar -	Diameter
Pipe -	Diameter
	Wall Thickness

Tightened sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test and Inspection Sampling Plan. Accept on 0 defects and reject on 1 or more defects.

TESTING REQUIREMENT

Chemical Composition Testing/Verification

Perform PMI on pressure boundary and structural stainless steel.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

Chemical Composition Comparator Test

Perform additional PMI at the time of receipt on materials that have been remarked.

In addition to the chemical composition test that is required on all received materials (normal sampling plan), PMI is required of all other sub-supplier remarked and untested pieces in a lot. For this comparator test either XFR or OES PMI may be used. For each heat of material the results of the comparator and chemical composition test shall be the same, taking into account the margin of error of the PMI gun used.

Pressure Boundary Integrity Testing/Verification

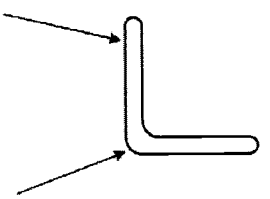
Perform tensile/yield/elongation testing on the pressure boundary and structural carbon and stainless steel.

Hardness testing may be used in lieu of tensile/yield/elongation testing of carbon steel and the stainless steel HEPA stand.

Sample per EPRI TR-017218 Table 2-2, Recommended Destructive Test and Inspection Sampling Plan.

Pressure Boundary Integrity Testing/Verification

If plate is cut and bent to be used as angle, hardness testing is to be performed at the locations specified in the following diagram –



Sample per EPRI-017218 Table 2-1, Recommended Set of Nondestructive Test and Inspection Sampling Plan.

3.16.4.19 Testing and Inspection Requirements for **Weld Filler Material** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with AWS/ASME A/SFA 5.9, A/SFA 5.18, A/SFA 5.20, and A/SFA 5.22, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection

Inspect each container/spool of weld filler to confirm that the material marking/identification is in accordance with the applicable AWS specification, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

Dimensional Inspection

Measure the diameter of the weld filler metal for conformance with the applicable AWS/ASME specification.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on all the weld wire per applicable AWS/ASME standard.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

3.16.4.20 Testing and Inspection Requirements for **fan Boots** to be performed by the Completion Supplier

All inspections shall be performed, as detailed below, to verify compliance with all applicable purchase order requirements.

INSPECTION REQUIREMENTS

Visual Inspection

Visually inspect each fan boot to verify configuration and marking conformance to the PO requirements including drawings and datasheets.

Sampling is not permitted.

Visual Inspection of Bellows Material

Visually inspect bellows material shows no indication of delamination, tears or compression set.

Sampling is not permitted

Dimensional Inspection

Measure the inside diameter of the fan boot for conformance with PO requirements.

Sampling is not permitted.

Pressure Boundary Integrity Testing/Verification

Perform pressure test, the performance of this test will use the system design pressure, no less than 1.1 times the system design pressure for pneumatic test, according to the location of the item tested.

Sampling is not permitted.

3.16.4.21 Testing and Inspection Requirements for **Instrument Tubing, Valves, and Fittings** to be performed by the Completion Supplier

All testing and inspections shall be performed to verify compliance with ASME SA240, ASME SA182, ASME B31.3, ASME B16.5, ASME B&PVC Section VIII-Div. 1, and other PO requirements, as applicable.

INSPECTION REQUIREMENTS

Visual Inspection

Inspect each item to confirm that the material marking/identification is in accordance with the applicable ASTM/ASME specification, is clearly readable, and has no indication of re-marking by other parties.

Sampling is not permitted.

Dimensional Inspection

Perform dimensional inspection of the instrument tubing and fittings that are to be used in production as follows:

Tube - Wall thickness at each end

Tube Fittings- Wall thickness at each end

End to End and / or End to Centerline

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

Visual Inspection for Yellow metal

Perform visual inspections of the valves and fittings to verify that the accessible pressure boundary components are not made from yellow metals (copper based alloys).

Sampling is not permitted.

TESTING REQUIREMENTS

Chemical Composition Testing/Verification

Perform PMI on the tubing.

Normal sampling per EPRI TR-017218 Table 2-1, Recommended Set of Nondestructive Test, and Inspection Sampling Plan.

Pressure Boundary Integrity Testing/Verification

Perform pressure test for installed items per the functional test.

Sampling is not permitted.

3.16.4.22 Testing and Inspection Requirements for **Insulating Pads** to be performed by the Completion Supplier

All testing and inspections shall be performed, as detailed below, to verify compliance with all applicable purchase order requirements.

INSPECTION REQUIREMENTS

Visual Inspection

Visually inspect each insulating pad to verify configuration and marking conformance to the PO requirements including drawings and datasheets.

Sampling is not permitted.

Dimensional Inspection

Measure the length, width, and height of each insulating pad to ensure conformance with PO requirements.

Sampling is not permitted.

TESTING REQUIREMENTS

Compression Testing/Verification

~~Perform Compression tests per TBD to verify conformance with TBD.~~

Perform compression tests on the test samples to verify that the insulating pad material is capable of withstanding a minimum load of 1,300 psi. Destructive sampling per EPRI TR-017218 Table 2-2 Recommended Destructive Test. Sample plan shall be used in conjunction with the lot defined as "all line items on a single PO, from a single manufacturer".

3.17 Engineering requirements for commercial components purchased from a sub supplier or commercial items provided by WTP for reuse.

3.17.1 The TCO skid and ammonia dilution skid are fabricated from raw materials and purchased components. Fabrication and testing the TCO and ammonia dilution skid from raw materials is well understood and adequately defined in this specification. The purchase of commercial components or reuse of commercial components provided by WTP for a Q application is a complex process and in some cases requires additional engineering controls above those established for CGD. Some commercial components with a quality level of Q or CM are manufactured using a special process (welding, heat treatment and NDE). WTP may define additional requirements for commercial items manufactured using a special process. Based on the components quality level and safety function, engineering will define in the sections below any additional requirements or define requirements that are not required for purchased or reused commercial components.

3 .17.2 Round bellows for the TCO, LVP-BLWS-00053 and LVP-BLWS-00061.

The Quality level for the round bellows is Q. The safety function is confinement of offgas. Round bellows are commercial items for general industry use and are basically catalog items ready for installation from the manufacturer. The round bellows for the TCO will be manufactured using a special process (welding and nondestructive examination). Heat treatment is not required, as defined in Section 3.1.12.

- The Completion Supplier / bellows manufacturer shall submit outline drawings with welding and NDE defined on the drawings.
- The Completion Supplier/ bellows manufacturer shall submit weld procedures for review.
- The Completion Supplier / bellows manufacturer shall have welder qualifications on file for review by the WTP supplier Quality representative.
- The Completion Supplier / bellows manufacturer shall submit NDE procedures for review.
- The Completion Supplier / bellows manufacturer shall submit test procedure(s) for review.
- The Completion Supplier / bellows manufacture is not required to minimize halide or chloride exposure during the manufacturing process or shipping. If the bellows manufacturer has a practice in place for minimizing halide and chlorides it may be used. Submittal of halide / chloride control program is not required because the LAW Offgas contain chlorides.

- The Completion Supplier / bellows manufacture shall notify WTP Supplier Quality Representative in advance for witnessing the first operation basis for each reviewed weld procedure and NDE procedure. It is acceptable for WTP SQR to witness welding and NDE of similar production items.
- The WTP supplier Quality Representative will witness testing performed for each test procedure.

3.17.3 Thermowells for the TCO, TW 0507, 0508, 0511, 0513, 0517, 0519, & 0524.

The Quality level for the thermowells is Q. The safety function is confinement of offgas. Thermowells are commercial items for general industry use and are basically catalog items ready for installation from the manufacturer.

- The Completion Supplier / thermowell manufacturer shall submit outline drawings.
- The Completion Supplier / thermowell manufacture is not required to minimize halide or chloride exposure during the manufacturing process or shipping. If the thermowell manufacturer has a practice in place for minimizing halide and chlorides it may be used. Submittal of halide / chloride control program is not required because the LAW Offgas contain chlorides.

3.17.4 Recuperative heat exchanger, LVP-HX-00001, (non Pressure boundary welding, NDE) Commercial Material (CM), enclosed in a Q confinement enclosure.

The recuperative heat exchanger with inlet and outlet bellows are commercial items for general industry use. The recuperative heat exchanger with inlet and out bellows will be manufactured using a special processes (welding, (heat treatment if required) and nondestructive examination (NDE)).

- The Completion Supplier / recuperative heat exchanger manufacture shall submit outline drawings with welding and NDE defined on the drawings.
- The Completion Supplier / recuperative heat exchanger manufacturer shall submit weld procedures for review. Include weld procedure(s) for bellows fabrication.
- The Completion Supplier / recuperative heat exchanger manufacturer shall have welder qualifications on file for review by the WTP supplier Quality representative (SQR).
- The Completion Supplier / recuperative heat exchanger manufacturer shall submit NDE procedures for review.
- The Completion Supplier / recuperative heat exchanger manufacturer shall submit heat treat procedures for review (if used).
- The Completion Supplier / recuperative heat exchanger manufacturer shall submit test procedure(s) for review.
- The Completion Supplier / recuperative heat exchanger manufacturer is not required to minimize halide or chloride exposure during the manufacturing and shipping process. If the recuperative heat exchanger / bellows manufacturer has a practice in place for minimizing halide and chlorides it may be used. Submittal of halide / chloride control program is not required. The process flowing through the recuperative heat exchanger will include chlorides.
- The Completion Supplier / recuperative heat exchanger manufacturer shall notify WTP Supplier Quality Representative in advance for witnessing the first operation basis for each reviewed weld procedure, heat treat procedure (if used) and non destructive examination (NDE) procedure. It is acceptable for WTP SQR to witness welding, heat treatment and NDE of similar production items.
- The Completion Supplier / recuperative heat exchanger manufacturer shall notify WTP Supplier Quality Representative in advance for witnessing the first operation basis for pressure testing.

3.17.5 Rectangular bellows for the TCO, LVP-BLWS-00055, 00056, & 00058.

The Quality level for the rectangular bellows is Q. The safety function is confinement of offgas. Rectangular bellows are commercial items for general industry use and are basically catalog items ready for installation from the manufacturer. The rectangular bellows for the TCO will be manufactured using special processes (welding and nondestructive examination). Heat treatment is not required, as defined in Section 3.1.12.

- The Completion Supplier / bellows manufacturer shall submit outline drawings with welding and NDE defined on the drawings.
- The Completion Supplier / bellows manufacturer shall submit weld procedures for review.
- The Completion Supplier / bellows manufacturer shall have welder qualifications on file for review by the WTP supplier Quality representative.
- The Completion Supplier / bellows manufacturer shall submit NDE procedures for review.
- The Completion Supplier / bellows manufacturer shall submit test procedure(s) for review.
- The Completion Supplier / bellows manufacturer is not required to minimize halide or chloride exposure during the manufacturing and shipping process. If the bellows manufacturer has a practice in place for minimizing halide and chlorides it may be used. Submittal of halide / chloride control program is not required because the LAW Offgas contains chlorides.
- The Completion Supplier / bellows manufacturer shall notify WTP Supplier Quality Representative in advance for witnessing the first operation basis for each reviewed weld procedure. It is acceptable for WTP SQR to witness welding of similar production items.
- The WTP supplier Quality Representative will witness testing performed for each test procedure.

3.17.6 Process heaters LVP-HTR-00002A, B, C, D & E

The Quality level for the process heaters is Q. The safety function is confinement of offgas. Process heaters are commercial items for general industry use and are basically catalog items ready for installation from the manufacturer. The process heaters for the TCO will be manufactured using special processes (welding and nondestructive examination).

- The Completion Supplier / process heater manufacturer shall submit outline drawings with welding and NDE defined on the drawings.
- The Completion Supplier / process heater manufacturer shall submit weld procedures for review.
- The Completion Supplier / process heater manufacturer shall have welder qualifications on file for review by the WTP supplier Quality representative.
- The Completion Supplier / process heater manufacturer shall submit NDE procedures for review.
- The Completion Supplier / process heater manufacturer shall submit test procedure(s) for review.
- The Completion Supplier / process heater manufacturer is not required to minimize halide or chloride exposure during the manufacturing and shipping process. If the process heater manufacturer has a practice in place for minimizing halide and chlorides it may be used. Submittal of halide / chloride control program is not required because the LAW Offgas contains chlorides.
- The Completion Supplier / process heater manufacturer shall notify WTP Supplier Quality Representative in advance for witnessing the first operation basis for each reviewed weld procedure. It is acceptable for WTP SQR to witness welding of similar production items.

- The WTP supplier Quality Representative will witness testing performed for each test procedure.

3.17.7 Flanged ball valves for the TCO, LVP-V-01547, 01548, 01609, 01610, 01611, 01612, 01613, 01614, 01615, 01616, 01617, 01618, 01619, 01620, 72263, 72264, 72265, 72266, 72267, 72334 and 72335.

The Quality level for the flanged ball valves is Q. The safety function is confinement of offgas. Flanged ball valves are commercial items for general industry use and are basically catalog items ready for installation from the manufacturer. The requirements specified under section 3.16.4.5 are adequate for the flanged ball valves. Additional engineering requirements are not required.

- The Completion Supplier / ball valve manufacturer is not required to minimize halide or chloride exposure during the manufacturing and shipping process. If the ball valve manufacturer has a practice in place for minimizing halide and chlorides it may be used. Submittal of halide / chloride control program is not required because the LAW Offgas contains chlorides.

3.17.8 LVP-SCO-00001 and SCR-00001 catalyst sheet metal enclosures

The Quality level for the catalyst sheet metal enclosures is CM. The catalyst sheet metal enclosures do not have a safety function. The catalyst sheet metal enclosures are commercial items for general industry use and are catalog items ready for installation from the manufacturer. The catalyst sheet metal enclosures are manufactured using a special process (welding), based on the quality level and safety function additional engineering requirements are not required.

- The Completion Supplier / catalyst sheet metal enclosure manufacturer is not required to minimize halide or chloride exposure during the manufacturing process. Submittal of halide / chloride control program is not required because the LAW Offgas contains chlorides.

3.17.9 Deleted

3.17.10 Pipe and tubing for the TCO and ammonia dilution skid, production made, seamless or welded.

The Quality level for the pipe and tube is Q. The safety function is confinement of offgas, ammonia, C3 air and instrument air. Pipe and tubing are commercial items for general industry use and are basically catalog items ready for installation from the manufacturer. Welded pipe and tube is manufactured using a special process (welding and nondestructive examination). The requirements specified under section 3.16.4.2 are adequate. Additional engineering requirements are not required for pipe and tube.

- The Completion Supplier / pipe or tube supplier is not required to minimize halide or chloride exposure during the manufacturing or shipping. Submittal of halide / chloride control program is not required.

3.17.11 Junction boxes LVP-JB-00012, JB-0027 and / Control panel LVP-PNL-00003

The Quality level for junction boxes and the control panel is CM. The junction boxes and the control panel have no safety function. The junction boxes and control panel are commercial items for general industry use and are catalog items ready for installation from the manufacturer. Junction boxes and control panels are manufactured using a special process (welding). Based on the quality level and safety function additional engineering requirements are not required.

- The Completion Supplier / junction box control panel supplier is not required to minimize halide or chloride exposure during the manufacturing or shipping. Submittal of halide / chloride control program is not required.

3.17.12 Ammonia Dilution air fans, LVP-FAN-00001 and LVP-FAN-00002.

The Quality level for the fans on the ammonia dilution skid is Q for air permit. The fans do not have a safety function. Fan manufacturers produce commercial items for general industry use. These fans are basically catalog items ready for installation from the manufacturer. The fans are manufactured using a special process (welding and nondestructive examination). A standard fan from a manufacture is acceptable for this application. The Completion Supplier will perform additional tests and inspections as defined in section 3.16.4.3 as part of the CGD process after the fans arrive at the Completion Suppliers shop. The tests below are designed to minimize quality risk and provide reasonable assurance that the product specified will perform as intended.

- The Completion Supplier / fan manufacture shall submit outline drawings for installation and maintenance. Detailed fabrication drawings with weld symbols, are not required.
- Controls to minimize halide or chloride exposure during manufacture and shipping are not required. This fan is exposed to air and not subject to stress corrosion cracking, where halide / chloride control is important.
- The Completion Supplier / fan manufacture weld procedures are not required for review.
- The Completion Supplier shall submit fan pressure test procedure(s) for review.
- The Completion Supplier / fan manufacture shall submit technical data sheets for the coating, MSDS and fill out Appendix H, "Manufactures standard coating data sheet".

The fan manufacture shall perform a pressure test on the fans prior to shipping. It is preferred that the fan pressure test be performed before any coating system is applied. Since this fan may be made from coated parts already in inventory, the pressure test maybe performed after coating. The fan manufacture shall perform a bubble test when the fan is not operating. The Completion Supplier Quality Representative will witness pressure testing. The acceptance criteria shall be no bubble growth in the area being inspected (flanged joints, gasket joints, mechanical seal tubing / piping). The object of the test is to confirm that the fan will hold pressure before the fan is shipped. This pressure test is required by engineering to minimize commercial risk.

3.17.13 Manual valves, control valves, solenoid valves, strainer, pressure control valves, coalescing filters, rotometers, flexible metal hose, pressure gauges, pressure indicating transmitters, HEPA housings, flow meters and thermowells on the ammonia dilution skid supplied by the Completion Supplier or reused by WTP.

The Quality level for these items is Q. These items are commercial items for general industry use and are basically catalog items ready for installation from the manufacturer. The requirements specified under section 3.16 are adequate for these items. Additional engineering requirements are not required for these items on the ammonia dilution skid.

- The Completion Supplier / manufacturer / supplier are not required to minimize halide or chloride exposure during the manufacturing or shipping. Submittal of halide / chloride control program is not required.

3.17.14 Insulation stud material

- The Completion Supplier weld program has been surveyed and found acceptable.
- The Completion Supplier shall use a stud weld procedure with a status determined by WTP.

• The Completion Supplier shall check that stainless steel insulation studs are Nonmagnetic with a magnet. Nonmagnetic insulation studs are acceptable for use.

4 Materials

4.1 General

4.1.1 The Completion Supplier shall comply with specification 24590-WTP-3PS-G000-T0002, *Engineering Specification for Positive Material Identification (PMI) for Shop Fabrication.*

4.2 Construction

4.2.1 Materials of construction shall have properties suitable for the service conditions defined in the MDSs.

4.2.2 The ASME and/or ASTM material numbers and grades shall be identified and MTRs showing actual test report values shall be provided for the housing, ducts, weld filler metal, and support framing integral to the Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution assemblies. Material designations shall be indicated on the fabrication drawings and in the material lists.

4.2.3 Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution skids shall be fabricated from structural steel shapes and plates properly reinforced to be self-supporting, capable of carrying the static loads of components and the stresses imposed during shipment, installation, and operation.

4.2.4 Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution housings and outlet piping shall be fabricated from materials specified in the MDSs in Section 2 of the MR. Structural supports in contact with the offgas stream shall be constructed from the same material as the high temperature surfaces as specified on the MDS in Section 2 of the MR.

4.2.5 Where the Buyer has not specified material types, the Completion Supplier shall select materials giving consideration to the design life of the equipment, compatibility with adjacent materials, compatibility with the process materials and conditions, environmental conditions, and coating requirements. The Buyer shall review and approve materials selected by the Completion Supplier.

4.3 Prohibited Materials

4.3.1 As applicable, mercury, zinc, cadmium, or other low melting point materials and halogens shall not be used in direct contact with stainless steel. This prohibition also applies to use of tools, fixtures, paints, coatings and sealing compounds, and any other equipment or materials used by the Completion Supplier in handling, assembly and storage of stainless steel parts or components. Except as excluded in section 3.17.

4.3.2 Asbestos shall not be used in any component of the Thermal Catalytic Oxidizer/Reducer, the associated Ammonia/Air Dilution units, and appurtenances.

4.3.3 The prohibited materials list excludes materials that might be used for bearings, brazed joints, or instruments.

4.3.4 The equipment provided to the Buyer shall not contain any of the materials listed in 24590-WTP-LIST-CON-08-0001, *Restricted Materials List WTP Safety Assurance* unless BUYER (Safety Assurance) approval is obtained.

4.4 Insulation

4.4.1 The Completion Supplier shall provide detailed insulation installation procedures for removable insulation only.

4.4.2 The Completion Supplier shall recommend cements, mastics, and adhesives that will be suitable for the maximum design temperature of the Thermal Catalytic Oxidizer/Reducer. The mixing of cements, mastics, etc., shall be done with deionized water.

4.4.3 Provide removable / reusable insulation for the TCO inlet and outlet bellows (LVP-BLWS-00053 and 00051), and rectangular / round expansion joints.

4.4.4 Insulation thickness greater than three (3) inches applied to the exterior of the Thermal Catalytic Oxidizer/Reducer shall be applied in multiple layers with staggered joints. Each layer of multiple layer and double insulation shall be held in place separately.

4.4.5 Exterior insulation shall be jacketed with 304 stainless steel. The stainless steel jacketing shall be 0.024 inch thick flat and smooth sheet, and conform to ASTM A240. The jacketing shall be furnished in the annealed or soft condition with a regular 2B mill finish and have a factory applied moisture barrier.

4.4.6 Design jacketing with an overlap of 2 inch minimum between sections. Standard process industry practices shall be followed.

4.4.7 The TCO insulation shall be designed to prevent the ingress of water during the 2.0 hour fire water spray. The fire water spray is expected to occur once during the 40 year life of the plant. The design of the jacketing shall be such that the joints shed water. Process Industry Practices, PIP INIH1000, Hot Insulation Installation Details, provide generic details for weatherproof jacketing.

4.4.8 All insulation components, including facings, mastics, and adhesives, shall meet ASTM E84 fire hazard rating not to exceed 25 for flame spread and 50 for fuel contributed and smoke developed. Ratings used are determined by Underwriters Laboratories Inc. (UL).

4.4.9 Submit welding procedures for any insulation tabs or studs that are welded to the pressure boundary, as required.

4.5 Government Material

If the Completion Supplier so chooses, the Buyer shall supply, as Government Furnished Equipment (GFE), miscellaneous parts, and a certified bulk quantity of 347 stainless steel. See Section 4b, Special Conditions of the PO.

5 Fabrication

5.1 General

5.1.1 Fabrication of the thermal catalytic oxidizer/reducer units shall be in accordance with the requirements of 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication.*

5.1.2 Fabrication of piping shall meet the requirements of the Buyer specification 24590-WTP-3PS-NWP0-T0001 *Engineering Specification for General and NDE Requirements for*

Supplier Fabricated Piping, Attachment PS02 *Engineering Specification for Shop Fabrication of Piping*, and ASME B31.3.

5.1.3 All stainless steel metal working, grinding, cutting, machining and welding shall use tools and consumables dedicated and segregated from all others to prevent cross contamination. A dedicated work area for tools, equipment storage, parts storage and raw materials must be established to control contamination. Welding consumables for stainless steel welding must be segregated from other consumables.

5.1.4 Ammonia gas pipe line connections

- To minimize ammonia gas leaks inside the LAW facility, socket weld and or butt weld fittings and components are preferred, followed by flanged connections. Hy-Lok valves and tubing are acceptable for instrument connections. Threaded connections 1/2 inch and smaller are acceptable, but should be minimized.
- Thread Sealant Tape- Anti-Seize technology, Inc., Item Number 46230, POLYTEMP HD Extra Heavy Duty PTFE tape or engineering approved equal, 1/2 inch wide, 0.0032 inches thick, density 1.2 - 1.5 g/cc, MIL-T-27730A.

5.2 Welding

5.2.1 Design and fabrication of the TCO pressure boundary shall be in accordance with specification 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication*

5.2.2 Welding of the TCO pressure boundary shall be in accordance with specification 24590-WTP-3PS-MVB2-T0001, *Engineering Specification for Welding of Pressure Vessels, Heat Exchangers and Boilers.*

5.2.3 Fabrication of TCO piping shall be in accordance with Attachment PS02 *Engineering Specification for Shop Fabrication of Piping.*

5.2.4 Welding and NDE of TCO piping shall be in accordance with specification 24590-WTP-3PS-NWP0-T0001, *Engineering Specification for General Welding and NDE Requirements For Supplier Fabricated Piping.*

5.2.5 Welding of carbon structural steel shall be in accordance with AWS D1.1 and specification 24590-WTP-3PS-SS00-T0001, *Engineering Specification for Welding of Structural Carbon Steel.*

5.2.6 Welding of structural stainless steel shall be in accordance with AWS D1.6 and BUYER specification 24590-WTP-3PS-SS00-T0002, *Engineering Specification for Welding of Structural Stainless Steel and Welding of Structural Carbon Steel to Structural Stainless Steel.*

5.3 Coating

5.3.1 Shop coating shall be in accordance with Attachment AFPS *Engineering Specification for Shop Applied Special Protective Coatings for Steel Items and Equipment,* Appendix D, Number 8.20, System Code D.

5.3.2 A manufacturer's coating data sheet (see Attachment AFPS *Engineering Specification for Shop Applied Special Protective Coatings for Steel Items and Equipment*, Section 6.2.1.2) is required for each commercial off the shelf (COTS) item or component that is supplied with a manufacturer's standard coating.

5.3.3 The top coat shall be ANSI 70 grey in color.

5.4 Assembly

5.4.1 The Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution unit shall have edges that are both smooth and not sharp to the touch.

6 Tests and Inspections

6.1 General

6.1.1 The Completion Supplier shall provide all instruments, cables, and facilities necessary to perform any shop tests, the Functional Tests (FT) and NDE.

6.1.2 In addition to the pressure tests required by the Boiler and Pressure Vessel Code and piping code, the Completion Supplier shall functionally test the TCO. The Completion Supplier shall provide test hardware. Test hardware is expected to include, but is not limited to: fan/exhauster/ blower, pre heater, piping, ducting, instrument tubing, power, controls and temporary insulation. The functional test shall include a fan/exhauster/blower that provides enough flow to bring the TCO up to or near the design temperature (without damage to the heating elements due to low flow). The functional test flow rate is expected to be between (2,000 scfm and 3,000 scfm). During the functional test the TCO will be brought up to temperatures that approach the operating temperature of the unit. The expected test temperature measured after heater LVP-HTR-00002 will be in the range of 600 to 700 F. This temperature range is subject to change as test details are developed. Air will be used during the test, no chemicals or test gases will be injected into the gas stream. The SCO and SCR catalyst modules will be installed during the test. The major test objectives are: verify heater operation using control panel LVP-PNL-00003, after unit cool down verify the SCO and SCR catalyst modules can be removed and reinstalled. Verify by visual observation the catalyst racks and catalyst gaskets are not distorted after being subjected to elevated temperatures.

6.1.3 In addition to the pressure tests required by the piping code, the Completion Supplier shall functionally test the LAW ammonia / air dilution skid. The Completion Supplier shall provide the necessary test hardware to run the ammonia /air dilution fans LVP-FAN-00001and 00002 on skid LVP-SKID-00003. Test hardware is expected to include, but is not limited to: a compressed air source, instrument tubing, power and controls. The Ammonia /air dilution skid does not have to be connected to the TCO for the functional testing. Ammonia gas will not be required for testing. Air at 15 psig will be used to simulate the ammonia gas during testing. HEPA filters for the HEPA housing may or may not be installed for this testing. The major test objectives are: verify fan operation and control using panel LVP-PNL-00003, verify valves open and close, verify flow meter operation.

6.1.4 The following section only applies to rectangular flanges or proto type testing. The LAW TCO is located in the offgas system near the LAW exhausters that generate the entire system vacuum. The LAW TCO rectangular flanges are normally under fairly high negative pressure and high operating temperatures. Rectangular flanges that allow excess air to leak into the offgas system during normal operations are not acceptable. The Completion Supplier shall test a mockup of the rectangular flange design to prove the design works at ambient temperature. Holding pressure at ambient temperature provides confidence that the flange design will perform as designed at elevated temperatures and pressure. The rectangular flange design shall be proved by testing as early as possible to minimize schedule delays.

The Completion Supplier shall select the appropriate test or tests. For example; a Bubble Test in accordance with ASME B & PVC, Section V, Article 10, Appendix I- Bubble Test, may be conducted at 2 psi to check for gross leaks. The bubble test could be followed by a negative pressure test. These tests shall be performed well ahead of the Functional Test (FT) to be of any benefit to the project. A complete mock up test assemble can be fabricated from new material or GFE material available for this fabrication. The objective of this test is to confirm the flange design including fasteners and gaskets will perform as designed at system negative pressure with some margin.

The flange / proto type test(s) are designed to confirm the flange design and mitigate risk. Submittal of test procedures for this section is optional, since similar test procedures will be submitted when the FT is conducted.

6.2 Personnel Qualifications

NDE personnel performing NDE shall work in accordance with the following the Buyer specifications:

- 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication*
- 24590-WTP-3PS-MVB2-T0001, *Engineering Specification for Welding of Pressure Vessels, Heat Exchangers and Boilers*
- 24590-WTP-3PS-SS00-T0001, *Engineering Specification for Welding of Structural Carbon Steel*
- 24590-WTP-3PS-SS00-T0002, *Engineering Specification for Welding of Structural Stainless Steel and Welding of Structural Carbon Steel to Structural Stainless Steel*
- 24590-WTP-3PS-NWP0-T0001, *Engineering Specification for General Welding and NDE Requirements for Supplier Fabricated Piping*
- Attachment PS02 *Shop Fabrication of Piping*

6.3 Non-Destructive Examinations

6.3.1 NDE shall be performed in accordance with the following the Buyer specifications:

- 24590-WTP-3PS-MV00-T0001, *Engineering Specification for Pressure Vessel Design and Fabrication*
- 24590-WTP-3PS-MVB2-T0001, *Engineering Specification for Welding of Pressure Vessels, Heat Exchangers and Boilers*
- 24590-WTP-3PS-SS00-T0001, *Engineering Specification for the Welding of Structural Carbon Steel*
- 24590-WTP-3PS-SS00-T0002, *Engineering Specification for Welding of Structural Stainless Steel and Welding of Structural Carbon Steel to Structural Stainless Steel*
- 24590-WTP-3PS-NWP0-T0001, *Engineering Specification for General Welding and NDE Requirements for Supplier Fabricated Piping*
- Attachment PS02 *Shop Fabrication of Piping*

6.3.2 NDE procedures shall be submitted to the Buyer for review and approval prior to use.

6.3.3 Submittal of exposed radiographs is required. Original set of exposed radiographic film must be sent, along with technique and reader sheets. Film must be packaged in such a manner as to preclude moisture and handling damage.

6.4 Shop Tests

6.4.1 Pre-Functional Test

6.4.1.1 The Completion Supplier shall perform instrument testing, inspection and calibration required to verify compliance with this specification. When requested, procedures and reports provided for records shall be submitted for the Buyer's review in accordance with Part 2 of the material requisition, Forms G321-E of the material requisition to which this specification is attached.

6.4.1.2 The Buyer's Supplier Quality (SQ) and an engineering representative shall witness the Completion Supplier's functional tests.

6.4.2 Instrumentation and controls that contain solid state components shall be subjected to burn-in as required. Burn-in duration shall be 72 hours minimum. The Completion Supplier shall provide the Buyer with 10 business day's notification to allow the Buyer to witness the test.

6.4.3 All wiring provided by the Completion Supplier shall be verified 100% with a point to point continuity test. Wiring errors that are detected shall be corrected, including drawings, prior to the Buyer's inspection.

6.4.4 Software functional testing shall be governed by 24590-WTP-3PS-JQ00-T0004, *Engineering Specification for Management of Supplier Software.*

6.4.5 A simulated signal shall be injected and varied over the full range for each devise in the instrumentation and control circuits. Each device shall be calibrated and checked for correct operation by simulating inputs, actuating switches, and monitoring outputs, indicating lights, etc.

6.4.6 Failure to perform such tests or failure of any part shall be cause for rejection of part or all of the system components.

6.4.7 The Completion Supplier's shop tests shall include the following:

a. Megger test before termination of all 480V wiring pulled into conduit. See Part 2, Attachment SQ of the MR for Witness and Hold Points schedule. Record on the FT.

b. Continuity check of all wiring for conformance with drawings. See Part 2, Attachment SQ of the MR for Witness and Hold Points schedule. Record on the FT.

6.4.8 Prior to notification by the Completion Supplier that a unit is ready for the Buyer to witness the Functional Test portion of the FT, the Completion Supplier shall perform all other FT mechanical and electrical inspections to ensure completed equipment is functioning and ready for the Functional Test. See Part 2, Attachment SQ of the MR for Witness and Hold Points schedule.

6.4.9 The Completion Supplier shall have the unit up and ready for Functional Testing prior to the Buyer's team arriving.

6.4.10 The Completion Supplier shall submit the Functional Test Procedure for the Buyer to review prior to use by the supplier.

6.4.11 The Completion Supplier shall submit a report of the FT results.

6.4.12 The Functional Test Procedures shall be prepared by the Completion Supplier in accordance with Attachment JQ07, Section 11.3.2.

6.4.13 The following is a list of preliminary Buyer expectations for the TCO Functional Test. This list is subject to change during review of the proposed test procedure. All results shall be recorded on the FT datasheet.

a. The TCO is completely assembled for the following tests:

i. Pressure testing shall be performed in accordance with required testing specified in ASME B31.3-1996 or ASME Section VIII, Division 1, as applicable. In addition to these code required pressure tests, additional testing shall be performed to further demonstrate the pressure boundary integrity of the equipment.

ii. Sensitive Leak Testing shall be performed on piping in accordance with ASME B31.3, Section 345.8, as required.

iii. Bubble Testing shall be performed in accordance with ASME Section 5, Article 10, as required.

iv. Obtain unit pressure drop measurements at ambient conditions and at heat up intervals. Record on FT datasheet.

v. Deleted

vi. Preheat the incoming air prior to LVP-HTR-00002, to simulate the hot offgas from the melter, as required.

vii. Provide power and temporary controls for LVP-HTR-00002.

viii. Operate the TCO at test temperature for 24 hours. This time frame includes initial system heat up and time for the TCO to stabilize at operating temperature.

b. Test Objective

i. Verify the TCO heater, LVP-HTR-00002, provides the required heat to maintain temperature.

ii. Verify the JC 0510A loop controls LVP-HTR-00002 within the operating range.

iii. Verify the 2 Melter nominal flowrate of approximately 4702 ACFM (or as specified in the MDS) can be achieved. The flowrate provided here is for information only and subject to change. Refer to the MDS for the actual flowrate.

iv. Verify the actual differential pressure drop is less than the allowable differential pressure. Refer to the MDS for the actual pressure. Record on the FT datasheet.

v. Verify the TCO outlet temperature at TE-0524 is less than 486°F. The temperature provided here is for information and subject to change. Refer to the MDS for the actual temperature.

vi. Deleted

vii. Deleted

viii. Verify the unit pressure drop is within acceptable limits as stated in the Buyer approved FT. Record on the FT datasheet.

ix. Deleted

c. Deleted

d. After the TCO unit has cooled, verify no deformation or degradation to the housing and internal components has occurred.

e. Deleted

f. After the TCO has cooled, remove the SCO and SCR catalyst modules. Verify by visual observation if the catalyst racks and or catalyst gaskets have distorted during the functional test. Reinstall all of the catalyst to confirm the catalyst modules can be completely reloaded. If distortion was observed, repair / replace as required. If distortion was observed repeat the test after repairs / replacements are complete. Repeat test duration can be 8 hours or less. Record results on FT datasheet.

g. The Completion Supplier shall submit the catalyst installation and removal procedure.

h. Demonstrate heater removal and insertion. This step can be accomplished at any time, before or after the functional testing.

6.4.14 The following is a list of requirements for the Ammonia / Air Dilution Skid Functional Test. This test is subject to change by the Buyer during the review of the proposed test procedure. Changes to these expectations, agreed to during the review, do not need to be reflected in a revision to this specification. All results shall be recorded on the FT datasheet

a. The ammonia dilution skid is completely assembled. Control panel, LVP-PNL-00003 is complete and ready for testing.

i. Pressure testing shall be performed in accordance with the required testing specified in ASME B31.3. In addition to these code required pressure tests, additional testing shall be performed to further demonstrate the pressure boundary integrity of the equipment.

ii. Sensitive Leak Testing shall be performed on piping in accordance with ASME B31.3, Section 345.8, as required.

iii. It is acceptable to use temporary air and controls to open and close valves on the skid.

b. The Completion Supplier shall provide the following air source:

i. Not Used

ii. Dry, oil and dust free Instrument Service Air (ISA) at 90-150 psig and with a dew point of -40°F at 100 psig based on ISA 7.0.01.

c. Test Objective

i. Satisfactory results for 6.4.14a criterion as stated above.

ii. Actuated valves are fully cycled a minimum of 3 times and flow instrument loops respond per the design.

iii. Verify fan control using the control panel LVP-PNL-00003.

iv. Verify the fans produce the required flow and pressure.

6.4.15 The Completion Supplier provided lifting equipment, such as, but not limited to spreader beams, strong backs and yokes shall be tested in accordance with Section 9.4 of 24590-WTP-3PS-G000-T0003, *Engineering Specification for Packaging, Handling and Storage Requirements*. Engineering Specification, 24590-WTP-3PS-G000-T0003, only requires custom spreader beams, strong backs, and yokes when these items are not available from commercial sources.

6.4.16 All overhead lifting points shall be proof tested. Test and examination certificates / documentation shall be provided to the Buyer for review. Lifts shall be conducted in accordance with the Buyer reviewed handling procedure.

6.4.17 Deleted

6.4.18 After the proof tests, the lift points shall be inspected.

6.4.19 The welds on fabricated lifting lugs shall be dye penetrant tested. Acceptance criteria shall be from the prevailing weld design code or standard.

6.4.20 Lift points shall be inspected for visual permanent plastic deformation of the material that may invalidate the design analyses for the lift points.

6.4.21 Deleted

6.5 Site Tests

The Buyer startup personnel shall perform acceptance tests after initial installation to confirm the Thermal Catalytic Oxidizer/Reducer and the associated Ammonia/Air Dilution unit meets the performance requirements specified in Section 3.4 of this specification.

7 Preparation for Shipment

7.1 General

The Thermal Catalytic Oxidizer/Reducer, catalysts, assemblies and the associated Ammonia/Air Dilution units shall be packaged, handled, and stored in accordance with the Buyer specification

24590-WTP-3PS-G000-T0003, *Engineering Specification for Packaging, Handling, and Storage Requirements.*

7.2 Tagging

7.2.1 A stainless steel nameplate shall be attached in a visible location to the Thermal Catalytic Oxidizer/Reducer and Ammonia/Air Dilution unit showing the manufacturer's name, shop location, date of manufacture, serial number, equipment rating, equipment tag numbers, weight of assembly and purchase order number.

7.2.2 Electrical/Control panels shall be tagged with component identification numbers per Attachment JQ07, Section 3.6.8 and Section 8.

7.2.3 Mechanical subcomponents (valves, strainers, expansion/flex joints, filters, etc.) shall have component identification number engraved on a 1/16" minimum thick stainless steel tag with ¼" minimum character height, securely attached with 1/16" minimum diameter aircraft cable and ferrules.

7.2.4 Component identification numbers shall be as shown on the Buyer's P&IDs or MDSs attached to the MR, or will be provided via the Buyer markup of the Completion Supplier submitted drawings.

7.3 Nameplates

7.3.1 Permanent nameplates or labels shall be provided to identify each meter, relay, control switch, indicating light, circuit breaker compartment, and to identify all devices and terminal blocks within the compartments.

7.3.2 Exterior nameplates shall be made of laminated, beveled plastic of manufacturer's standard, with black lettering or numbering on a white background and shall be permanently affixed on the exterior. The method of affixing shall not violate the NEMA rating of the enclosure. Chloride / halide testing is not required for glue used to attach name plates.

7.3.3 Interior labels for all devices, parts and components shall be machine printed, permanent and self-adhesive labels. Chloride / halide testing is not required for self-adhesive labels.

7.4 Indoor storage

7.4.1 All line items/equipment shall be packaged per LEVEL C storage requirements. Level C: Indoor Storage (ASME NQA-1 2000 Level C). Materials shall be stored within a fire-resistant, weather-tight, and well-ventilated building or equivalent enclosure. Precautions shall be taken against vandalism. This area shall be situated and constructed so that it shall not be subject to flooding; the floor shall be situated and constructed so that it shall not be subject to flooding; the floor shall be paved or equal and well drained. Items shall be placed on pallets or shoring to permit air circulation.

8 Quality Assurance

8.1 General Requirements

This section does not delete or revise (but is in addition to) those requirements defined by the procurement documents. If a supplier believes that an inconsistency exists between this section and the procurement documents and referenced codes and standards, the Completion Supplier shall immediately notify the Buyer requesting resolution.

8.1.1 The Completion Supplier is responsible to promulgate the requirements of this specification to sub-suppliers providing items or services related to this procurement.

8.1.2 The Completion Supplier's QAP Requirements are included in the Buyer's specification 24590-WTP-3PS-G000-T0001, *Engineering Specification for Supplier Quality Assurance Program Requirements*.

8.1.3 The Completion Supplier's Quality Assurance Manual Document Number 40-001, Rev 4, dated 3/13/13 shall be submitted to the Buyer for review. All work shall be performed in accordance with their QL-3 program and QL-3 implementing procedures. A Commercial Grade Survey was performed at the Completion Supplier's facility October 7, 2013 in order to observe and record the process and controls to their QL-3 program. If at some time during this procurement the Completion Supplier revises their Quality Assurance Manual or implementing procedures, WTP procurement Engineering shall be notified immediately in order to assess the changes and determine the impact, if any, to the dedication of the LAW TCO and Ammonia Dilution skid (ADS).

8.1.4 For items designated quality level commercial (CM), no additional QA program requirements are mandated by the Buyer beyond the Completion Supplier's commercial QA program.

8.2 Quality Program Requirements

8.2.1 Deleted

8.2.2 The Completion Supplier must pass a survey by the Buyer.

8.2.3 The Completion Supplier shall allow the Buyer, its agent, and DOE access to their facility and records pertaining to this purchase order for the purpose of Quality Assurance Audits and Surveillance at mutually agreed times.

8.2.4 Deleted

8.3 Supplier Deviation

Each supplier shall be required to identify and promptly document all deviations from the

requirements of the procuring documents. In addition, the supplier shall be required to describe the recommended disposition for the Buyer's acceptance based on appropriate analysis. Submittals of request for deviations from lower-tier suppliers shall be through the prime supplier to the Buyer. The supplier-proposed deviations from procurement documents shall be initiated by use of Supplier Deviation Disposition Request (SDDR) form in Part 2 of the MR.

9 Configuration Management

Equipment and/or components covered by this specification are identified with plant item numbers shown in the MDSs. Each item shall be identified in accordance with Tagging in Section 7.2 of this specification.

10 Documentation and Submittals

10.1 General

The Completion Supplier shall submit to the Buyer Engineering and Quality Verification documents in the forms and quantities shown in Form G-321-E, *Engineering Document Requirement*, and Form G-321-V, *Quality Verification Document Requirements*, attached to the MR.

10.2 Submittals

The Completion Supplier shall submit the following:

10.2.1 Drawings

Drawings shall be in accordance with ASME Y14.100 and show the following information:

10.2.1.1 The outline dimensions of each Thermal Catalytic Oxidizer/Reducer and Ammonia/Air Dilution units, including outline and detail drawings for each component. These drawings shall reflect the "as-shipped" configuration of the equipment and instrumentation.

10.2.1.2 Details of construction.

10.2.1.3 Mounting dimensions and information required for the design of supports and foundations.

10.2.1.4 Operating weight and center of gravity of each Thermal Catalytic Oxidizer/Reducer and Ammonia/Air Dilution unit.

10.2.1.5 The space required for the removal of components.

10.2.1.6 The location of access doors.

10.2.1.7 Deleted

10.2.1.8 Wiring and schematic diagrams. Diagrams shall include wire gauges and fuse sizes applicable to the supplied units only.

10.2.1.9 Deleted

10.2.1.10 Nozzle locations for connections to BUYER's process and utility piping including electrical and instrumentation connections.

10.2.1.11 Piping and instrumentation diagrams (P&IDs).

10.2.2 Procedures

Procedures shall include but are not limited to:

10.2.2.1 Completion Supplier's shipping preparation and storage procedures.

10.2.2.2 Startup, operation, shutdown, and idle procedures/manual.

10.2.2.3 Catalyst change out procedures.

10.2.2.4 Performance test procedures and acceptance criteria for shop tests.

10.2.2.5 Insulation installation procedures, for removable insulation.

10.2.2.6 Surface preparation and coating procedures for components specifically fabricated for the TCOs/SCRs.

10.2.2.7 Inspection and Test Reports

10.2.2.8 Performance test reports for shop tests.

10.2.2.9 Deleted

10.2.3 Deleted

10.2.3.1 Deleted

10.2.3.2 Deleted

10.2.4 Manuals

Manuals and instructions shall include:

10.2.4.1 Erection and installation manuals which provide complete, detailed procedures for installing and placing equipment in initial operation. The manuals shall include all erection and installation drawings. Refer to the Buyer specification 24590-WTP-3PS-G000-T0003 *Engineering Specification for Packaging, Handling and Storage Requirements*, for additional requirements.

10.2.4.2 Operation, accessibility, and maintenance manuals which provide complete, detailed descriptions of components and appurtenances with data sheets showing design, construction and performance data for equipment. Manuals shall include drawings required for operation, maintenance and repair, maintenance requirements, instructions and operational troubleshooting guides.

10.2.4.3 Instruction manuals shall cover items purchased, including materials that the Completion Supplier has obtained from a subcontractor. The supplier shall obtain such manuals and lists, and submit them to the Buyer.

10.2.4.4 The Completion Supplier shall provide instructions regarding transportation, site storage and preparation, and protection of equipment after installation and prior to operation. Refer to the Buyer's specification 24590-WTP-3PS-G000-T0003, *Engineering Specification for Packaging, Handling and Storage Requirements*, for additional requirements.

10.2.5 Certificates of Conformance and Acceptance

10.2.5.1 The Completion Supplier shall provide Certificates of Conformance demonstrating compliance with all applicable standards, specifications, and drawings. See Attachment 11 for a sample Certificate of Conformance.

10.2.5.2 The Completion Supplier shall certify lifting eyes or lugs and/or spreader bars are suitable for the safe, lifting, and handling of the equipment.

10.2.5.3 Attachment 7 provides the Certificate of Analysis (COA) for BASF Catalysts, LLC (VOCat 300S) used in Catholic University's Vitreous State Laboratory (VSL) testing. Prior to release for shipment the Completion Supplier shall provide the COA demonstrating the performance of the oxidation catalyst is equal to or better than the oxidation catalyst used in the reference VSL testing (Ref. MDS General Note 9) for the Buyer's acceptance.

10.2.6 Deleted

10.2.6.1 Deleted

10.2.6.2 Parts list, and cost for parts and items subject to deterioration and replacement.

10.2.6.3 List of recommended spare parts. The spare parts list shall include names of the original equipment manufacturer with appropriate part numbers.

10.2.7 Materials Certificates/Statistics

10.2.7.1 Deleted

10.2.7.2 Material Test Reports (MTRs)

10.2.7.3 Deleted

10.2.7.4 Deleted

10.2.7.5 Deleted

10.2.7.6 Material Safety Data Sheets (MSDSs).

10.2.8 Data

Data shall include:

10.2.8.1 The Buyer's Mechanical Data Sheets, completely filled out by the supplier, showing all information required to determine that the units are of the design and materials specified herein.

10.2.8.2 All data compiled during FT testing transmitted in a final report based on the Buyer's approved FT procedure/results/datasheet.

11 References

Design changes incorporated by reference:

24590-WTP-SDDR-MS-11-00054

24590-WTP-SDDR-MS-11-00200

24590-WTP-SDDR-MS-11-00298

24590-WTP-SDDR-MS-12-00094

24590-WTP-SDDR-MS-12-00110

24590-WTP-SDDR-MS-12-00167

24590-WTP-SDDR-MS-12-00173

24590-WTP-SDDR-MS-13-00001

24590-WTP-SDDR-MS-13-00006

24590-WTP-SDDR-MS-13-00023

24590-WTP-SDDR-MS-13-00074

24590-WTP-SDDR-MS-14-00002

24590-WTP-SDDR-MS-14-00003

24590-WTP-SDDR-MS-14-00004

24590-WTP-SDDR-MS-14-00042

24590-WTP-SDDR-MS-14-00048

24590-WTP-SDDR-MS-14-00049

24590-WTP-SDDR-MS-14-00050

24590-WTP-SDDR-MS-14-00061

24590-WTP-SDDR-MS-14-00062

24590-WTP-SDDR-MS-14-00064, superseded by 24590-WTP-SDDR-MS-15-00010

24590-WTP-SDDR-MS-14-00066

24590-WTP-SDDR-MS-14-00068

24590-WTP-SDDR-MS-14-00076

24590-WTP-SDDR-MS-15-00010

24590-WTP-SDDR-MS-15-00012

24590-WTP-SDDR-MS-15-00017

24590-WTP-SDDR-MS-15-00023

ATTACHMENT JQ07

LAW TCO CUSTOMIZED JQ07

24590-WTP-3PS-JQ07-T0001, Rev. 3, **SCN's 24590-WTP-3PN-JQ07-00015 & 00016 as applicable**
ENGINEERING SPECIFICATION FOR INSTRUMENTATION FOR PACKAGED SYSTEMS

This attachment defines the requirements for instruments, control devices, and control systems associated with the Low Activity Waste Thermal Catalytic Oxidizer/Reducer (LAW TCO). For continuity and maintaining configuration control, the section numbers from the specification noted above have been retained.

1.7 Work by Others

1.7.1 External Connections

All external connections of wiring and piping between the Supplier provided instruments and the Buyer's utilities are excluded unless specified in the RFP or otherwise agreed to by the Buyer and Supplier.

1.7.2 Instrument and Service Air

The Buyer will provide the following air sources for instruments and equipment:

Dry, oil and dust-free instrument air, 90 to 150 psig, with a dew point value of - 40 °F at 100 psig based on ISA 7.0.01. Service air, dew point –32 °F, 90 to 150 psig.

1.7.3 Power Supply

The Buyer will provide normal power and/or Uninterruptible Power Supply (UPS) for the Supplier's instruments unless otherwise specified on the parent specification. Each source will be delivered at 120 VAC, single phase, 60 Hz, grounded system. 480 VAC, 3 phase, 60 Hz power will be provided as required for motors. All other voltages required by the Supplier shall be derived from the Buyer provided 120 VAC or 480 VAC.

2.1 Codes

2.1.1 American Society of Mechanical Engineers (ASME)

ASME B31.3 (1996)	Process Piping
ASME/ANSI PTC 19.3	Performance Test Code for Temperature Measurement

2.2 Industry Standards

2.2.3 Telecommunications Industry Association / Electronic Industries Alliance (TIA/EIA)

TIA/EIA-232-F	Interface Between Data Terminal Equipment and Data Circuit-terminating Equipment Employing Serial Binary Data Interchange

TIA/EIA-485-A	Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems

2.2.4 Instrumentation, Systems, and Automation Society (ISA)

50.02, Part 2,3,4,5&6	Fieldbus Standard for Use in Industrial Control Systems Part 2 (1992), 3 (1997), 4 (1997), 5 (1998), 6 (1998)
S75.01	Flow Equations for Sizing Control Valves
S84.01 (1996)	Applications of Safety Instrumented Systems for the Process Industries

2.2.6 International Electrotechnical Commission (IEC)

IEC 60751	Industrial Platinum Resistance Thermometer Sensors
IEC 61508-2/3	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

2.2.7 National Electrical Manufacturers Association (NEMA)

NEMA ICS 6	Enclosures for Industrial Controls and Systems

2.2.9 WTP Project Specifications

24590-WTP-3PS-JQ00-T0004	Management of Supplier Software

3.3 Design Conditions

3.3.1 Units of Measurement

The following units shall be used for design parameters, calculations, and scales.

Positive gauge pressure	inches H_2O or psig
Vacuum	inches Hg Vac or H_2O Vac
Absolute pressure	inches Hg or psia
Differential pressure	inches H_2O or psi
Temperature	degrees F
Flow: Solids	lb/hr
Flow: Liquids and slurries	gal/min or lb/hr
Flow: Gases or Vapors	std ft^3/min (scfm), std ft^3/hr (scfh) or lb/hr
Flow: Steam or vapors	lb/hr
Level	inches, feet or %
Composition	%, Wt. Fraction or PPM
Density	lb/ft^3
Velocity	feet/second
Viscosity	centipoise (cP)
Current (Electrical)	ampere
Electrical Potential	volt
Resistance	ohm
Conductivity	micro-siemens (μS) per centimeter

3.3.2 Interlock and Alarm Requirements

Packaged systems shall be provided with a Common trouble (if specified) alarm, an Emergency shutdown alarm, and a Safety instrumented system (if specified) alarm to annunciate in the Buyer's control room. In addition, the following control requirements shall also be met:

- Field contacts shall open in the alarm condition
- Field contacts shall open to initiate shutdown
- Instruments and interlock systems shall be designed to be fail safe

3.3.3 Spare Capacity

The Supplier shall provide 25 percent spare intermediate terminal blocks and space for an additional 15 percent increase in terminal blocks.

3.3.4 Instrument Signal/Power Circuit Protection

Instrument circuits shall be protected and housed to meet the electrical area classification in which it is installed. The choices of housing shall satisfy all pertaining codes.

Intrinsically safe instrument systems should not be used, unless there are special site requirements, and then only with the Buyer's approval. Intrinsically safe system requires certification by Underwriters Laboratory (UL) or Factory Mutual (FM) Insurance Company.

Each PLC or controller discrete output signal shall have its own independent fuse. Fuses shall be located in the leg of the wiring scheme that provides power from the source to the field devices.

3.3.6 Local Control Panel Instrumentation Indicators

Local motor controls (i.e. single local/remote switch per equipment control panel, momentary forward/reverse for each motor) shall be provided on control panel for operating equipment in local mode. Local mode will allow control to be taken away from the control system. Operations will be performed from the control panel and will not be subject to ICN interlocks. Independent protection interlocks will remain in force to prevent damage to Supplier's equipment. Indicating lights for local control panels which include indications, status, and alarms from instruments and motor drives shall conform to the following requirements for indicating lights for status, alarms, information, or control:

Color	Meaning
Red	Stopped, Closed, OFF, Alarm
Green	Running, Opened, On
Yellow	Transition, Indeterminate, Force
Cyan (Light Blue)	Manual
Purple	Local Control (HMI Displays)
Clear	Local Control (Local Panels)

NOTE 1: Switches or control effectors shall be turned clockwise or moved upward to increase function or energize a device. For single switch multi-direction control a 3 position switch with center position spring return is recommended (i.e. Forward/Reversing Motors, etc.)

NOTE 2: Applicable standards and guidelines direct consistency of man-machine interface features in order to minimize operator errors. All control panels that are used for normal process operation should feature color-coding and display features that are consistent with the color scheme as defined in section 3.3.6 above. The color scheme applies to vendor packaged control indications as well as any

SELLER developed human machine interface screens. However, for control and indication panels that are intended for maintenance operation only, or that are not used for routine operator control, deviations from the color scheme listed above may be approved at the Buyer's discretion.

3.3.7 Push To Test Alarm Actuator

All alarm indicators (visual) and annunciators (audible), and all lights on Control Panels (ref 3.3.6) shall be activated with an integral momentary contact push to test feature or when a common momentary contact push to test button on the front of the panel is pressed. This function is provided to verify that the alarm and/or indication functions satisfactorily.

3.4 Controls and Instrumentation Requirements

3.4.1 General

It is the intention of this specification that the instrumentation and designated portions of the control system be designed, fabricated, and installed as far as it is practical to the Supplier's design offering. However, the Buyer will select specific manufacturers for purposes of quality and standardization of the instrumentation and control system throughout the WTP facility.

3.4.2 Controls

Control software provided by the Supplier shall be governed by 24590-WTP-3PS-JQ00-T0004.

3.4.2.1 WTP Integrated Control Network (ICN) Architecture

The Buyer has selected the Industrial^{IT} product line supplied by ABB Automation Inc. as the primary control system for the WTP facility. The selected platform is a highly versatile "hybrid" type system which is designed to implement the traditional Distributed Control System (DCS) applications as well as the traditional Programmable Logic controller (PLC) applications. For the purpose of standardization and maintainability, it is a requirement to utilize components from this manufacturer to the extent possible with packaged systems.

Packaged systems shall be integrated into the WTP ICN, the following options are available, listed in order of preference:

3.4.2.1.1 ICN Control Platform

This is the Buyer's preferred implementation method.

When the packaged system implements the ICN control platform it shall utilize the Buyer's selected manufacturer's control system hardware. This includes the processors, input/output modules, power supplies, communications hardware, etc. to be installed in the Supplier's supplied control cabinets. Dependent on the operational requirements of the package this could also include connectivity server equipment and operator interfaces.

The Buyer selected manufacturer's product line is a follows:

Description/Manufacturer	ABB
Controller Platform	AC800M
Input/Output Module Platform	S800
Software Development Environment	Control^{IT} for AC800M/C
Operate Environment	Operate^{IT}

All ABB hardware shall be procured by the Buyer on behalf of the Supplier for applications provided the agreement was made prior to the contract award.

Preliminary design for controls implementation shall be submitted for the Buyer approval prior to the detailed design effort.

3.4.2.1.2 Commercial-Off-The-Shelf (COTS) Controls

Procured packaged systems considered as COTS are acceptable for integration into the ICN systems. For this determination, COTS controls are control hardware/software which do not require customization or design engineering for use on WTP. The Supplier shall supply the interface to the ICN using ICN supported communication hardware as follows:

Package Description		Interface	Media
Status Only – No control via ICN	Limited data exchange – Preferred	Profibus DP®	Multimode Fiber Optic
	Limited data exchange – Alternate*	4-20 mA - AI/AO	Hardwired
		24 VDC - DI	
		Dry contact – DO	
	Significant data exchange	OPC over Ethernet	Fiber Optic
Control via ICN	Preferred	Redundant Profibus DP®	Multimode Fiber Optic
	Alternate*	4-20 mA - AI/AO	Hardwired
		24 VDC - DI	
		Dry contact – DO	

* Buyer approval is required for substitution of these or other alternative interfaces.
AI- Analog Input, AO- Analog Output, DI- Digital Input, DO- Digital Output.

3.4.2.1.3 Third Party Platform

If utilization of the Buyer's selected controls manufacturer is determined to be unfeasible, a third-party control platform can be utilized with the Buyer's concurrence. Unless otherwise stated, application software development will be by the Supplier. The interface of the third party platform to the ICN shall be per table shown in the above paragraph 3.4.2.1.2.

Preliminary design for controls implementation on the third-party platform shall be submitted for the Buyer's review prior to the detailed design effort.

3.4.2.2 WTP Integration

3.4.2.2.1 Interface Data Requirements

Where the application software is provided by the Supplier, the Supplier shall provide a complete listing and detailed description of data points available for integration into the Buyer's ICN for operational, maintenance, and archiving purposes. All required control points required for the appropriate level of ICN control shall be clearly identified. The list shall be submitted to the Buyer for review and mutual concurrence. The final submission listing shall include all applicable interfacing details (entity names, addressing, etc.).

Where the application software is provided by the Buyer, refer to paragraph 3.5 for software design documentation requirements.

3.4.2.2.2 Interface Integration Testing

The Supplier shall provide proposed Profibus DP®, Foundation® Fieldbus, protocol converters, and interface devices immediately after the 90% design review. This will facilitate testing at the Buyer's facility in Richland, WA. Previously tested devices by Buyer will not need to be supplied at this time.

3.4.3 Non-Safety Signal Transmission Interface

The Buyer is striving for a consistent implementation of the connection of field instrumentation and equipment to control systems throughout the WTP facility.

Preliminary design for connection of field instrumentation and equipment to control systems shall be submitted for Buyer review prior to the detailed design effort.

The Supplier shall organize circuits and circuit terminations in the Supplier's interfacing termination enclosures based on signal types or circuit configurations. These signal types will include AI, AO, DI, DO, serial, Profibus DP ☐ wi ☐ Foundation ☐ Fieldbu wire, or 4-wire circuit configurations. Based on quantities of these types, cable requirements can be established early. Subsequent to the contract award, C&I will work with the Supplier to "assign" signals to specific circuits and I/O channels as soon as possible.

The Supplier shall apply the following process when determining connection type:

3.4.3.1 Foundation® Fieldbus

Where available, process instrumentation shall be Foundation® Fieldbus compliant. Foundation® Fieldbus interfaces to communicate directly with Fieldbus enabled instruments and equipment. All Foundation® Fieldbus devices supplied shall be registered with the Foundation® Fieldbus, compliant with the current version of the Interoperability Test kit at the date of the purchase order, and supplied with manufacturer developed Device Description files. Only the Buyer-approved Interfacing devices shall be used to convert signals from their standard format to the Foundation® Fieldbus protocol. These devices shall be supplied by the Supplier and used only when a native Foundation® Fieldbus device is not available. The same communication, testing, and registration requirements apply to Fieldbus converters as to native Fieldbus devices.

3.4.3.1.1 Foundation® Fieldbus Accessories

All FOUNDATION Fieldbus devices shall be pre-wired with Pepperl + Fuchs (P+F) connector V9-R-M2-S.

3.4.3.1.2 Software Validation and Documentation

The Supplier shall provide Device Description (DD) files with every Purchase Order data sheet release. Device Description (DD) files shall be the manufacturer developed files and submitted in their native electronic form for each firmware version in the order.

The Supplier shall provide a list relating tag numbers to firmware versions and DD files, such as a MS Excel spreadsheet file.

The Supplier shall include manuals that describe how to configure the Foundation® Fieldbus parameters for the device.

If the Supplier changed any Buyer configurable parameters from their default state, these setting shall be documented on a per tag basis.

If the factory calibration settings are available and modifiable by the user, the Supplier shall document the settings and provide the settings along with the calibration certificate for each device.

The Buyer's control system can manage all parameters that are accessible though the Foundation® Fieldbus interface. However, if the Buyer is required to set any additional parameters that are available only though an alternate interface such as FDT/DTM, the Supplier shall provide the necessary hardware (cabling / hand held units) and software, including licenses, to interface with the device.

3.4.3.2 Profibus DP®

Communication interfaces to intelligent mechanical handling and electrical equipment shall be Profibus DP® compliant. Profibus DP® communication link shall be used to interface controllers directly with devices such as "intelligent" motor control centers (MCCs) and variable frequency drives (VFDs). All Profibus DP® devices shall be supplied with .GSD files and documentation describing data interchange. Other interfaces, such as DeviceNet®, AS-Interface®, TIA/EIA-232/485, etc. may be utilized with the appropriate converters with the Buyer's approval. The Supplier supplied conversion modules will be used where required. When Profibus DP® is the communications link between the Buyer's control system and the Supplier's control cabinets the following shall apply:

3.4.3.3 Communication Network Interface

The Buyer has selected the Industrial^{IT} platform from ABB, Inc. as the primary control system for the Buyer's facility. A Profibus DP® communication network will be used to communicate to drives and intelligent positioning instruments. The Supplier shall provide the following components for a Fiber Optic cable interface:

3.4.3.3.1 Profibus DP® Communication Interface

The Supplier shall provide a native Profibus DP® slave interface for the control panel or instrument and the associated drivers (GSD files) for communication with the Buyer's control system. The interface should support communication speeds up to 12 Mbit/sec over the Profibus DP® network.

3.4.3.3.2 Fiber Optic Connections

The Supplier shall provide the following component for proper network communication:

a) The Supplier shall install a Hirschmann OZD Profi 12M G12 fiber optic converter within the control panel or near the instrument for each communication network.

b) The Supplier shall derive the appropriate power to the fiber optic converter(s) from the control panel power feed. Where the Buyer provided a 120V single phase UPS supply, this supply shall be used to derive the 24VDC supply for the fiber optic converter. Where the only supply available from the Buyer is 480V 3Φ, then the Supplier shall use this to derive the 24VDC supply for the fiber optic converter. A separate power supply shall be provided for each communication network.

c) The Supplier shall follow the general fiber optic requirements described in section 3.4.3.5

3.4.3.3.3 Alternate Communication Interface

If a native Profibus DP® interface is not available, then the Supplier may propose an alternate communication interface or network that is compatible with the Buyer's control system for the Buyer's consideration and approval. If an alternate communication interface is proposed:

a) The Supplier shall provide all necessary interfaces or converters required to provide the Buyer's control system with the appropriate communications.

b) The Supplier shall provide any required drivers, software, and protocol conversion information to the Buyer for design, development, testing, and maintenance of the supplied networks and interfaces for the period of performance of the contract, including software or firmware upgrades or revisions.

c) The Supplier shall provide a description and examples of all required conversions between protocols and/or communication networks including required software applications and hardware components.

3.4.3.4 Classic I/O

If bussed communications are not feasible for connection of field instrumentation and equipment to control systems, standard Input/Output modules shall be used. Circuit design shall account for the WTP preferred I/O module types, as follows:

Analog Inputs – 4-20 mA current
Analog Output – 4-20 mA current
Discrete Input – 24 Volt dc
Discrete Output – 24 Volt dc

I/O modules shall be optically isolated from input and output wires to protect logic circuitry from high voltage transients. All output circuits shall have over-current protection. The I/O modules shall be of the plug-in type and shall be removable without turning off the power or disturbing field wiring ("hot swappable"). The I/O assemblies shall have indicators that are visible during operation to display the status of the I/O interface and individual I/O channels.

3.4.3.5 Fiber Optic Interface

For equipment packages that include a fiber optic interface the Supplier shall provide a fiber optic connection to the control panel or instrument per the following requirements:

a) The Supplier shall use 50/125 glass fiber patch cables to connect between the fiber optic patch plate(s) and the fiber optic converter(s). Any unused fiber optic connections shall be fitted with protective caps to guard against extraneous light and dust.

b) The Supplier shall utilize a Corning MT-RJ patch plate mounted in a protective housing to provide cable management, strain relief, and fiber protection.

c) Fiber optic patch cables shall utilize unpinned MT-RJ connectors on the converter side of the patch plate. Buyer-installed field cables will utilize pinned MT-RJ connectors.

d) For installations that have 24 fibers or less, the Supplier shall install a Corning CCH-CP24-97 patch plate and SPH-01P Single Panel Housing.

e) For installations that have more than 24 fibers, or where multiple fiber optic cables will be terminated on the field-side of the patch plate, the Supplier shall install the appropriate number of Corning WIC-02P or WIC-04P housings with corresponding CCH-CP24-97 patch plates.

f) All fiber optic designs and installations shall follow the manufacturer's guidance including equipment mounting, bending radius, strain relief, fiber termination, fiber and cable protection, and related items. The Supplier's designs shall make provisions for installation of Buyer's field cables that also meet these requirements.

3.4.5 Instrumentation Requirements

Instrument ranges shall be selected such that the normal operating point is between 35 and 75 percent of the range of the instrument. Except where the Buyer has specifically identified manufacturer and model, all the instruments shall be selected by the Supplier in accordance with guidelines provided herein. The instruments described below shall be selected to meet the required safety classification, specified quality, and the design criteria stated herein and in the primary equipment specification. The systems designed and fabricated shall meet the specified reliability and availability for each system or component.

The Supplier may suggest alternative instruments based on their past experience with similar applications subject to the Buyer's review and concurrence.

3.4.5.1 Flow Measurement

Flowmeters shall provide sufficient turn down ratio to accurately cover the required operating ranges of the Supplier's provided system and when installed shall meet the Buyer's required operational accuracy as stated in the package system specification. Isolation and drain valves shall be installed to allow inline flowmeters to be removed and replaced without having to completely drain the pipe.

Flow measurement devices shall be selected that are optimized for the application and environment of the measured fluid. This includes installation constraints, ambient conditions, and process conditions of the measurement device. The following describes the Buyer's requirements for specific type of flow measuring elements and systems.

3.4.5.1.1 Head Type Flowmeter

Head producing flow elements shall be located and installed in straight runs of pipe in accordance with the American Society of Mechanical Engineers (ASME) Standard MFC-10M.

Differential pressure transmitter in conjunction with concentric sharp edged orifice plates shall be considered for flow measurement devices where a turndown of less than 5, a significant permanent head loss, and an accuracy of ±2% of full scale for liquid or gas flow is acceptable. The calculated d/D (Beta ratio) shall be within the limits of 0.2 and 0.7. Two sets of flange taps with one set plugged and seal welded as a spare shall be supplied. The orifice plate shall be of 304L SS minimum and compatible with process fluid and shall comply with ASME MFC-14M-2003 or ASME MFC-3M-1989. Straight piping runs shall be per API Ch 14, Sec 3, Part 2. Honed meter runs shall be used for orifice measurements for line sizes less than 2".

3.4.5.1.4 Coriolis Mass Flow Meter

Coriolis flow meters may be applied to most liquid and some high pressure gas services where accuracy of less than 0.5% of measurement is required. It shall be considered for service applications requiring up to 50 to 1 turndown. The meter shall be sized for the desired accuracy at minimum and normal flow rate without exceeding the permissible pressure drop at the maximum flow rate. The meter shall be also considered for the service where process temperature and density measurement are also required. The meter shall be securely mounted in a vibration-free location in accordance with the manufacturer's recommendations.

3.4.5.1.8 Turbine Meter

Turbine meters shall be considered for clean low viscosity process streams, where there is no plug flow or water hammer; where higher rangeability (> 10 to 1), an accuracy of ±0.5%, and flow totalization is required. API MPMS standard and ISA RP-31.1 should be consulted regarding proper installation and calibration requirement.

3.4.5.1.9 Vortex Flow Meter

Vortex flow meters shall generally not be considered unless suitable alternate means for measuring flow are not practical. Vortex flow meters have a minimum of 10 to 1 rangeability and low head loss. They are generally applicable to liquids of low viscosity (<10 cP) and are often unsuitable for low pressure gas service. Vortex flow meters are vibration sensitive so they should not be located in the vicinity of large rotating machinery or in lines with hydraulic noise. The meters exhibit an unusually large low flow cut-off. The impact of this loss of signal from the meter on safety and process controllability should be evaluated for application.

3.4.5.2 Temperature Measurement

Temperature measurement devices shall be selected that are optimized for the application and environment of the measurement services. This includes installation constraints, ambient conditions, and process conditions of the measurement devices. The following describes the Buyer's requirements for specific types of temperature measuring elements and systems.

3.4.5.2.1 Temperature Elements

All temperature elements, Thermocouples (T/C's) or Resistance Temperature Devices (RTDs), shall be installed in thermowells to permit removal without process disturbance except where there is no risk to personnel from the process fluid during removal of the measuring element, i.e. shell skin, motor bearings and motor windings. Where a thermowell is not used, and the temperature element is not surface mounted, a permanent label shall be affixed to the primary element, indicating that there is no thermowell.

Sheathed RTDs with transmitters shall be used for remote temperature indication.

Sheathed, grounded junction type E T/C's are preferred temperature sensors when process conditions prohibit the use of RTD's, types J & K T/C's are allowed. T/C's shall be according to ISA MC96.1 or equivalent. Underground junction T/C's shall be used where the process fluids or equipment are at a potential above ground that could lead to dangerous conditions for maintenance personnel and signal conditioning equipment.

Use T/C where:

- No air permit functions are supported by the device.
- The temperature sensor is installed in a high vibration environment; or
- A temperature span exceeding 1400°F is required; or a response time of less than four (4) seconds is required.
- Unsheathed tip thermocouples shall be used where induced electrical voltages or high potentials may be present (e.g. in the measurement of bearing temperature in electrical machinery.)
- Motor bearing temperature measurements may use thermocouples provided local transmitters are used.

RTD elements shall be Platinum with a nominal resistance of 100 Ohm at 0 °C (32 °F). The resistance-vs.-temperature characteristic curve shall conform to DIN 43760, IEC 60751 with a temperature coefficient of 0.00385 ohms/ohm/°C. Three wire element design shall be used.

Unless otherwise specified, RTDs shall be sheathed with Magnesium Oxide insulation. The sheath shall comply with ASTM A276, 316L and ¼" diameter as a minimum. All T/Cs or RTDs shall be duplex design, spring loaded, and supplied with a connection head with internal grounding screw and external ground terminal. All elements shall be connected in the connection head.

Temperature measurements using RTDs shall use remote mounted transmitters with the appropriate input/output voltage isolation and located in the field or panel to connect an isolated signal to the Buyer's or Supplier's control system.

Test thermowells shall have a plug or cap permanently attached with a chain or wire and labeled as a test point.

3.4.5.4 Absolute, Gauge, and Differential Pressure Measurement

Pressure instruments shall be ranged for normal operation at 40-60% of scale for pressure gauge and transmitters.

3.4.5.4.1 Pressure and Differential Pressure Transmitters

Pressure and differential pressure transmitters shall have the following performance as a minimum:

Standard accuracy:	±0.15% of calibrated span for ±50°F temperature changes for rangedown of 5:1 or less
Rangedown ratio:	30 to 1 minimum
Overall stability:	±0.125% of upper range limit for ±50°F temperature changes over 5 year period

For draft range differential pressure transmitters the available spans shall be 0.1 to 3.0"WC. The accuracy shall be ±0.10% of span with a stability of ±0.2% of span per year.

Wetted parts shall be a minimum of 316SS for flanges and 316L SS for the process isolating diaphragm. Mounting bolts shall be 316 SS. Pressure transmitters shall normally be gauge pressure type referenced to atmospheric pressure.

On low pressure applications where composition is being controlled using the pressure measurement, absolute pressure type transmitters referenced to a constant true zero pressure shall be used. Filled fluid shall be compatible with process material, pressure, and temperature. When required by the physical properties of the process fluid, a factory sealed filled system with a diaphragm shall be considered, although these should be avoided at low differential pressures. The capillary should be protected by a 316SS armor. Differential pressure transmitters shall be rated for a minimum 1000 psig static pressure and shall be able to withstand overrange pressure equal to the meter body rating and the pressure conditions or relevant piping specifications.

3.4.5.4.3 Pressure Gauges

All pumps, except sump pumps, shall have a discharge pressure gauge and a suction pressure test connection. Pressure gauges shall be provided downstream of pressure reducing stations and with blind pressure switches.

Pressure indicating scales shall be graduated in direct engineering units for the range specified. Pressure gauges shall be 4 ½" diameter, ½" MNPT bottom connection, plastic case, white laminated phenol dials with black graduations. Process gauges shall be solid front with a blowout back. Movement may be either rotary geared stainless steel or cam and roller type. Accuracy shall be 0.5% of full scale. Bourdon tube, socket, and tip shall be stainless steel or suitable alloy for specific services. Back-of-panel receiver gauges used for testing shall have 2 ½ inch dial.

Pulsation dampeners or snubbers shall be required on all pulsating services such as reciprocating pumps and compressors. Other applications where severe service from pulsating pressure is anticipated, pulsation dampeners may be specified at engineer's discretion. Dampening shall be provided by liquid filled gauge bodies.

Gauge ranges shall be selected such that the operating pressure falls between 40 to 60% of the gauge scale.

3.4.5.5 Control Valves

Valves shall be sized per ISA S75.01. Valves shall be sized to control normal operating design flow at 50% to 70% of its maximum opening. Valves shall be sized to be no more than 90% open at maximum operating flow and no less than 10% open at minimum operating flow. If calculated Cv dictates valve size two line sizes below process line, reduced trim in valve one line size below process line shall be used. The valve shall be selected and sized so that the installed rangeability is at least 20:1.

The potential for cavitation shall be evaluated and the valve size, trim, or type selected to prevent the occurrence of cavitation.

The valve trim shall be selected so that the installed operating characteristics of the control valve shall be nominally linear over the operating flow range. To achieve this, equal percentage trim shall normally be used for control applications except for some applications where linear trim is required. Linear trim shall be used for those applications where the pressure drop across the control valve is more than 50% of the upstream pressure or constant pressure across the control valve. A quick opening valve characteristic shall generally not be used for throttling services. Valve trim materials shall be as follows:

1. For metal to metal seating configuration, 316L SS shall be the normal and minimum acceptable material.
2. Stellite faced seating surfaces or other approved hardened materials shall be provided in difficult services, i.e. cavitation or flashing.
3. Soft seat trim material shall be used when bubble-tight shut off is a requirement or where determined by the process fluid's corrosiveness. Elastomer used for seating material shall be compatible with process fluid and service application.

Valves with soft seats shall be used within the limitations of the seating materials for positive bubble tight shut-off. On/off valves shall have integral solenoid pilots and limit switches. Foundation® Fieldbus compliant topworks are preferred by the Buyer for on/off valves. Seat leakage shall be in accordance with ANSI/FCI 70-2 seat leakage definitions and requirements. Fire testing and certification of on/off valves shall be in accordance with provisions of API SPEC 6FA or API STD 607. It should be noted that this testing does not qualify control valves to meet redundancy separation / single failure criteria requirements of Section 4.5-1 of the Safety Requirements Document.

Spring opposed pneumatic diaphragm actuators shall be the normal mechanism for operating throttling valves. Actuator sizing shall permit full valve stroking against the maximum process differential pressure and spring tension with the available instrument air supply pressure and output from positioner. Piston actuators shall be used where stroke length or thrust required exceeds that available from diaphragm actuators, or environmental conditions preclude the use of diaphragm actuators.

Valve positioners shall be furnished for all control valves. Positioners shall have input, output(s), and supply pressure gauges. Any split range requirements shall be achieved by using the control system. The failsafe action of the valves shall be determined by process requirements with regard to safe operation and emergency shutdown requirements and shall be marked on P&IDs. Foundation® Fieldbus positioners shall be supplied for all non-Safety valves and standard positioners shall be supplied for all SAFETY SSC valves. Remote Foundation® Fieldbus positioners shall be supplied where valve environment precludes the use of microprocessor based devices.

All valves shall be designed to meet the maximum noise level as defined in OSHA paragraph 1910.95. Maximum noise level is defined as 85 dBA when measured 3 feet from the valve under normal operating conditions. Noise prediction methods shall be those recommended by the specific valve Supplier.

Limit switches shall be hermetically sealed and suitable for mounting on the valve. Independent switches shall be provided as required for valve open and closed positions.

When control valves are installed in horizontal lines the actuator shall be installed above the line. Sufficient clear space shall be provided above the valve to allow removal of the top works with stem and plug as an assembly. A hand-wheel shall be furnished on each accessible control valve

where required for manual control during upset conditions. Modulating control valves shall be provided with isolating block valves, gate or globe type, and vent/drain valve to allow the control valve to be taken out of service and a globe bypass valve for hand control, if required and approved, around the control valve during the time the control valve is out of service. Both isolating block valves and bypass valve shall have flow capacity more than control valve capacity.

3.4.5.6 Solenoid Valves

All solenoid valves shall operate with zero pressure differential and shall close against the maximum design differential pressure. Solenoid valves shall be suitable for the environmental conditions and the electrical area classification specified in the referenced material requisition or data sheet. Solenoid coils shall be rated for continuous operation and heavy duty type equipped with class H insulation and a minimum of temperature class T3 encapsulated coils. Low wattage type shall be supplied for 24VDC applications and shall not exceed 12 watts. Coil enclosures shall include provisions for terminal connections rather than pigtails and have ¾ inch or ½ inch NPT conduit connections. Vent port is to be fitted with a bug screen.

3.4.5.7 Limit Switches

Limit switches shall be electromechanical type with lever arms, pushbuttons, or cams as actuators that operate momentary contacts.

Switch contacts, if supplied, shall be snap action, hermetically sealed design and suitable for the environmental conditions where they're located. As a minimum, switch contacts shall be of a Single-Pole-Double-Throw (SPDT) design. Contact rating shall be at a minimum 5A @ 120 VAC or 2.5A @ 24 VDC.

Limit switches shall be mounted such that actuation does not cause damage or excessive limit switch movement.

3.4.5.16 Rotating Equipment Monitoring Systems

Detection of imminent machine failure in time to safely shutdown the associated process shall be provided as required by the primary equipment specification. Instrumentation required to protect rotating machinery from damage is addressed herein.

3.4.5.16.1 Machinery Parameters for Monitoring

Machinery requiring high availability should be provided with sensors to continuously monitor:

1. Both radial vibration (X and Y directions) and thrust of shaft
2. Temperature of all journal and thrust bearings
3. Lubrication system operation including oil pressure and temperature
4. Rod drop and impact monitoring for reciprocating compressors.

Consideration shall also be given to providing seal system leak detection.

The Supplier shall provide and install non-contacting vibration and position sensor probes for machine monitoring of both radial vibration and thrust position of the shaft. The installation of all bearing thermocouple and shaft position monitoring equipment shall be in accordance with API 670. Bearing thermocouples shall be type E calibration.

3.4.5.16.2 Shaft Speed Monitoring and Control

Speed transmitters shall have sensors of non-contact type. Speed control of rotating equipment shall be accomplished by the use of speed transmitters and fast response control loop, Electronic governors are preferred where machine speed regulation is important for process control. Overspeed protection independent of the governor should be provided.

3.4.6 Safety Instrumentation and Controls

3.4.6.1 SS instruments serving an active safety function and designated as "Z" instruments have been deleted from the Supplier's work scope.

3.4.6.1.1 Deleted

3.4.6.1.2 Deleted

3.4.6.2 Deleted

3.4.6.3 Deleted

3.4.6.4 Deleted

3.5 Deleted

3.6 Enclosures, Cabinets, Panels, and Racks Requirements

The Supplier shall provide the instrument enclosures, cabinets, panels, and racks necessary to support the instrumentation and control systems required by the primary equipment specification. Instruments that require physical or environmental protection shall be installed in enclosures that meet the specifications of this section. Instruments that have a construction and NEMA rating that permits unprotected installation in the field shall be either individually field mounted or installed on open instrument racks that meet the requirements of this section. Operator control panels for interfacing to the control systems shall meet the requirements of this section. All enclosures, cabinets, panels, and racks shall be designed and fabricated to be in full compliance with NFPA 70-1999.

3.6.1 Rating and Type

All enclosures shall be designed for front access only unless otherwise specified. All components and equipment in the enclosure shall be accessible and removable from the front. Enclosures shall be either outdoor, indoor, hose down, or corrosive environments per the NEMA 250 and ICS 6 standards based on the environmental specification requirements. In the absence of a specific NEMA requirement in the main mechanical package specification, a NEMA rating of 12 shall be the minimum acceptable requirement for indoor and NEMA 4X for outdoor. In areas where radioactive contamination is likely, only stainless steel enclosures shall be used.

3.6.2 Enclosure Internal Environmental Conditions

The enclosure design shall ensure that no internal equipment or component is subjected to levels of dirt or dust that exceed those specified by the equipment or component manufacturer. The temperature inside of the enclosure shall not exceed the maximum and minimum operating temperatures of any device located within it.

Natural convection and conduction cooling is the preferred method of dissipating heat within the enclosure. If "Hot Spots" such as those generated by power supplies or other electrical equipment are present, or an internal temperature exceeding 100 °F is anticipated, the enclosure shall be fitted with adequately sized ventilation fans where ambient conditions permit.

Where forced-air cooling is necessary and practicable for proper operation of the apparatus housed in the enclosure, the Supplier shall provide special filters, blowers or other suitable filtration or cooling devices that will meet the requirements of NEMA 250 and ICS 6.

The Supplier shall provide enclosures with thermostatically controlled space heaters, where required by ambient conditions, to maintain temperature above dew point and above freezing. If equipment is located outdoors, space heaters must be provided, unless otherwise stipulated by the Buyer.

The Supplier shall provide all mounting brackets, wire, and equipment needed to attach the heating or cooling devices to the enclosure without degrading the NEMA 250 and ICS 6 enclosure requirements.

3.6.3 Mechanical Requirement

Freestanding enclosures shall be fitted with a base, have rigid bracing, removable lifting eyes and include provisions for securing to floor with anchor bolts or bolted or welded to the Buyer's floor embed. Wall mounted enclosures shall be sized by the Supplier and shall include all rigid bracing, door latch, and mounting fixtures needed to mount the enclosure to the wall.

Where lockable enclosure doors are specified on the primary equipment specifications, datasheets, or drawings, the doors shall have a common key lock. The Buyer will review and concur with the key arrangement and selection. All packaged systems and equipment controls shall be pre-wired to terminal blocks in permanently mounted enclosure.

The terminal blocks shall be designed for easy interconnection to the Buyer's control and communication circuits (see section 3.4.3 design requirements of this specification for signal transmission interface).

Interconnecting wire shall be run in intermediate metallic conduit. Interconnecting Fieldbus communication cables shall be armored type and supported in unistrut channel or on existing structure.

Access to enclosure internal components or equipment shall not require the use of hand tools other than for opening the door. Access to any component within the enclosure for maintenance or replacement shall not be prevented by proximity to other components within the enclosure. Equipment mounted in the rear of the enclosure shall be on a back-panel and positioned to facilitate removal and replacement. Enclosure back-panels shall be fabricated from low-carbon steel and shall be finished with semi-gloss or gloss white paint. Enclosures shall be sized to allow clearance between the enclosed components, cables, print pockets, and components mounted on the door.

Suites of enclosures shall be designed to accommodate shipment for a two bay interface. Where a suite of enclosures is made of discrete cabinet sections that will be separated for shipment and movement on site and then reconnected in the same configuration, provisions shall be made (such as the inclusion of dowel pins) for the alignment to be reproduced on site. If two or more enclosures are connected and share wiring, the side-panels they share shall be removed.

Where enclosures are to be installed by the Supplier, they shall be placed in a position that allows the doors to be opened fully for easy access to wiring and components for maintenance, testing and troubleshooting.

Where enclosed or protected installation is not required, then racks shall be used for mounting instruments to provide ease of maintenance and calibration. The rack frame for mounting non-Safety instruments shall be constructed of stainless steel unistrut channel and stainless steel unistrut systems components and designed to support the weight of installed instruments. The rack frame for mounting SAFETY SSC instruments shall be designed, constructed, and qualified to the requirements stated in the primary equipment specification. Free standing racks shall be fitted with a base, rigid bracing, and lifting eyes. Racks shall also include provisions for securing to walls or floor with anchor bolts or bolted to the Buyer's embed. All rack mounted instrumentation shall have NEMA 4X rating or better.

3.6.4 Enclosure Segregation Requirements

Deleted

3.6.5 Enclosure Grounding Requirements

The enclosure grounding system shall be installed in conformance to IEEE Guide 1050-1996, section 5.3.1 "Single point grounding system". All instrumentation enclosures shall have an equipment safety ground bus and an isolated signal ground bus, except instrument junction box. Instrument junction box shall only have an equipment safety ground. The grounding bus shall be constructed with solid copper, and all connections shall be drilled and tapped. The ground bus shall be drilled and tapped for an additional 20 percent spare terminations.

The equipment safety ground bus shall be solidly bolted to the enclosure structure. Where enclosures are to be connected together after final installation, each end of the safety ground bus will include provisions for connection to the adjacent enclosure safety ground bus. A bolted compression type 2/0 terminal lug shall be installed at each end of the bus to facilitate connection of the Buyer's 2/0 AWG stranded copper ground cable.

All removable metal components shall be connected to the equipment ground bus. Enclosure and back-panel shall be bonded to the equipment ground. Grounding for electrical devices and instruments, including signal and power supply shall be in accordance with manufacturer's recommendations and applicable NEC requirements. Instrument cable shield and signal common conductors shall be connected to the isolated signal ground bus, unless otherwise required by the manufacturer.

The isolated signal ground bus shall be electrically isolated from the enclosure structure and the safety ground bus. A bolted compression type 2/0 terminal lug shall be installed at each end of the isolated ground bus to facilitate connection either to another isolated signal ground bus in a connected adjacent enclosure or to the Buyer's 2/0 AWG stranded copper ground cable.

Instrument cable shields and signal common conductors shall be connected to the isolated signal ground bus. Each signal ground conductor shall be fastened to the isolated signal ground bus. For junction boxes with signal wiring going back to the Buyer's control system, the cable shield shall be terminated on an isolated terminal block and carried back to a ground supplied by the Buyer. Ground conductors connected to the isolated signal ground bus shall have an insulation color code of green with yellow tracer.

3.6.6 Electrical and Wiring Requirements

The Supplier shall mount, connect and wire each instrument or control device such that adjustment, maintenance, removal and replacement may be accomplished in a safe manner without interruption of service to adjacent but unrelated equipment and without placing undue stress on installed wiring or devices. Accommodations for strain relief shall be made when routing wire to hinged enclosure doors and shall be wrapped with spiral wire wrap.

Terminal points shall be used for only one wire unless specifically identified for more than one wire by an NRTL. Wire splicing shall not be used unless approved by the Buyer. Bridge or comb jumpers shall be used for adjacent terminal connections. Jumpers shall not be installed on the field side of the terminal strip.

Terminal blocks shall incorporate the following features:

Space saving design
Screw clamp wire connection
Single level configuration
Integral test facilities
DIN-rail (35mm) mounted

Isolating type terminal blocks shall be Weidmuller "W" series, Allen Bradley 1492-JKD3TP, Phoenix Contact, or Buyer approved equal. Non-isolating feed-thru terminal blocks shall be Weidmuller "W" series, Allen Bradley 1492-W4, Phoenix Contact, or Buyer approved equal. Terminal blocks for the

incoming power supply shall be capable of connecting #4 AWG to #12 AWG conductors, such as Allen Bradley 1492-W16S, or Weidmuller WD 35. The terminal blocks for incoming 120 VAC power and 120 VAC power distribution shall provide separation between Control/Instrumentation power and enclosure utility power, with separate termination points for each. Enclosure utilities include convenience accessories, cooling fans, and heaters.

All terminal blocks shall be identified by a unique terminal block number and approved by the Buyer.

For all enclosures, each incoming power supply shall be provided with circuit protection and shall have a manually actuated electrical power disconnect device mounted on/in the enclosure in an easily accessible location. The electrical power disconnect device may be a single device or multiple devices for individual circuits.

Each device that uses 120 VAC for power shall have individual connections protected via rail mounted circuit breakers. The circuit breakers used for individual control or power circuit protection within the enclosure shall be thermal magnetic breakers such as Weidmuller CB, Allen Bradley type 1492, Phoenix Contact, or Buyer approved equal. The circuit breakers used for individual control or power circuit protection external to the enclosure shall comply with UL489. They shall be Dual-In-Line, DIN-rail mountable TS35, TS32, or equivalent. Power shall not be "daisy chained" from instrument to instrument; however, the bridge or comb jumpers may be used on the supply side of the circuit breakers. A fuse and circuit breaker directory shall be contained in a holder permanently affixed on the inside of each door or back-panel and protected by a clear window.

All internal enclosure wiring shall be neatly dressed in slotted non-metallic wireways. The wireway shall be securely fastened to the enclosure back-panel by use of Stainless Steel screws. Circuits of different voltages (service level) shall be terminated on physically separate terminal strips and clearly labeled to show the circuit voltage. Terminal blocks shall be segregated according to signal type. In the event SIS system components are included in an enclosure, the wiring shall be clearly identified and segregated from non SIS circuits.

See table 1 for the instrumentation cable schedule:

TABLE 1
Instrumentation Cable Schedule

Cable Code		Cable Desc.	Specific Cable Spec	Comments	Circuit ID	Cable General Spec (superceded by specific cable specification)
Inst. cables-analog circuits	**In SR**	**Analog signals**				
1TSPR#16	X	Single twisted pr, #16AWG, 300V, ITC, PLTC	Single twisted pair with overall foil shield	Individual instrument signals, instrument 24 vdc power	Black, White	Cables UL listed as ITC and PLTC, 300 V insulation, UL1581 listed for 70,000 BTU vertical tray flame test; 100% foil polyester/aluminum individual and overall shields with 22AWG drain wire. Each circuit shall have a minimum of 6-8 twists/ft.
2TSPR#16	X	Two twisted shielded pr #16AWG, 300V, ITC,PLTC	Individually twisted shielded pairs with overall foil shield		Black, White conductors -individual circuits numbered	
Inst. cables-thermocouple circuits	**In SR**	**Thermocouple signals**				
1JX#16	X	Single twisted pr, #16AWG, 300V, ITC, PLTC	Single twisted pair with overall foil shield	Type J thermocouple - iron (+), constantan (-)	White (+), Red (-)	Cables UL listed as ITC and PLTC, 300 V insulation, UL1581 listed for 70,000 BTU vertical tray flame test; 100% foil polyester/aluminum individual and overall shields with 18AWG or 22AWG drain wire.
1KX#20	X	Single twisted pr, #20AWG, 300V, ITC, PLTC	Single twisted pair with overall foil shield	Type K thermocouple - chromel (+), alumel (-)	Yellow (+), Red (-)	
Data communication cables	**In SR**	**Foundation Fieldbus**				
1TSPR#18FF	X	Single twisted shielded pair, Foundation Fieldbus	Foundation Fieldbus Type ER crush resistant cable, orange jacket, preset lengths with Pepperl-Fuchs connectors	Pepperl-Fuchs FieldConnex mini cordsets, Belden 3076F	Blue (-) pin 1; Orange (+) pin 2; Shield pin 3; not used pin 4	Cable UL 1581 listed for 70,00 BTU vertical tray flame test, 100% foil polyester/aluminum overall shield with 20 AWG drain wire
Instrument cables-digital circuits	**X**	**Discrete I/O**				
use 1TSPR#16 above	X	Single Twisted pr #16AWG, 300V, ITC, PLTC	Single twisted pair with overall foil shield	Individual instrument signals, instrument 24 vdc power		Cables UL listed as ITC and PLTC, 300 V insulation, UL1581 listed for 70,000 BTU vertical tray flame test; 100% foil polyester/aluminum individual and overall shields with 22AWG drain wire. Each circuit shall have a minimum of 6-8 twists/ft.
2TPR#16	X	Two twisted pr #16AWG, 300V, ITC, PLTC	Individually twisted pairs with overall foil shield	Valve limit switches, process switches	Black, White conductors -individual circuits numbered	

AC power shall be routed through separate wireways or separated with a divider from 24 VDC discrete and analog instrument signals within enclosures. Power and signal cabling shall not be run in parallel, except in separate wireways, and should cross at a 90-degree angle only.

The interior of each Freestanding, floor-mounted enclosure shall be equipped a 120 VAC light and switch. The enclosure shall be equipped with a 120 VAC duplex receptacle. Route wiring within the enclosure for convenience power receptacles, cooling fans (where approved), and space heater (if required) in accordance with standard industrial practice. The Supplier shall derive power for these components from the Buyer provided 480 VAC power supply. If a 480 VAC power supply is not available, the Buyer will provide the 120 VAC supply. Control and instrumentation power sources shall be separate from utility power sources.

All instrument signal cables shall be of the type and specification as listed in Table 1– Instrumentation Cable Schedule. Power cable, wire size and type shall be in accordance with NFPA 70 - 1999.

All wires and cables external to an enclosure shall be of the instrument tray cable (ITC) type, flame-retardant (passes IEEE 1202 vertical flame test), and have a 90 °C continuous rating in wet or dry locations. All cable insulation and jacket material shall be resistant to heat, moisture, impact, ozone, and meet or exceed the following requirements:

300 V rated for low voltage instrument cables (up to 120 VAC and 125 VDC)

600 V rated for power/motor control cables (up to 480 VAC and 250 VDC)

The wire insulation color for power wiring shall be of the following:

Black	Ungrounded conductors more than 50 VAC
White	Grounded conductors more than 50 VAC
Green	Equipment grounding wire
Green/Yellow tracer	Isolated instrument grounding wire
Light Blue	Ungrounded supply voltage less than 50 V (DC or AC)
Violet	Switched ungrounded voltage less than 50 V (DC or AC)
White/Blue tracer	Grounded or return supply voltage less than 50 V (DC or AC)

3.6.7 Accessibility and Maintenance

The enclosures shall be designed so that tools and test equipment may be used to accomplish all necessary adjustments, maintenance, cleaning, testing, and calibration. If specialized tools are needed for adjustments, maintenance, cleaning, testing, and calibration the Supplier shall provide two sets per order to Buyer upon delivery. Test points and calibration areas shall be accessible, clearly identified, and labeled. Adequate space shall be provided for removal and replacement of individual instruments or components located inside the enclosure. Equipment mounted in the rear of the enclosure shall be positioned to facilitate removal and replacement from the front of the enclosure.

3.6.8 Enclosure Nameplates, Labels, and Wire Markers

Where one end of the wire is provided by the original equipment manufacturer, connected to the component, in a pigtail configuration, and identifiable by other means such as color coding, only the

end of the pigtail that is provided un-terminated by the original equipment manufacturer is required to be identified by the mean described in this section.

The Buyer will provide the enclosure name, service description as detailed in section 8.1, and wire marker syntax and name/number.

External enclosure nameplate shall be constructed from 2-ply laminated plastic with white surface and black core. Letters shall be engraved through the white surface to the black core. Enclosure nameplate shall be engraved with the equipment tag number and a very brief service description. The nameplate shall be a minimum of 1/8 inch thick with beveled edges. The nameplates shall be attached to the enclosure either with an industrial adhesive appropriate for the tag and enclosure materials or by using stainless steel drive screws without violating the NEMA rating of the enclosure. The minimum character height for enclosure name/number shall be no less than 5/8 inch. The minimum character height for service description shall be no less than 1/4 inch.

Internal enclosure nameplates shall be provided for instruments, instrument accessories, switches, relays, terminal strips, lamps and equipment with a field wiring connection. Nameplates shall be visible from the front of the cabinet with the doors open. The nameplates shall be constructed from 3-ply laminated plastic with white surface and black core. Internal enclosure nameplates shall be attached using epoxy if it is compatible with the mating materials, causes no detrimental effects, and will not cause any structural damage. For a viewing distance of 3 feet, the minimum character height shall be no less than 1/8 inch.

Safety Labels shall not be attached to removable items that could be replaced in a different orientation.

Each wire shall be clearly identified with a wire marker at each end by means of heat shrinkable plastic sleeves or other Buyer approved permanent type wire marker in black text on white background. Open markers or "C" type sleeves that can be applied after a conductor is terminated will not be accepted. Minimum character size for wire marker shall be no less than 3/32 inch. The wire markers shall be attached within a maximum of 2 inches from the termination of the wire. Orientation of the wire marker shall be such that its identification is visible when viewed from the front of the enclosure looking in.

3.6.9 Human Factors

Controls, indicators, and the similar type devices shall be mounted between 36 and 70 inches above the floor.

3.7 Equipment Electrical Requirements

Refer to Attachment EKP0 for any additional electrical requirements.

3.7.2 Discrete Interfaces

The Supplier shall provide isolated, dry contacts where hardwired signals from controls or monitoring equipment on Supplier's packaged equipment is required by the Buyer's control system. The interfaces are distinct from control systems communications interfaces described in paragraph 3.4.

3.7.3 Analog or Continuous Signal Interfaces

The Supplier shall provide current loop isolators where a continuous signal in the Supplier's system is required to be monitored by the Buyer's control system.

3.7.4 Surge Protection

The Supplier shall provide surge protectors for solid-state equipment, if not inherent in the equipment design, to prevent damage from the effect of lightning strikes or other electrical transients.

3.7.5 Arc Suppression

The Supplier shall provide and install a suitable arc suppression device or kickback diode across switched loads unless the switching component includes inherent arc suppression. Kickback diodes shall be supplied and installed on all inductive DC loads.

3.7.6 Emergency Stop and Reset

All machinery Equipment Control Panels shall be provided with an emergency stop (E-stop) independent of software or electronic logic. Where physical injury is credible, E-stops will be provided local to the machine. In addition, where mechanical handling equipment is controlled remotely, E-stops shall be provided at such control points. In order to prevent a subsequent restart, while the dangerous condition exists, the emergency stop circuit shall remain in the shutdown state until the circuitry is reset.

For machinery equipment which has no communication with the Buyer's control system, the E-Stop circuits shall provide a local indication of the status of the E-Stop when activated. Local indication of E-Stop status may be provided by either a local indicating light and/or a physically depressed E-Stop button/switch.

Machinery equipment in communication with the Buyer's control system shall provide status of all E-Stop circuits which shall be individually monitored in the Buyer's control system. This will be achieved by additional contacts on the switch wired directly to the Buyer's control system. Contacts wired from motor control relays will not be accepted.

3.7.7 Conduit and cable

Exposed conduit for process power and instrumentation shall be rigid, galvanized steel (RGS) and supported with corrosive resistant hardware. As a minimum, single pair instrumentation cable shall be 18 AWG, multiple pair instrumentation cable shall be 20 AWG, and control and instrument power circuits (120 VAC/125 VDC) shall be 14 AWG.

3.7.7.3 Separation

AC power shall be routed through separate raceways or separated with a divider from 24 V DC discrete and analog instrument signals within enclosures. Power and signal cabling shall not be run in parallel, except in separate raceways or wireways, and should only cross at a 90-degree angle. This includes wiring to door mounted instruments contained in spiral wrap. A minimum of 1/4" separation shall be maintained between power & instrumentation / signal wiring.

Internal enclosure wiring shall be neatly dressed in slotted non-metallic wireways. The wireway shall be securely fastened to the enclosure back-panel. Non-metallic wireways shall be provided on the opposite sides of the field terminations to be used by the Buyer. Adequate space shall be provided around terminal blocks to allow the Buyer to install, route and terminate cables. The field side wireway shall be designed for multi-core field cables with a minimum conductor size of #14 AWG.

Circuits of different voltages (service level) shall be terminated on physically separate terminal strips and clearly labeled to show the circuit voltage. Terminal blocks shall be segregated according to signal type. If safety instrument system components are installed in an enclosure, the wiring shall be clearly identified and segregated from non-safety instrumentation systems.

Power supplies will be provided from separate sources for safety and non-safety instrument use. The Supplier shall design and provide a physically and electrically separate power supply distribution and circuitry, as required, for safety instrumentation systems and non-safety instrumentation systems in accordance with IEEE 384.

Instrumentation cables shall be terminated in separate junction boxes from the power and control cables.

3.7.8 Wire and Cable Markers

Where one end of the wire is provided by the original equipment manufacturer, connected to the component, in a pigtail configuration, and identifiable by other means such as color coding, only the end of the pigtail that is provided un-terminated by the original equipment manufacturer is required to be identified by the mean described in this section.

All Supplier provided wiring shall be identified at each end with a numbering system that is cross-referenced on all appropriate drawings. The wire-numbering scheme shall be proposed by the Supplier with the Buyer's concurrence. Ferrules or wire markers shall be indelibly and clearly marked in black on white plastic, heat shrinkable sleeves. Open markers or "C" type sleeves that can be applied after a conductor is terminated will not be accepted. Junction box (JB) terminals shall have adequate space between them and the JB internal walls so connected cables and individual wire numbers can be easily read without disturbing the wiring within the JBs.

All cables provided by the Supplier shall be clearly identified with a heat shrink type label.

3.8 Process Connections, Tubing and Instrument Mounting

3.8.1 Instrument Process Connections

The preferred orientation of process connections in horizontal piping is shown in Appendix A. The purpose, for all pipe runs for instrumentation use, is to avoid gas pockets in liquid and vapor sensing lines and to avoid liquid pockets in gas sensing lines. Sensing lines for gas measurements shall slope downward toward the process at least 1/4" per foot. Sensing lines for liquid shall slope downward toward the instrument at least 1/4" per foot. Measurement of pressure or flow in steam lines or condensable vapor lines shall be provided with condensate pots to ensure known liquid fill level in sensing lines.

Piping specifications are generally as required in the process piping section of the primary equipment specification. Pressure measurement connections shall be ¾ inch except where the process piping is ½ inch or less. If the process piping is ½ inch or less, the instrument connection shall be ½ inch. Instruments mounted in-line or tanks shall be installed per manufacturer's requirements. Welded process connections shall be socket or butt welded per the requirements of the piping specification in the primary equipment specification.

Generally provide connections on piping and vessels for instruments in accordance with the following:

Type of Measurement	Screwed	Socket Welded	Flanged
Analyzer	¾"	-	1 ½"
Flow			
Orifice Tap	½"	¾"	2"
Flow Tube Tap	¾"	¾"	2"
Level			
Differential Type			
Standard	½"	¾"	2"
Flange Mounted	-	-	3"
Ball Floated			
External Cage	1 ½"	1 ½"	1 ½"
Vessel Mounted	-	-	4"
Capacitance	1"	1"	3"
Radar	-	-	6"
Ultrasonic	1"	1"	3"
Purged Tube	½"	½"	6"
Bridle (Standpipe)	3"	3"	3"
Pressure			
Piping	¾"	¾"	-
Vessels	¾"	-	1 ½"
With Seals	-	-	3"
Temperature			
In Piping	1"	1"	1 ½"
In Vessels/Tanks	-	-	1 ½"

3.8.2 Instrument Isolation Valves at the Instrument

To allow isolation of pressure sensing instruments, each pressure-sensing instrument shall have a shutoff valve, or a 2-valve manifold for transmitters, that is close to the instrument and is readily accessible. The Supplier shall, however, provide bleed valves on direct connected pressure gauges and pressure switches. Individual isolation or bleed valves shall be Swagelok instrument ball valve series 40 or Buyer approved equal with either screwed or compression end fittings as appropriate. All remote mounted pressure instruments shall have an integral manifold (block and bleed). All differential pressure instruments shall have integral five valve manifolds. All instrument valve manifolds shall be of 316 SS construction with Viton O-ring seals unless otherwise specified in the primary equipment specification. Other materials shall be required depending on ambient radiation conditions. The Supplier shall propose alternate materials for instruments as appropriate for the Buyer's review and concurrence.

3.8.3 Thermowells

Thermowells shall be provided for each temperature sensor. Thermowells shall withstand two times the maximum system pressure where installed. Wake frequency calculation shall be performed using ASME PTC 19.3 to ensure that the velocity-induced frequency is not more than 80 percent of the critical frequency during all modes of operation. Protective tubes in lieu of thermowells are acceptable for HVAC air duct applications.

All thermowells shall have sufficient extension to preclude interference with process pipe or vessel lagging (insulation).

The following are standard thermowell length, insertion (U) length and Lagging (T) length proposed for the project:

A. Threaded Thermowells

Line Size	"U" Length	Stem Length	Remarks
≤ 2"	2 1/2"	4"	Line swage or elbolet installation
3" & 4"	4 1/2"	6"	Elbolet or latrolet installation
4"	2 1/2"	4"	
6 & 8"	4 1/2"	6"	
10 & 12"	7 1/2"	9"	
≥14"	10 1/2"	12"	

Insulation Thickness	"T" Length	Remarks
2" & less	None	
3"	3 1/2"	
4"	4 1/2"	
5"	5 1/2"	
6"	6 1/2"	

B. Flanged Thermowells

Line Size	"U" Length	Stem Length	Insulation Thickness
3"			See note below
4"			See note below
6"		9"	See note below
			See note below
		12"	See note below

Note: Approximately 6" clearance between the top of line and the top of well flange face available for insulation.

Thermowells shall not be installed in the minimum straight run of pipe, upstream or downstream of a flow element.

3.8.4 Sensing Tubing

Sensing lines shall be kept as short as possible and shall have a continuous slope to promote them being kept free of liquid, as appropriate. Slope shall be 1/4 inch per foot minimum. Slope instrument impulse lines toward the process to prevent the accumulation of condensable liquid in gas lines.

Tubing runs shall be properly supported in tube clamps or channel and protected from mechanical loads. Expansion bends shall be provided if necessary to allow for movement of supporting structures or change of length due to temperature caused expansion or contraction. Tubing runs shall not prevent access to equipment or instruments for operation or maintenance. Tubing bends will be provided to allow easy removal of instruments.

Use air or liquid purges, chemical seals, or other suitable means to ensure low maintenance, trouble-free operation for instruments in particulate and/or chemical service. Purges shall be provided such that purge velocity is greater than process velocity. Process leads filled with a special liquid shall not be used.

Tubing runs that can contain high temperature fluids shall be covered with insulation or screens where necessary for personnel protection. Prefabricated heat-tracing bundle is preferred for condensing gasses.

3.8.5 Pneumatic Supply and Signal Lines

Pneumatic piping and tubing shall be grouped and supported in parallel runs. Unless otherwise specified all pneumatic tubing shall be seamless 316 SS as a minimum. To facilitate installation by the Buyer at site, all incoming/outgoing air connections shall terminate at clearly identified bulkhead fittings. Instrument tubing shall be identified at the bulkhead terminal connection with a suitable tag indicating the instrument tag number or an identifier used on the Supplier's piping/tubing diagrams.

Where the Supplier requires instrument air, the Buyer's instrument air supply headers will be connected to the Supplier's package at one location. The Supplier shall provide filtration and pressure reduction as necessary for air utilization. Where pressure reduction is necessary, The Supplier shall provide two pressure regulators and two filters piped in parallel with the necessary valving to allow removal and maintenance of either regulator or either filter without impacting operation of the supplied equipment.

Provide isolation valves and calibration connections on impulse and pneumatic signal lines to permit in-place calibration. When two or more instruments or accessories are connected through fittings to the same bulkhead connection, needle type shutoff valves shall be located at each instrument or accessory.

Where pressure switches are provided as secondary devices for alarm initiation, a plugged tee shall be installed between the isolating valve and the switch to facilitate testing.

3.8.8 Instrument Location and Mounting

Instrument mounting locations shall be selected with consideration of both function operation and accessibility requirements for maintenance. Instrumentation should not be mounted on vibrating equipment or light duty support. Instruments shall not be mounted on handrails or safety railings. Instrument mounting bolting and hardware shall be 316 SS. Mounting brackets and stands for SS instrumentation shall be qualified to the seismic requirements specified by the primary equipment specification.

3.8.8.1 Operability Requirements

The location of pressure sensing instruments shall be selected to minimize the need for purged leads and special seals to achieve satisfactory operation.

3.8.8.2 Accessibility Requirements

Each instrument shall be installed so as to allow adequate safe access for both operation and maintenance.

4 Materials

4.1 General

Selection of material shall be based on fluid properties, environmental conditions, or as specified on the primary equipment specification and/or material requisition, to which this specification is attached.

4.1.1 Instrument Impulse Tubing and Tube Fitting

Instrument impulse lines shall generally be 3/8 inch OD x 0.035 inch wall, seamless, annealed, ASTM A269, Grade TP316 SS with a carbon content of less than 0.03% and an RB80 hardness. Instrument tubing shall be marked in accordance with the ASTM material specification, which shall indicate as a minimum, the type and grade of material.

All compression fittings shall be machined or forged from 316 SS with carbon content less than 0.03% or 316L SS. Other tube fitting materials may be used (with Buyer's approval) as required for the service applications and the environmental conditions. All tube compression fittings shall be of the two ferrule, flareless design, gageable, and maintain a leak tight connection after 20 remakes (minimum) per fitting manufacturer's remake instructions on any recommended tubing. All components of the fitting shall carry the manufacturer's name and trademark. The Supplier shall only supply tube fittings from one product line of a single manufacturer. Materials for flareless compression type stainless steel tube fittings shall be ASTM A182 for forgings and ASTM A276 for parts machined from bar stock.

Tubing within radiation areas such as process cells or canyons shall be fusion welded and fabricated from 316L SS. Any tubing fittings within these process cells or canyons shall be butt welded tube fittings fabricated from 316L SS.

Manufacturers of tube and fittings shall also have tubing and fittings available in 316 stainless steel, Alloy 400, Alloy 20, Alloy C-276, Alloy 600, titanium, and carbon steel.

4.1.2 Instrument Manifold Valves

Integral 2-valve manifolds shall be supplied with pressure transmitters. Integral 5-valve manifolds shall be supplied with differential pressure transmitters. The manifolds shall be fabricated of 316 SS. These manifolds shall be manufactured by Anderson Greenwood or Buyer approved equal.

4.1.3 Enclosures, Panels, Cabinets, and Racks

In areas where radioactive contamination is likely, only stainless steel enclosures, panels, and cabinets shall be used.

The Rack structural components and all mounting material shall be constructed entirely with stainless steel. This includes bolts, nuts, washers, screws, retainer springs, and clips.

4.2 Prohibited Materials

Mercury containing instruments or devices such as mercury wetted switch contacts; mercury thermometers or capillary systems using mercury shall not be used.

4.3 Special Requirements

Where a conduit enters a junction box, a bushing shall be provided to protect the wire insulation from damage due to sharp metal edges.

4.4 Painting Requirements

In general, instrument manufacturer's standard painting color and finish shall apply. However, Supplier shall also follow the project Shop applied special protective coating as required by the parent specification.

4.5 Storage of Special Materials

The Supplier shall cover or plug all openings on equipment, tubes, pipes, and instruments prior to shipment and/or for storage.

5 Fabrication

Platforms, ladders, or other means of access shall be provided for instrumentation or components that require maintenance or adjustment which are not accessible from a floor or a major structure.

8 Identification

8.1 Nameplate

Each instrument shall have nameplate information that includes following:

Applicable to ALL Instrumentation

- Manufacturer's Name
- Manufacturer's model and serial number
- Buyer's Purchase Order No.
- Buyer's Item No.
- Buyer's Tag Number

Applicable to PROCESS Instrumentation

- Nominal Pipe size, inches
- Body material
- Size
- Minimum and Maximum flowrate
- Meter Factor
- Pressure and Temperature rating
- Flow direction arrow and/or words IN and OUT on the piping connections

Applicable to ELECTRONIC Components

- Power rating
- Electrical Area Classification
- Approvals and Listings per NEC

Where the combination of manufacturer's standard nameplate and instrument body stampings are unable to accommodate all of the required and applicable information, a separate stainless steel nameplate shall be provided to include the Buyer's tag number, PO number, and all of the applicable missing information. This separate stainless steel nameplate shall have the information impressed, stamped, or etched directly on the stainless steel surface. The nameplate, where physically possible, shall be secured to the body of the instrument by corrosion resistant screws tapped into a low stress area of the assembly, so the structural integrity and functional capability of the assembly are not impaired. If it is not physically possible to secure the nameplate to the body of the instrument, then the nameplate shall be attached using a stainless steel wire.

8.2 Panel Mounted Instrument Nameplate

In addition to the nameplate requirements for instruments, each panel mounted instrument shall be identified by tag number (Buyer provided tag number) engraved as specified in section 3.6.8. Letter shall be a minimum of 1/8 inch in height. Nameplates shall be attached as specified in section 3.6.8.

10 Training

Then Supplier shall include training courses and durations as required to train the Buyer's engineering, maintenance and operation personnel in system overview, system architecture, hardware maintenance, software engineering, software maintenance, operation, troubleshooting, etc. for the supplied instrumentation system.

11 Documentation and Submittals

Refer to Part 2, Drawings and Data Requirements of the Material Requisition to which this specification is attached and the following for specific requirement of each instrument.

11.1 Instrument Tagging

Instrument tag numbers will be assigned and provided by the Buyer to the Supplier. The Supplier shall incorporate these tag numbers into the design documents and shall comply with instrument identification requirements.

11.2 Drawings and Data

11.2.1 Instrument Data Sheets

Process instrument data sheet forms will be supplied for some equipment by the Buyer and shall be completed by the Supplier for field mounted process instrumentation.

11.2.2 Instrument List

The Supplier shall provide an equipment instrument list, in MS Access format, which lists each instrument and is arranged in numerical order. The fields required are as follows:

- Instrument tag number
- Supplier's referenced tag number if applicable
- Service description
- Instrument type
- Signal type
- P&ID number
- Data sheet number
- Location drawing number
- Instrument installation details
- Manufacturer name
- Model number
- Calibration range of instrument
- Set point
- Wiring diagram number
- Schematic drawing number
- Device address of serial communication link data
- I/O address of serial communication link data
- Shipped loose

In addition, where applicable, a separate list of instruments designated as Safety Significant shall be maintained and provided. See Section 3.1.14 for detailed information.

The list shall include:

The performance specifications for normal operation and under conditions existing during and following accidents.

The load, pressure, voltage, frequency, and other characteristics, as appropriate, for which the performance specified can be ensured.

11.2.3 Panel, Cabinet, Enclosure Outline and Dimensional Drawings

Outline and dimensional drawings shall show the size and location of electrical, pneumatic and service connections and information necessary to locate and mount the equipment, if it is to be mounted by the Buyer.

A dimensional layout drawing shall show the location of electrical and control equipment. This drawing will include the dimensioned outline of the required electrical working space boundary around electrical and control enclosures. Electrical and control equipment enclosures shall be installed so that they comply with NFPA 70-1999, section 110-26 and sections 110-32 through 110-34. Include the working space boundary required for all outward facing (facing out from the skid) electrical and control enclosures.

The outline and dimensional drawings shall also include the enclosure weights and approximate location of the enclosure center of gravity with all instruments and components installed. This drawing or a separate drawing shall include dimensional and material information for the enclosure base, including bolt location and size for permanent attachment of the enclosure(s) to the building structure.

Outline and dimensional drawings shall be provided for all instruments shipped loose for Buyer's installation. The drawing shall include the instrument tag number.

11.2.4 Installation Details

Deleted

11.2.5 Wiring Diagrams

Point to point wiring diagrams provided by the Supplier shall include, but not be limited to the following features:

- Identify all devices with the Buyer's tag numbers, where applicable
- Identify grounding method for incoming cable shields
- Be relative to the equipment or panel terminals
- Show devices and their terminals in relative location
- Include contact developments for control switches, pushbuttons and relays.

11.2.6 Electrical Schematics

Schematics shall be provided for all motor controls. Motor Control Center interfaces with Supplier's provided motors shall be clearly shown with all wiring interfaces shown in schematic form.

11.2.7 Instrument Loop Diagrams

Loop diagrams depicting the wiring between components of electronic analog loops and discrete (on/off) loops shall be provided. These drawings shall contain, as a minimum all the information required by ISA S5.4 Figure 3 with notes and drawing references. The interface between Supplier's and Buyer's equipment, wiring and instruments shall be shown in detail, including terminal and wire identification. Electronic loop diagrams shall show Supplier's grounding and shielding provisions.

In the case of bussed network instruments, network segment drawings shall be provided in lieu of loop diagrams.

11.2.8 Pneumatic Piping or Interconnection Diagram

Diagrams depicting the signal tubing and air source interconnections between pneumatic devices shall be provided. The interface between the Supplier's and the Buyer's devices and air source shall be shown in detail.

11.2.9 Control Diagrams

Control diagrams consisting of schematics showing the equipment functional controls shall be provided for the Buyer's review. These drawings shall show in detail all the control circuits and the their relationship with other components within the Supplier's package and the interface between the Buyer and Supplier provided controls. If the Buyer is to implement the Supplier's control on a Buyer provided control system, the controls necessary to operate the Supplier's equipment will be based upon these drawings.

11.2.10 Software Documents

Documentation as defined within this specification shall be provided. These will be used for the design development, quality assurance, verification review, approval, and validation testing of all the software supplied by the Supplier and/or its subcontractor. They shall be in accordance with all the requirements depicted in this specification and industrial standards.

11.2.11 Cable Block Diagrams

Cable Block diagrams shall identify the relationship of all cabling with cable numbers that interconnect between panels, junction boxes and components. These diagrams shall identify the size and number of conductors in each cable. Preliminary versions of these diagrams shall be made available for 50% design review. The formal submittal shall be submitted prior to fabrication. Cables that will be provided and installed by the Buyer will be identified on the cable block diagram. The Supplier shall identify at the 50% design review the equipment breakdown for shipping that identifies those cables that need disconnecting for shipment. The Buyer will provide tag numbers for all junction boxes and panels that the Buyer has to terminate to.

11.2.12 Manufacturer's Technical Literature

The Supplier shall provide manufacturer's technical literature for all technical components and instrumentation provided within the Supplier's package.

11.3 Procedures

11.3.1 Site Storage and Handling Procedure

The Supplier shall provide site storage and handling procedures in accordance with Part 2 of the Material Requisition to which this specification is attached. Procedures shall be issued to the Buyer nine-months prior to shipment. One copy of the procedure shall be attached to each shipping container. The Supplier is responsible for stipulating any site storage requirements necessary to maintain any implied or stated equipment warranty including shelf life for spare parts. Refer to Engineering Specifications for Packaging, Handling, and Storage Requirements, 24590-WTP-3PS-G000-T0003 for additional requirements.

11.3.2 Functional Test Procedure

The Supplier shall submit equipment functional test procedures that will be used to demonstrate to the Buyer's satisfaction that the equipment will function in accordance with the specified requirements. Procedures shall be submitted for the Buyer's review in accordance with the Part 2 of the Material Requisition to which this specification is attached. Procedures shall be submitted at

least one month prior to scheduled performance of the functional demonstration to be witnessed by the Buyer's engineer(s). Scope of these tests shall be agreed to between the Buyer and Supplier via review of the proposed test procedure.

The functional test procedure shall include:

- Requirements for maintaining records of functional tests
- Description of method used to track status of testing
- Requirements for inspection prior to testing to determine test readiness
- Procedures for documenting failures and errors encountered
- Procedures for documenting agreed test modifications or procedure corrections deemed necessary to resolve a test finding
- Method of documenting final resolution of test anomalies
- Acceptance criteria

11.3.3 Operating, Startup and Shutdown Procedures

The Supplier shall provide procedures in hard copy as well as in electronic describing the method of starting, operating and shutting down the equipment package.

11.4 Calculations

Calculations shall be submitted for the Buyer's verification as indicated in Part 2, Drawings and Data Requirements, in the Material Requisition to which this specification is attached. Calculations shall be orderly, complete, and sufficiently clear to permit verification.

The body of the calculation shall include:

- A concise statement of the purpose of the calculation
- Input data, applicable criteria, and stated assumptions
- A list of references used, including drawings, codes, standards, and computer programs, indicate the version or issue date
- A discussion of the rationale used for design assumption basis
- Equations used for all computations
- Numerical calculations, including identification of units used
- A concise statement addressing the calculation results and/or recommendations
- A table of contents for complex calculations.

11.4.1 Electrical Load

The Supplier shall submit calculations showing the electrical power consumption, both peak and continuous for each power voltage level required by the Supplier to operate all equipment and instruments provided.

11.4.2 Heat Loads

The Supplier shall submit a list of all calculated and estimated control panel/cabinet heat loads.

11.4.3 Instrument and Service Air Consumption

The Supplier shall submit calculations showing the instrument and service air consumption both peak and continuous. The submittal shall identify instrument and service air consumption separately.

11.4.4 Sizing Calculations

The Supplier shall provide, for review and approval, the sizing calculations used to size modulating control valves per ISA S75.01, head producing flow elements, and pressure relieving devices per API RP 520 PT I.

11.5 Manuals

Operation and maintenance (O&M) manuals in both hard copy and electronic form shall be provided for the equipment package. The O&M manual shall include startup, operating and shutdown procedures as well as periodic and preventative maintenance procedures. The requirements for the package O&M manuals are contained in the Material Requisition.

11.6 Schedules

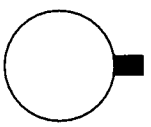
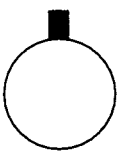
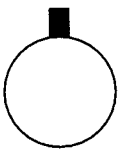
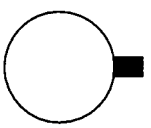
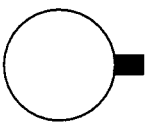
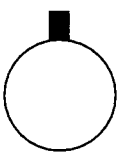
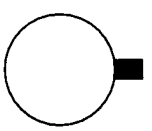
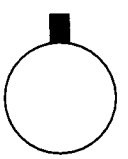
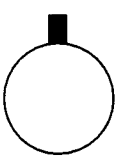
11.6.1 Material Schedule

A schedule of material listing all instruments and devices to be located on or supplied with the equipment package shall be provided. The schedule or bill of material shall contain the Buyer's tag numbers where applicable, manufacturer, model number, part number, description, quantity and brief material description.

11.6.2 Spare Parts List

The Supplier shall submit a recommended spare parts list covering all items within the Supplier's scope. The spare parts recommendation shall be based upon Supplier's experience with component failure, maintenance requirements, environmental conditions, as well as consideration of the total quantities of each device supplied by the Supplier. The Supplier's recommendation shall include both construction/commissioning and operating spares. Construction/commissioning spare parts are those parts to be held for use during construction, testing, and commissioning. Operating spare parts are those to be held for the first year of operation of the plant.

APPENDIX A-1 Sensing Line Process Connection Orientation

MEASURED VARIABLE	LINE FLUID: LIQUID	LINE FLUID: STEAM VAPOR OR SLURRY	LINE FLUID: AIR OR GAS
FLOW			
PRESSURE OR DIFFERENTIAL PRESSURE			
ANALYSIS	LIQUID: 	STEAM, VAPOR, AIR, OR GAS: 	
TEMPERATURE	ALL FLUIDS: NOTE: THIS ORIENTATION FOR TEMPERATURE INSTRUMENTS WILL NOT APPLY IF THE PIPE DIAMETER IS SMALL AND REQUIRES A TEE OR ELBOW TO BE USED. 	**INSTRUMENTATION: MEASURED VARIABLE TAPPING POINTS ORIENTATION**	

ATTACHMENT EKP0

LAW TCO CUSTOMIZED EKP0

Per 24590-WTP-3PS-EKP0-T0001, Rev. 5
ENGINEERING SPECIFICATION FOR ELECTRICAL REQUIREMENTS FOR PACKAGE SYSTEMS

This attachment defines the requirements for electrical equipment, materials and installation associated with the Low Activity Waste Thermal Catalytic Oxidizer/Reducer (LAW TCO), which are provided as manufacturer standard or custom design and pre-assembled units, in accordance with the National Codes and Industry Standards. For continuity, the section numbers from the specification noted above have been retained.

1.7 Work by Others

1.7.3 Power Supply

The Buyer will provide normal power and/or Uninterruptible Power Supply (UPS) for the Supplier's instruments unless otherwise specified on the parent specification. Each source will be delivered at 120 VAC, single phase, 60 Hz, grounded system. 480 VAC, 3 phase, 60 Hz power will be provided as required for motors. All other voltages required by the Supplier shall be derived from the Buyer provided 120 VAC or 480 VAC.

2.0 Criteria for Acceptability of Electrical Equipment

- All electrical equipment for facility and equipment wiring, as defined by the National Electrical Code NFPA 70-1999, shall be Approved. Approval will be in accordance with Article 90-4, "Enforcements", Article 90-7, "Examination of Equipment for Safety," and Article 110-3, "Examination, Identification, Installation, and Use of Equipment."
- Approved means "Acceptable to the Authority Having Jurisdiction" (AHJ), as defined in Article 100 of NFPA 70-1999. Only the WTP Electrical AHJ can provide the approval.
- "Equipment" is defined by the NFPA 70 as, "A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as a part of, or in connection with an electrical installation". As used here, the entire mechanical assembly is not considered an electrical installation, only the electrical and/or electronic components, and the interconnecting wiring.
- Listing and labeling by an OSHA Nationally Recognized Testing Laboratory (NRTL) is the primary means (Method 1 below) of obtaining WTP AHJ approval for electrical equipment, devices and materials.
- All Control Panels shall be UL labeled by a certified UL 508A shop.
- Electrical Equipment that is installed on (standard or custom fabricated) Mechanical Equipment shall comply with the requirements stated above.
- Electrical Equipment, that is part of Mechanical Packaged Equipment, where the entire mechanical skid is field-evaluated and Labeled at the factory by an NRTL is an alternate method of obtaining WTP AHJ approval.

2.1 Method 1 (Primary): Listed, Labeled or Certified (i.e. UL508A)

2.1.1 The WTP AHJ shall approve and accept electrical equipment without additional examination if it is Listed, Labeled, or Certified by a US NRTL, as recognized by OSHA under 29 CFR 1910-Subpart S and is acceptable for the application, environment and other requirements of NEC Article 110. For a listing of and Typical Registered Certification Marks of US NRTL's recognized by OSHA go to http://www.osha.gov/dts/otpca/nrtl/nrtlmrk.html.

2.2 Method 2 (Alternate): Field Evaluation by a NRTL

2.2.1 Electrical equipment that is part of an overall electrical or mechanical assembly having a NRTL safety evaluation or a field evaluation, which states the equipment has been accepted or otherwise deemed safe by the NRTL recognized by OSHA under 29 CFR 1910-Subpart S, using US standards, will be evaluated by the WTP AHJ for acceptability. If found acceptable no further examination of the equipment is required. The Supplier shall submit the NRTL safety/field evaluation report, or evidence of compliant labeling/listing of electrical equipment including UL 508A certification/labeling of control panels for the Buyer's Electrical AHJ review and approval prior to having the equipment released for shipment.

2.2.2 The Supplier shall submit all field evaluation reports completed by an OSHA recognized NRTL to the Buyer for review and approval by the AHJ. These field evaluation reports shall show compliance to the applicable USA Electrical Standard(s) recognized by OSHA that are listed on the OSHA website http://www.osha.gov/dts/otpca/nrtl/allstds.html. The NRTL Label will be as shown on the OSHA website with whatever additional markings that are necessary to indicate acceptability for use in the USA http://www.osha.gov/dts/otpca/nrtl/nrtlmrk.html.

2.2.3 The Supplier shall submit a Certificate of Compliance (C of C) document for review and approval by the AHJ that lists the USA Electrical Standard(s) that each electrical material or equipment is evaluated to for it's NRTL Listing. Only those standards that are listed on the OSHA website http://www.osha.gov/dts/otpca/nrtl/allstds.html are acceptable to the AHJ. The certification shall confirm that the NRTL Label for each electrical component will be as shown on the OSHA website including the additional markings required to indicate acceptability for use in the USA http://www.osha.gov/dts/otpca/nrtl/nrtlmrk.html.

2.3 If the Supplier is unable to meet the criteria in Method 1 or Method 2, the Supplier shall request in writing a variance by the Buyer's Electrical AHJ.

3.0 Applicable Documents

3.1 Codes and Standards

The equipment and installation shall conform to the applicable sections of the following National Codes and Industry Standards:

29 CFR 1910,	Occupational Safety and Health Standards, Electrical Sub part S
NFPA 70-1999	National Electric Code (NEC)
ANSI C80.1	Rigid Steel Conduit – Zinc Coated (GRC)
IEEE 383-1974	Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations *(Only Section 2.5 - Flame Tests, shall be applicable.)*
IEEE 515	Standard for Testing, Design, Installation and Maintenance of Electric Resistance Heat Tracing for Industrial Applications

IEEE 1202	Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies
NEMA ICS-1	Industrial Control and Systems General Requirements
NEMA ICS 6	Enclosures for Industrial Controls and Systems
NEMA RN1	Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metallic Conduit
UL 6	Standard for Safety Electrical Rigid Metal Conduit - Steel
UL 6A	Standard for Safety for Electrical Rigid Metal Conduit - Aluminum, Red Brass, and Stainless Steel
UL 13	Standard for Power-Limited Circuit Cables
UL 2250	Standard for Safety Instrumentation Tray Cable
UL 44	Standard for Safety Thermoset Insulated Wires and Cables
UL 360	Standard for Safety Liquid Tight Flexible Steel Conduit
UL 508	Standard for Safety Industrial Control Equipment (17th Edition)
UL 514B	Standard for Safety Conduit, Tubing, and Cable Fittings
UL 1581	Safety Reference Standard for Electrical Wires, Cables, and Flexible Cords
UL 1666	Safety Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts
NEMA WC 55	Instrumentation Cables and Thermocouple Wire - ICEA S-82-552
NEMA WC 57	Standard for Control Cables - ICEA S-73-532
NEMA WC 70	Non-shielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy - ICEA S-95-658
NFPA 262-2002	Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces

3.2 WTP Project Specifications

24590-WTP-3PS-JQ00-T0004 Management of Supplier Software

3.3 Nuclear Standards for Equipment Classified as Q

In addition to the above, when required for complying with the nuclear standards for SC and SS equipment or components, the Supplier shall follow the version as called out in this specification.

Deleted	
IEEE 383-1974	Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations
Deleted	
IEEE 1023-1988	Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations
ASME NQA-1	Quality Assurance Program Requirements for Nuclear Facilities -2000 (not applicable to this LAW TCO procurement)

3.4 Reference Documents/Drawings

Specification	Title
24590-WTP-3PS-MUMI-T0001 *(As applicable)*	Engineering Specification for Medium Voltage Induction Motors
24590-WTP-3PS-MUMI-T0002	Engineering Specification for Low Voltage Induction Motors
24590-WTP-3PS-EVV1-T0001 *(As applicable)*	Engineering Specification for Low Voltage Adjustable Speed Drives
Addendum JQ07	Engineering Addendum for Instrumentation for Package Systems
24590-WTP-3PS-JQ06-T0005 *(As applicable)*	Engineering Specification for Environmental Qualification of Control and Electrical Systems and Components

4.0 Design Requirements

•4.1 General

4.1.1 The Buyer will provide electrical service at the following voltages for Supplier's system, as applicable.

4.1.1.1 Medium voltage:

••13.8 kV, 60 Hz, 3 phase, 3 wire, low resistance grounded neutral, with the ground fault current limited to 2000 amps.

4.1.1.2 Low voltage:

••480 V, 60 Hz, 3 phase, 3 wire, solidly grounded

••208 V / 120 V, 60 Hz, 3 phase, 4 wire, solidly grounded

••120 V AC, 60 Hz, 1 phase UPS

5.0 Construction

•5.1 Motor Starters and Control

Unless otherwise stated in the primary specification, motor starters for 460 V, 3 phase motors ½ Hp and larger will be provided by the Buyer and installed remotely from the packaged unit. However, special consideration will be given to packages in which the provision of motor starters by the Supplier may be beneficial. When furnished with the packaged unit, the starters shall have the following configuration. Starter units with electronic overload shall only be used for Non-Safety applications. Electromechanical starters can be furnished for both Non-Safety and Safety applications.

5.1.1 Motor Starters with Electronic Overload

5.1.1.1 Motor starters with electronic overload protection can be supplied for SSCs classified as RRC, or Non-Safety, (i.e. CM quality level). (Note: Siemen # Simocode 3UF50 protection device is used in the Buyer's MCCs and is preferred.)

5.1.1.2 Combination starters shall be equipped with a pad-lockable disconnecting means, a magnetic contactor, a dedicated control power transformer (CPT), and a motor overload protection device.

5.1.1.3 Control panels with multiple starters may have a common disconnecting means and CPT.

5.1.1.4 When the motor control is designed for local and remote modes of operation, local controls shall be operable from the starter or control panel door, and remote control signals will be provided through the Buyer's communication network.

5.1.1.5 When furnished, the following local controls shall be available at the starter or control panel door:

1. Start/Stop function (pushbuttons or selector switch)
2. Local/remote selector switch (when local/remote mode is specified)
3. Trip reset
4. Indicating LED for Status (Green - motor stopped, Red - motor running, Amber - motor tripped)

5.1.1.6 When furnished, the electronic overload protection shall include the following features available for remote mode operation through the Buyer's communication network:

1. Start/Stop capability
2. Trip reset
3. Status indication (motor stopped, run and tripped)
4. Current monitoring of all three phases
5. Programmable parameters for the protective functions
6. Diagnostic information
7. Control voltage status
8. Other functions if available in the relay
9. Communication port to interface with the Buyer's Profibus communication network

5.1.2 Motor Starters with Thermal Overload Relay

5.1.2.1 Motor starters with thermal overload relays shall be supplied for SSCs classified as SC or SS, (i.e. QL-1 or QL-2 quality level). The Supplier may also provide thermal overload relays for SSCs classified as Non-Safety upon the Buyer's approval.

5.1.2.2 Each motor starter unit shall consist of a pad-lockable disconnecting means, a dedicated control power transformer (CPT), and a magnetic contactor with thermal overload relay including, but not limited to the following features:

1. Start/Stop function (pushbuttons)
2. Local/remote selector switch (when local/remote mode is specified)
3. Thermal overload relay (Class 20)
4. Trip Reset
5. Indicating LED for Status (Green - motor stopped, Red - motor running, Amber - motor tripped)
6. Two sets of contacts for the remote position of the selector switch shall be wired to terminal blocks for the Buyer's use
7. Spare main contactor auxiliary dry contacts (1 NO, 1 NC minimum) wired to terminal blocks for the Buyer's use

8. Auxiliary contact (1 NC) of overload relay shall be wired to terminal blocks for the Buyer's use.

9. Terminal blocks with approximately 20% spare terminals.

5.1.3 Space Heater

Where motors are supplied with space heaters, the CPT shall be sized to be the power source, and a dedicated control contact for the heater shall be provided and wired.

5.1.4 Local Disconnects

Where required, local disconnecting means shall be provided in accordance with section 430-102 and 430-113 of NFPA 70-1999.

5.1.5 Emergency Stop and Reset

Control panel for operating machinery shall be provided with an emergency stop (E-stop). Local emergency stop push buttons shall be provided on equipment where physical injury is credible. The emergency stop push button shall be readily identifiable and when depressed, shall remain depressed until it is manually reset. A spare contact shall be available for the Buyer's use. Emergency stop shall be hard-wired to the motor controller.

5.3 Power Protection and Disconnecting Means

5.3.1 Disconnecting means

Enclosures with incoming power supply shall have a manually actuated disconnecting means mounted on or close to the enclosure in an easily accessible location.

5.3.2 Overcurrent Protection

Devices in panels utilizing power shall have suitable overcurrent protection. Power shall not be "daisy chained" from device to device; however, bridge or comb jumpers may be used on the supply side of the circuit breaker or a fuse block.

5.5 Cables and Wiring

5.5.1 The Supplier shall mount, connect and wire each instrument or control device such that adjustment, maintenance, removal and replacement may be accomplished in a safe manner without interruption of service to adjacent but non-associated equipment, and without placing undue stress on installed wiring or devices. Accommodations for strain relief shall be made when routing wire to hinged enclosure doors and shall be wrapped with spiral wire wrap.

5.5.2 Other than the special cables furnished by the Supplier, cables shall be in accordance with the following:

a) Low voltage power and control cables shall be stranded copper, 600 V type XHHW-2 or Buyer-approved equivalent.

b) Internal wiring shall be stranded copper, flame-retardant, 600 V, synthetic heat resistant (SIS), or machine tool wire (MTW), or high-flexible thermoset.

c) The minimum size of conductor will be as follows (not including cabling integral to components):

Duty	External Conductor Size (AWG)	Internal Wiring in enclosures Size (AWG)
Power and Lighting (480 V and below only)	12	14

Current Transformer Wiring	10	10
Control Circuits (120 V AC / 125 V DC) and Instrument power circuits	14	16
~~Instrumentation - Single pair or triad cable~~	~~16~~	~~18~~
~~Instrumentation - Multi pair or triad cable~~	~~18~~	~~18~~
~~Communication cable (Fieldbus, Profibus)~~	~~18-22~~	~~18-22~~

~~d) Approximately 25% spare conductors shall be included in multi conductor 300 V analog and low level signal cables. Spare conductors shall be terminated on the terminal blocks.~~

5.5.3 Inter-connecting wiring or cabling for packaged units furnished by the Supplier, shall be terminated and tested according to this specification.

5.5.3.1 No more than two wires shall be connected to one terminal point if rated for more than one wire. Internal wiring shall be continuous from terminal to terminal without splices (except devices with pig tails). Bridge or comb jumpers are preferred to wire jumpers on terminal strips. Jumpers shall not be installed on field side of the terminal strip.

5.5.3.3 Circuits of different voltages (service level) shall be terminated on physically separate terminal strips and clearly labeled to show the circuit voltage. Terminal blocks shall be segregated according to signal type. In the event safety instrument system components are included in an enclosure, the wiring shall be clearly identified and segregated from non-safety instrument system circuits.

5.5.3.4 AC power shall be routed through separate wireways or separated with a divider from 24 VDC discrete and analog instrument signals within enclosures. Power and signal cabling shall not be run in parallel, except in separate wireways, and should cross at a 90-degree angle only.

5.5.3.5 Wires shall be tagged with the Supplier's cable designation number at both ends with (heat shrinkable or non-shrinkable) plastic sleeve type wire markers.

5.5.4 The Supplier shall furnish terminal boxes or control panels as follows:

5.5.4.1 Instrumentation cables shall be terminated in separate junction boxes from the power and control cables.

5.5.4.2 Where cables supplied and installed by the Buyer are run to the package unit, the Supplier shall provide space for installing and terminating the cables.

5.5.4.3 Approximately 25% of spare terminals shall be included in the terminal blocks.

5.5.5. Wiring for electronic, instrument, communication and signal cables shall be segregated from both power and control cables.

5.5.6 Terminal blocks shall be selected to accommodate the function and electrical requirements associated with each wiring application. They shall incorporate the following features:

a) Screw clamp wire connection
b) Single level configuration
c) Integral test points
d) DIN-rail mounted

5.6 Raceway System

5.6.1 Conduit System

5.6.1.1 Wiring shall be installed in metal conduit. Minimum conduit size shall be ¾ inch. ½ inch conduit is allowed when connecting to devices with ½ inch hubs.

5.6.1.2 Liquid-tight flexible metallic conduit shall preferably be used to isolate the transmission of vibration to the conduit system, and for connection to equipment which may be periodically removed.

5.6.1.3 Liquid-tight flexible metallic conduit shall be supported within 12 inches of each box, cabinet, conduit body, or other conduit termination and shall be secured at intervals not to exceed 4½ ft.

5.6.1.5 Conduit connections to junction boxes shall be made using watertight threaded hubs or factory threaded hubs.

5.6.4 Enclosures shall be designed for front access only unless otherwise specified. All components and equipment in enclosure shall be accessible and removable from the front. Enclosures shall be suitably rated for the environment specified.

5.7 Grounding

5.7.1 Non-current carrying metallic parts of electrical equipment shall be bonded together and made electrically continuous. Two grounding pads shall be furnished at diagonally opposite corners at the edge of skids for connection by the Buyer to the area ground grid.

5.7.2 Electrical equipment on the packaged unit shall be bonded to the package unit skid.

9.0 Documentation and Submittals

- **9.1 General**

The Supplier shall furnish the following documents as per form G-321E and G-321V in the subcontract or primary mechanical packaged equipment material requisition or purchase order (all drawings and data shall be in U.S. units):

9.1.1 Functional description of the electrical operation of the package.

9.1.2 Overall Single line diagram showing all electrical equipment.

9.1.3 Overall layout showing location of electrical items.

9.1.4 Interconnection diagram and cable schedule showing details of all internal connections and Buyer external connections. The Supplier's furnished cable schedule shall include service voltage and Class of Circuit per NEC Articles 725, 760 and 800 for each cable.

9.1.5 Individual equipment schematic diagrams, wiring diagrams, general arrangement drawings, foundation details and junction/terminal box details.

9.1.6 Material list with specific model number, manufacturer and catalogue cut sheets shall be submitted as part of the product data.

9.1.7 The SELLER shall include a list of all the electrical loads in the package, their individual consumption (in kW) and voltage level (in volts).

9.1.8 Recommended Spare Parts List

9.1.8.1 The Supplier shall provide a list of recommended spare parts as follows:

a) Startup/warranty spare parts – are those parts that may be required at any time during equipment installation, startup, testing and unit operation through the warranty period.

b) Operational spare parts – are those parts that required replacement at regular intervals to maintain continuous operation of the supplied equipment and/or system.

c) Capital spare parts – are major parts or equipment that provide reliable equipment operation throughout the plant life and having a significant lead time for manufacturer and delivery.

9.1.8.2 The spare parts list shall include pricing and delivery information valid for one year after delivery of the equipment.

9.1.9 Test reports as required by the primary specification.

9.1.10 In addition to the above, when required for complying with the nuclear standards for SS equipment or components, the Supplier shall submit the qualification documentation as required by the primary specification, material requisition and purchase order.

ATTACHMENT NN00

LAW TCO CUSTOMIZED NN00

Per 24590-WTP-3PS-NN00-T0001, Rev. 2
ENGINEERING SPECIFICATION FOR THERMAL INSULATION FOR MECHANICAL SYSTEMS

This attachment defines the minimum thermal insulation requirements for piping and mechanical equipment associated with the Low Activity Waste Thermal Catalytic Oxidizer/Reducer (LAW TCO) where insulation is specified on drawings, specifications, data sheets, and associated lists. This attachment does not address insulation that is designated as "Safety" or quality level 1 or 2, nor does it cover proprietary tank insulation systems, cryogenic insulation systems, or the insulation of furnaces and buildings. For continuity and maintaining configuration control, the section numbers from the specification noted above have been retained.

1.3 Material and Services Required

SELLER shall provide all insulation materials with associated cements, compounds, jacketing, fasteners/securements, personnel protection guards, and other necessary items for complete insulation systems as defined herein, as well as all services necessary for complete installation of insulation on piping and equipment identified on specified drawings, specifications, data sheets, and lists.

1.4 Conflicts

Instructions on specified equipment drawings and piping isometric drawings, including notes, shall supersede any conflicting requirements of this specification. At the time of quotation, the BUYER shall be notified of all conflicts between this specification and any other documents such as the referenced codes and standards, P&ID, or other procurement documents. Discrepancies, errors, or omissions shall be resolved in writing with the BUYER before the work is started.

2.0 Applicable Documents

Work shall be done in accordance with the referenced codes, standards, and documents listed below, which are an integral part of this specification. When specific chapters, sections, parts, or paragraphs are listed following code, industry standard, or reference document, only those chapters, sections, parts, or paragraphs of the document are applicable and shall be applied. If a date or revision is not listed, the latest issue, including addenda, at the time of Request for Quote (RFQ) shall apply. When more than one code, standard, or referenced document covers the same topic, the requirements for all must be met with the most stringent governing.

2.1 American Society for Testing and Materials (ASTM)

A 240 Standard Specification for Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

B 209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

C 167 Standard Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations

C 195 Standard Specification for Mineral Fiber Thermal Insulating Cement

C 302 Standard Test Methods for Density of Preformed Pipe Covering Type Insulation

C 303 Standard Test Method for Density of Preformed Block-Type Thermal Insulation

C 449 Specification for Mineral Fiber Hydraulic-Setting Thermal Insulating and Finishing Cement

C 533 Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation

C 547 Standard Specification for Mineral Fiber Pipe Insulation

C 552 Standard Specification for Cellular Glass Thermal Insulation

C 585 Standard Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing

C 592 Standard Specification for Mineral Fiber Blanket Insulation and Blanket-Type Pipe Insulation (Metal-Mesh Covered)(Industrial Type)

C 610 Standard Specification for Expanded Perlite Block and Pipe Thermal Insulation

C 612 Standard Specification for Mineral Fiber Block and Board Thermal Insulation

C 692 Standard Test Method of Evaluating the Influence of Wicking-Type Thermal Insulations on the Stress Corrosion Cracking Tendency of Austenitic Stainless Steel

C 795 Standard Specification for Wicking-Type Thermal Insulation for Use Over Austenitic Stainless Steel

C 871 Standard Test Methods for Chemical Analysis of Thermal Insulation Materials for Leachable Chloride, Fluoride, Silicate, and Sodium Ions

C 1136 Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation

D 312 Standard Specification for Asphalt Used in Roofing

2.2 Process Industry Standards

INIH1000 Hot Insulation Installation Details

2.3 Occupational Safety and Health Administration

29 CFR 1910.144 Safety Color Code For Marking Physical Hazards

29 CFR 1910.1200 Hazard Communication

3.0 General Requirements

3.1 Insulation Systems

The following insulation codes are used to identify the functions of thermal insulation on mechanical pipe and equipment:

- Hot services
  - HC: heat conservation
  - PS: process stability
  - PP: personnel protection
  - HF: hot and fire protection
  - PG personnel protection guards
- No insulation
  - NI: no insulation

Insulation for cold services shall be cellular glass. Contraction joints and a vapor barrier covering are not required for cellular glass. Joint sealant shall be used in all insulation joints and to provide vapor stops at insulation terminations.

Insulation for hot services shall be as follows:

- Vertical Equipment
  - Shell mineral fiber semi-rigid board
  - Top head expanded perlite block, or calcium silicate
  - Bottom head mineral fiber blanket
- Horizontal Equipment
  - Shell expanded perlite block, or calcium silicate
  - Heads mineral fiber blanket
- Piping
  - All surfaces expanded perlite block, or calcium silicate

Cellular glass, mineral fiber, or calcium silicate materials may be used for hot services, if approved by the BUYER, but only in the allowable temperature ranges specified in Section 4.2.

The Component Information System (CIS) and associated lists identify the appropriate insulation function code(s) for piping. Piping isometric drawings show the extent of insulation for piping and associated components. Equipment general arrangement drawings and equipment data sheets specify the extent of insulation for equipment. Piping and instrument diagrams (P&IDs) indicate where insulation is required.

If several insulation function codes are applicable, the most stringent requirements shall govern. For example, surfaces above 140°F that can be readily touched by operating or maintenance personnel require personnel protection (code PP). Where other insulation functions may be specified, the most stringent thickness requirement shall apply. In situations where insulation is not practical or appropriate, expanded metal guards (designated as code PG) shall be used for personnel protection rather than insulation.

All thermal insulation shall be protected by aluminum or stainless steel sheet metal jacketing unless specified otherwise. Jacketing shall support the insulation, protect it from damage, and provide weather protection (prevent ingress of water).

3.2 Extent

Removable and reusable insulation should be used in areas requiring periodic access for maintenance.

PP insulation shall be used on surfaces that are accessible to personnel if the maximum temperature exceeds 140°F, with guards (code PG) installed where insulation is not practical or appropriate. Accessible areas include those where personnel perform anticipated operations or maintenance, and include surfaces up to 7 ft above grade, floors, or platforms, and 3 ft horizontally from the periphery of platforms, walkways, or ladders.

Table 3.2 defines the extent of thermal insulation for other function codes.

Table 3.2, Extent of Insulation for Functions Other Than AS and PP

Surfaces to be Insulated	Insulation Function Codes		
	HC	PS	HF, ET, ST, PF
Straight or bent pipe; socketweld, threaded or buttweld pipe fittings, and valves.	YES	YES	YES
Pipe unions	NO[2]	NO[2]	NO[1]
Steam traps, related strainers	NO[2]	NO[2]	NO[1]
Flanged valves (except relief and control valves), flanged orifice sets, piping flanges connected to equipment nozzles	YES[3]	NO[1,3]	YES[3]
Primary piping for instrument connections, sample piping, vent and drain piping.	NO[1]	NO[1]	YES
Expansion or rotation joints, slide valves, etc.	NO[2]	NO[2]	YES[3]
Instruments and associated tube	NO	NO	YES
Relief valves	NO	NO	NO
Control valves, flanged pipe fittings	NO[1,3]	NO[1,3]	YES[3]
Tee and inline strainers	NO[1,3]	NO[1,3]	YES[3]
Heat exchangers, shell side, tube side, excluding body flanges	YES	YES	NA
Heat exchanger body flanges	NO[1,3]	NO[1,3]	NA
Pump casings	NO[1,3]	NO[1,3]	YES[3]
Compressors	[3]	NO[1]	NA
Blowers, fans	[3]	YES[2]	NA

[1] Insulate or guard only where required for personnel protection.
[2] Provide removable metal guards or barriers where required for personnel protection.
[3] Removable and reusable covers should be considered.
[4] Insulation should not be used in inaccessible areas where maintenance is infeasible (e.g., high radiation areas).

Removable, reusable insulation shall be used in areas where insulation may be removed more frequently than once every 20 months (e.g., for flanges or other components requiring periodic maintenance).

3.3 Thickness

Insulation shall be applied in one layer with the thickness per Appendix A unless specified otherwise. Insulation thickness depends on the insulation function (insulation code), normal or maximum operating temperature, and item diameter.

4.0 Materials

4.1 General

4.1.1 The BUYER only shall judge equivalency of materials. The SELLER shall submit complete details with any request for substitution or deviation from this specification.

4.1.2 All insulation and non-metallic accessory materials shall contain no asbestos.

4.1.3 All expanded perlite, calcium silicate, mineral fiber insulation, and mineral fiber cement or other proposed substitution products shall be qualified for use on austenitic stainless steel in accordance with ASTM C 795 by conforming to the pre-production test requirements of ASTM C 692 and the confirming quality control requirements for chemical analysis of ASTM C 871.

4.1.4 Deleted

4.1.5 Mineral fiber insulation materials shall have less than 30% cumulative shot content as determined by ASTM C 612 Annex A1. Density of mineral fiber products shall be determined by ASTM C 612, C 302, or C 303, as appropriate. "Delivered density" based on 40% shot content calculated per ASTM C 612 shall not be used.

4.1.6 All mastics, cements, caulks, compounds, kraft paper, and other materials used in insulation systems for stainless steel piping and equipment shall be free of leachable lead, bismuth, zinc, mercury, antimony, cadmium, and tin. The inorganic halogen content shall be less than 200 ppm; sulfur content shall not exceed 400 ppm. The low melting elements mentioned above shall be less than 1 percent by weight with mercury less than 50 ppm.

4.2 Insulation

4.2.1 Table 4.2 lists insulation materials and the allowable temperatures and functions for each material.

Table 4.2, Insulation Materials

Material	Description	ASTM Standard	Allowable Process Fluid Temperatures	Allowable Functions
Calcium Silicate	Block and Pipe Covering	C533	320°F to 1130°F	HC, PS, PP, HF
Cellular Glass	Block and Pipe Covering	C552	-355°F to 320°F	All
Mineral Fiber	Preformed Pipe Insulation	C547	230°F to 1130°F [1]	HC, PS, PP (see Note 1)
Mineral Fiber	Blanket	C592	230°F to 1130°F	HC, PS, PP
Mineral Fiber	Semi-Rigid Board	C612	230°F to 1130°F	HC, PS, PP
Expanded Perlite	Block and Pipe Covering	C610	77°F to 1130°F	HC, PS, PP, HF, ET, ST, PF

[1] Although not preferred, mineral fiber insulation material may be used in cold services (codes AS, ET, ST, and PF) at fluid temperatures down to 32°F with BUYER's approval if suitable ASTM C1136 vapor barriers are provided on all insulation surfaces and vapor stops are provided at insulation terminations to prevent water intrusion.

4.2.2 Mineral fiber board, rigid and semi-rigid, used for vertical equipment surfaces shall meet the requirements of ASTM C 612, Class 4 and be suitable for continuous service at system operating temperatures, and shall have a nominal density of 8 lbs/ft^3.

4.2.3 Mineral fiber blanket insulation used for bottom heads of vertical equipment and heads of horizontal equipment shall meet the requirements of ASTM C 592 Class II with the following exceptions:

- Nominal density shall be 8 lbs/ft^3
- One side shall be faced with stainless steel hexagonal mesh

4.2.4 Molded mineral fiber insulation piping ell covers suitable for operating temperatures may be used for all hot applications.

4.2.5 Expanded perlite block and pipe covering used for all piping, horizontal equipment, and vertical equipment top heads shall meet the requirements of ASTM C 610, Type II only, and shall exhibit water repellency up to a service temperature of 410°F.

4.2.6 Cellular glass insulation shall meet the requirements of ASTM C 552. For operating temperatures above 185°F, fabrication of piping insulation and curved radius segments shall be laminated using gypsum cement, not hot asphalt.

4.2.7 Calcium silicate block and pipe insulation shall meet the requirements of ASTM C 533 Type I and shall be marked continuously to designate that no asbestos is present.

4.3 Insulation Form

4.3.1 Shop-fabricated rigid insulation segments used for all elliptical, conical, torispherical, flanged and dished, or hemispherical top heads of vertical equipment shall be fabricated from cellular glass, rigid expanded perlite block, or calcium silicate. Both inside and outside surfaces shall be cut to match the compound curvature of the head. Each of the four sides shall be machined at the necessary bevel angle and radius to match the adjoining courses. Blocks shall be individually numbered and supplied with an assembly map to indicate the relative location of the numbered pieces.

4.3.2 Curved cellular glass sections used for equipment shells and pipe insulation shall be of a density between 7 and 8 lb/ft^3 in accordance with ASTM C 552, "Cellular Glass Block and Pipe Thermal Insulation". Acceptable materials are Pittsburgh-Corning Corporation "Foamglas" or approved equal. Thermal conductivity at 50°F shall be less than 4.6 x 10^{-4} Watts cm/cm^2 °C (0.32 BTU in/hr ft^2 °F). Curved sections for equipment shells and piping insulation shall be manufactured from billets assembled with ASTM D 312 Type III hot asphalt. A factory coating of ASTM D 312 Type II or III hot asphalt shall be applied on the exterior curved surfaces and interior bore. For operating temperatures above 185°F, gypsum cement should be used instead of hot asphalt per section 4.2.6.

4.3.3 Flat stock insulation materials that are grooved to fit cylindrical surfaces for equipment shells and pipe sizes above 12 inches shall be vee-cut so that the cuts close completely along their entire length when the insulation is installed. Materials used for fabrication shall conform to the requirements of this specification. Dimensions of the installed product shall conform to ASTM C 585 for pipe insulation. Backing and adhesives are subject to review and approval by the BUYER.

4.3.4 Loose fill material and cushioning blanket for service temperatures to 680°F shall contain no asbestos, have a density greater than 8 lbs/ft^3, and be glass fiber needled together to form a mat without the use of binders. The following materials are acceptable:

- Alpha Associates "Filomat D"
- Burlington Glass Fabrics "Burlglass 1200"

4.4 Mastics and Cements

4.4.1 Mineral fiber thermal insulating cement shall meet the requirements of ASTM C 195. Insulating and finishing cement shall meet the requirements of ASTM C 449. Reinforcing wire mesh shall be 1 inch hex x 0.023 inch three twist Monel or 18-8 SS wire.

4.4.2 Caulking compound for temperatures up to 365°F sealant shall be silicone rubber, Dow Corning 999 Silicone Rubber, or equal. Compound exposed to temperatures between 365°F and 680°F shall be Childers CP-79 or equal.

4.4.3 Reinforced weatherproofing compound shall be acrylic or vinyl acrylic water base emulsion and reinforced with a Dynel, nylon, or polyester leno weave or knitted fabric with 10 x 10 mesh per inch and a weight of 2 oz/yd^2.

4.4.4 Heat transfer cement shall be appropriate for the tracer temperature and process temperature. The cement shall be compatible with the surface coating system or steel substrate. Preformed flexible heat transfer cement may be used. On carbon steel pipe, steel channel to cover tracer shall be galvanized. For coupling vessel walls with plate heat coils, a non-hardening heat transfer cement shall be used. If required, insulation tape shall be 2 inches wide x 1/8 inch thick plain weave, suitable for operating temperatures to 1000°F.

4.4.5 Joint sealant for cellular glass at all temperatures, and vapor stop sealant for temperatures above 5°F for cellular glass shall be Foster Sealant 95-50. Below 5°F, sealant for vapor stops shall be Foster 90-66. Reinforcement for vapor stops (and weather barrier) shall be synthetic cloth equal to Pittsburgh-Corning PC Fabric 79, or BUYER-approved equal.

4.5 Jacketing

4.5.1 Aluminum jacketing shall be ASTM B 209 Alloy, 1100, 3103, 3105 or 5005 with an H14 temper. Jacketing for piping size 28 inches and below shall be flat, smooth. Jacketing for horizontal equipment shells and piping sizes above 28 inches shall be stucco embossed sheet. Jacketing for vertical equipment shells shall be furnished 1 1/4 inch corrugated. The corrugations shall be 1/4 inch deep. Jacketing for exposed equipment heads shall be gores fabricated from stucco embossed sheet.

Nominal thickness shall be 0.016 inch for piping and 0.024 inch for equipment.

Jacketing shall have a factory applied moisture barrier that is continuously heat-sealed to the aluminum. The moisture barrier shall consist of a 3 mil high density polyethylene, Poly-Surlyn film, or one layer of 40 lb virgin kraft paper laminated with a one mil polyethylene adhesive.

If specified by the BUYER, jacketing shall be supplied with a polyvinylidene fluoride (PVDF) or acrylic exterior coating and the specific color shall be approved by the BUYER. Otherwise all metal jacketing shall be the natural color of the jacketing material.

4.5.2 Stainless jacketing shall be ASTM A 240 Type 304 flat, smooth sheet 0.016 inch thick furnished in the annealed or soft condition with a regular 2B mill finish and have a factory applied moisture barrier as specified for aluminum jacketing.

4.5.3 Die formed two-piece aluminum ell covers shall be used for NPS 12 and smaller pipe sizes. Die formed four piece aluminum ell covers or molded fiberglass covers shall be used for sizes above NPS 14. Aluminum covers shall be deep drawn from 0.024 inch thick aluminum alloy 1100-0. Fiberglass covers shall be 0.040 inch thick flame retardant polyester.

Aluminum covers shall have a factory applied moisture barrier coating such as PVDF or Poly-Surlyn on the inner surface. The external surface of aluminum covers shall be coated or not coated to match the adjacent pipe jacket. Vapor barriers used with fiberglass insulation or other mineral fiber insulation for cold services shall comply with ASTM C1136.

4.5.4 If available, stainless steel die formed covers with a factory applied moisture barrier shall be furnished for ells and tees. Gored segments or stove-pipe construction of 304 stainless steel may be substituted.

4.5.5 Gored segmented aluminum or stainless steel covers shall be used over welded tees. The metal thickness and coating shall be the same as adjacent pipe jacketing. The seams shall shed water and keep the insulation dry. Flanged tees shall be insulated with flexible removable covers and shall not have metal covers.

4.6 PP Guards (Code PG)

4.6.1 Personnel protection guards shall be fabricated from perforated or expanded metal. For hot stainless steel pipe or equipment to be protected, the expanded metal guard shall be Type 304 stainless steel. For carbon steel surfaces, galvanized steel shall be used. Support may be provided by structural steel anchored at the equipment foundation or by clips banded to the piping or equipment. Support clips shall be designed to locate the expanded metal a minimum of 3 inches from the hot surface, and shall be the same or compatible material as the pipe or equipment.

4.6.2 Guards on flanged connections and equipment shall be designed for convenient removal for maintenance access. Individual section shall not weigh more than 40 lbs.

4.6.3 Typical design sketches for metal shields shall be submitted by the SELLER and shall be approved by the BUYER prior to fabrication or installation.

4.7 Insulation and Jacketing Securement

4.7.1 Tie wire, lacing wire, and lacing hair pins shall be 16 gauge Type 304 soft annealed SS wire.

4.7.2 Tape for fastening cellular glass pipe insulation shall be 3/4 inch wide fiberglass reinforced filament tape. The tape shall not be applied to stainless steel unless it conforms to the halogen content requirements of Section 4.1.6.

4.7.3 Bands shall be 0.020 inch thick by 0.50 inch or 0.75 inch wide as required by Sections 4.0, 5.0, and 6.0 and conform to ASTM A 240 Type 302 or 304 stainless steel. Seals shall be heavy-duty wing type or crimp (closed) type fabricated from 0.032 inch thick ASTM A 240 Type 302 or 304 stainless steel. Crimp (closed) type seals are required with spring tensioned banding.

4.7.4 Springs for securement of jacketing on piping and rigid insulation on equipment shall be Type 302 stainless steel limited expansion type. Springs for securement of jacketing on vessels and tanks with diameters exceeding 10 feet shall be compression type.

4.7.5 Sheet metal screws shall be #8 x 1/2 inch 18-8 SS self-tapping screws with elastomeric gaskets.

4.7.6 Stainless Steel "S", "J", or "U" Clips for supporting metal jacket courses or banding shall be 0.020 inch thick by 0.75 inch wide ASTM A 240 Type 302 or 304 stainless steel.

5.0 General Installation Requirements

5.1 Safety

5.1.1 All surface preparation, materials, and work shall comply with all applicable environmental and safety provisions, laws, regulations, ordinances, etc., of the city, county, state, province, or nation pertaining to the work being performed and the materials being used. Work being performed in the United States shall also be in strict accordance with federal (OSHA Standard 29 CFR 1910.144), state, and local safety and environmental requirements.

5.1.2 SELLER shall comply fully with OSHA Hazard Communication Standard 29 CFR 1910.1200 or the applicable country code. Material Safety Data Sheets (MSDS) shall be provided by the materials Supplier and available at the place of application for review.

5.1.3 The volatile organic compound (VOC) content of all materials shall meet federal, state, and local or other regulatory requirements.

5.2 Weather Protection

All insulation and necessary materials shall be protected from moisture during storage and installation. Temporary polyethylene sheeting shall protect insulation in wet weather conditions until the final application of the permanent jacketing. Wet insulation is unacceptable and must be replaced with dry materials. Expanded perlite and cellular glass that has been exposed to the rain or other moisture shall be dried to the BUYER's satisfaction. Mineral fiber and calcium silicate that becomes wet shall be removed from the site and not used.

5.3 Conditions of Surfaces to be Insulated

5.3.1 All surfaces to be insulated shall be clean and dry.

5.3.2 Because corrosion is more aggressive to insulated surfaces than uninsulated surfaces operating in the temperature ranges just above ambient, all carbon steel normally operating at temperatures up to 300°F will be coated with epoxy.

5.3.3 No insulation shall be installed until completion of any stress relieving, chemical cleaning, coating application, pressure testing, tracer installation, and release of the surfaces in writing by the BUYER's site representative.

5.4 Insulation Fit-Up

5.4.1 All voids and cracks (larger than 3/32 inch) in hot insulation shall be pointed and filled with the insulating cement. Thickness of cement on irregular surfaces shall equal the thickness of the adjacent preformed insulation. Cracks larger than 5/16 inch shall be corrected by re-fitting the insulation unless filling is accepted by the BUYER.

For anti-sweat insulation, all joints shall be fitted up to be 1/16 inch or less or the insulation removed and remachined. All joints shall be completely filled with joint sealant from interior to exterior surface.

5.4.2 For rigid insulation materials, a 1 inch gap adjacent to support rings, tie bars, or piping ells shall be provided as an expansion joint. The joint shall be filled with loose fill material. Piping ells insulated with preformed mineral fiber do not require expansion joints.

5.4.3 Flanged fittings, flanged valves, flanged pumps, flanged blinds and single flange pairs on piping and equipment including manways and nozzles, if insulated, shall be insulated last, after the completion of all testing, and insulation of adjacent pipe or equipment surfaces.

5.5 Multi-Layer Insulation

Where possible, insulation shall be applied in a single layer as indicated in the insulation thickness tables of Appendix A. When multi-layer construction is used, joints of the top two layers shall be offset at least 1.5 inches from each other using staggered layer techniques to ensure all joints in each layer are offset.

5.6 Jacketing and Compound

5.6.1 Unless specified otherwise, aluminum jacketing shall be used for all insulation except for function HF, which shall have stainless steel jacketing.

5.6.2 Reinforced mastic weather coating compound may be used on surfaces of complex shapes that cannot be fitted with aluminum and do not require fire resistance as for function HF. It shall be used only on calcium silicate and perlite insulation. The emulsion-type weather coating shall not be applied when atmospheric precipitation or condensation may wet the finished surface within 24 hours after application.

The mastic weather coating shall be applied as follows for most applications:

- Apply a layer of finishing cement over the insulation to provide a smooth, even surface
- Apply mastic to 1/8 inch wet thickness
- While still wet, wrap with reinforcing fabric. Lap joints 2 inches
- Apply finish coat of mastic to completely cover fabric. The total dry film thickness shall be a minimum of 1/8 inch

5.6.3 Jacketing shall prevent entry of liquid water into the insulation under all normal weather conditions and wash down operations. The design of the jacketing shall be such that joints shed water and do not depend on organic caulks to prevent the ingress of water. All penetrations through the metal jacketing shall be flashed to lap the penetration and jacketing a minimum of 3 inches, banded, and sealed with caulk.

5.7 Fireproofing Insulation

For fireproofing insulation, function HF, the metal jacket on piping and equipment shall be stainless steel rather than aluminum or mastic coating. Insulation for function HF shall be cellular glass or calcium silicate. HF insulation thickness shall be as specified on applicable drawings, data sheets, and/or other specifications, but shall be 2.5 inches minimum thickness. For both piping and cylindrical equipment, the insulation as well as the jacketing shall be circumferentially banded with 1/2-inch stainless steel bands on 6 inch centers.

5.8 Installation Details

Typical insulation details are provided in Process Industry Practices INIH1000 and INIC1000. The SELLER may submit alternate sketches for BUYER approval.

5.9 Piping Versus Equipment Installation Methods

Heat exchanger and cylindrical equipment shells less than 24 inches in diameter shall be insulated in the same manner as piping. Piping larger than 48 inches shall be insulated by the methods specified for equipment. Heads on equipment less than 24 inches diameter shall be insulated with a flat disk of block butted against extended cylindrical shell insulation.

6.0 Specific Installation Requirements for Piping

6.1 Insulation Placement

6.1.1 On traced lines, the preformed pipe covering shall be of a larger insulation size or used in combination with straight block insulation as required to enclose the trace line without grooving the insulation.

6.1.2 Circumferential joints of pipe insulation sections shall be offset or staggered between top and bottom sections by a section half length. Longitudinal joints shall be nearly horizontal, and in multi-layer construction, shall not coincide with the longitudinal joints of previous (or subsequent) layers. The offset distance between staggered joints shall be at least 1.5 inches. Hinged vee-grooved pipe covering is permitted on hot piping insulation sizes larger than 12 inches. If hinged vee-grooved insulation sections are used, the hinge shall be located on top to shed any encroaching water. Only the second and third layers may be combined into a composite block for application as a unit.

6.1.3 Where insulation terminates on pipe runs, insulation will be stopped short a minimum 1.25 times the bolt length from the face of the flange or sufficient distance to remove flange bolts without disturbing the insulation and jacketing.

6.1.4 Hot welded and screwed fittings and valves 3 inches and smaller can be insulated with wire mesh reinforced combination insulating and finishing cement applied in 0.5 inch layers to achieve the thickness of the adjacent pipe insulation.

6.2 Insulation Support

6.2.1 Insulation and jacketing on vertical piping shall be supported on an approved bolt-on support ring supplied and installed by the SELLER. Carbon steel rings shall be installed on carbon steel pipe and stainless steel rings shall be installed on chrome steel (Cr-Mo), austenitic stainless steel, Inconel, and Hastelloy piping.

6.2.2 Ring supports shall be installed at the bottom of the pipe run and above interruptions in the pipe run such as at flanges and valves; however, maximum spacing shall be 13 feet. Support rings are not required for vertical rises less than 6 feet when measured from the bottom of a pipe run or from a support at an interruption.

6.2.3 Rings shall be sized to support all layers of insulation but smaller than the insulation diameter. A 0.5 inch gap shall be maintained between the insulation jacketing and the outside edge of the support ring.

6.3 Hot Insulation Expansion Joints

6.3.1 Periodically, circumferential joints shall be filled with loose glass fill or mineral fiber blanket to make an expansion joint in the rigid insulation covering. The fill shall be compressed 50% during installation to yield a joint 1 inch wide. The joint shall be filled completely to the full layer thickness of the insulation.

6.3.2 The expansion joints shall be spaced equally between pipe supports or pipe anchors but shall not exceed the distance between expansion joints listed in Table 6.3.

Table 6.3, Expansion Joint Spacing

OPERATING TEMPERATURE	MAXIMUM DISTANCE
Below 320°F	33 feet
320°F to 500°F	26 feet
Above 500°F	16 feet

6.4 Insulation Securement

6.4.1 Each individual pipe insulation section shall have a minimum of two securements.

6.4.2 Cellular glass shall be secured with adhesive tape on 9 inch centers before jacketing is banded in place.

6.4.3 Each layer of expanded perlite and calcium silicate insulation shall be secured to pipe using tie wire, 0.5 inch wide stainless steel bands, or adhesive tape on 9 inch or 12 inch spacing according to Table 6.4.

Table 6.4, Securement Spacing

PIPE SIZE (inches)	NUMBER OF LAYERS	OUTER LAYER SECUREMENT / SPACING (inches)	INNER LAYER SECUREMENT / SPACING (inches)
Below 12	1, 2 or 3	Wire/9	Wire/12
12 to 28	1	Wire/9	N.A.
12 to 28	2 or 3	Bands/12	Wire/9
Above 28	1	Bands/9	N.A.
Above 28	2 or 3	Wire/9	Wire/9

6.5 Jacketing Securement

6.5.1 On horizontal pipe insulation, metal jacketing shall overlap 3 inches both longitudinally and circumferentially. Seams shall be arranged to shed water, i.e., the upper shall overlap the lower sheet. Longitudinal seams shall be located at the 3:00 or 9:00 position on the pipe circumference. Securement of the metal jacket shall be by 0.5-inch wide bands placed on the circumferential overlaps and on 12-inch centers.

6.5.2 On vertical pipe insulation, metal jacketing shall overlap 2 inches for circumferential seams and 3 inches for longitudinal seams. Jacketing shall be supported from insulation support rings or from jacketing below using 3 or more stainless steel "S" clips. Circumferential joints shall be lapped to shed water. The longitudinal seam shall be located on the leeward side from the prevailing storm wind direction if possible. In any case, the joints shall be located so they are easily accessible for caulking. Securement of the metal jacket shall be by 0.5 inch bands placed on the circumferential overlaps and by screws on 3 inch centers along the longitudinal over-laps. Screws shall be placed in the longitudinal over-laps so that circumferential joints are free to accommodate expansion and contraction movements. Longitudinal seams of vertical pipe jacketing shall be caulked.

6.5.3 Expansion springs shall be fitted to bands that secure jacketing over multi-layer insulation on piping larger than 28 inches. Bands shall not be located adjacent to jacketing laps. Springs shall be extended 1.3 times their original length when tensioned.

6.5.4 Die formed covers shall have their heel and throat fastened with screws on 4-inch maximum centers. The cover sections shall overlap themselves and the pipe jacketing at least 2 inches. Bands 0.5-inch wide shall secure each end of the cover to the pipe jacketing.

6.6 Caulking

A heavy fillet of heat resistant caulk shall be applied around flashing at all protrusions through the jacketing. Protrusions must rely on flashing to keep water out. Other jacket-to-jacket seams not waterproof by virtue of their design shall be caulked with silicone rubber sealant.

7.0 Specific Installation Requirements for Vessels and Heat Exchangers

7.1 Insulation Placement

7.1.1 Unless otherwise approved by the BUYER, expanded perlite or calcium silicate rigid block insulation shall be used as the single layer on all shells of horizontal equipment. Semi-rigid mineral fiber board shall be used as the single layer on vertical equipment shells.

7.1.2 Joints shall not align between the top two layers of multi-layer insulation but shall be offset at least 1.5 inches.

7.1.3 Heads on equipment 24 inches diameter and less shall be insulated with a flat disk of block butted against extended cylindrical shell insulation.

7.1.4 Top heads and heads not protected by a skirt on vertical equipment larger than 24 inches diameter shall be insulated with shop fabricated rigid insulation segments. Machine cut rigid block for heads shall be installed in the locations indicated by the manufacturer's map.

7.1.5 Heads protected by a skirt and heads on horizontal equipment larger than 24 inches shall be insulated with mineral fiber blanket applied over steel surfaces operating below 680°F. For horizontal equipment shells, rigid blocks shall be installed with the long axis of the insulation block parallel to the equipment axis. The first course of block applied around the equipment shell circumference shall be applied with every other block cut to a half length so that circumferential joints are broken or staggered between adjacent blocks of the first and subsequent courses.

7.1.6 Cut and bevel blocks as necessary to obtain joints no wider than 7/32 inch at the outside surface of the insulation. Rigid block lengths shall be at least 18 inches. Acceptable maximum rigid block widths are as follows in Table 7.1.

Table 7.1, Rigid Block Widths

EQUIPMENT SIZE	MAXIMUM BLOCK WIDTH
Up to 39 inch diameter	3 inch vee-cut block or pipe covering
39 to 79 inch diameter	4 inch vee-cut block
79 to 118 inch diameter	6 inch vee-cut block
Above 118 inch diameter	9 inch vee-cut block

7.1.7 For Vertical Equipment shells, semi-rigid board shall be installed in vee-grooved sections for diameters less than 13 feet. For shell diameters larger than 13 feet, flat board is acceptable.

7.2 Insulation Securement

7.2.1 Adhesives shall not be used to hold insulation on equipment.

7.2.2 Cellular glass, if used, shall be secured with 0.75 inch wide fiberglass tape on 9 inch centers before jacketing is banded in place.

7.2.3 Each layer of rigid insulation shall be secured to equipment shells using 0.5 inch wide stainless steel bands. Where required, insulation shall be coped to accommodate expansion springs below the profile of the insulation. Expansion springs and securement shall be according to the Table 7.2.

Table 7.2, Expansion Springs and Securements

EQUIPMENT DIAMETER	NUMBER OF INSULATION LAYERS	OUTER LAYER SECUREMENT	INNER LAYERS SECUREMENT	EXPANSION SPRINGS PER BAND
39 to 118 inches	1, 2 or 3	Bands	Bands	None
Above 118 inches	1	Bands	N.A.	1
Above 118 inches	2 or 3	Bands	Bands	2, 180° Apart

7.2.4 Each layer of mineral fiber semi-rigid board insulation shall be secured with bands 0.75 inch wide. Expansion springs are not required.

7.2.5 Secure shell insulation by banding each layer on 12 inch maximum centers. For longer block or board lengths, 18 inch maximum centers may be used, but secure every block or board with a minimum of two bands.

7.2.6 Extend head bands radially from a central floating ring, and space them to provide at least one band per block at extreme circumference of the head. Bands shall be applied and sealed under tension by machine.

7.2.7 Where projections prevent a continuous band, secure the band at the projection by a bridle ring. Tie wire may be used to hold the blocks where projections prevent the use of continuous bands, e.g., between platform or ladder support brackets.

7.2.8 Insulating cement shall be used to fill up any voids or cracks flush with the block surface. See Section 4.4.

7.2.9 Expansion joints are required on horizontal vessels operating above 320°F or having a tangent length greater than 20 feet. An expansion joint shall be provided for each 10 feet of length and be equally spaced along the length. Fill expansion joints with loose mineral fiber or glass fiber.

7.2.10 Removable blanket insulation, where designated for manways, heads, and flanges shall be installed after all permanent insulation work is completed.

7.3 Jacketing Securement

7.3.1 Corrugated covering on vertical equipment shall be installed with corrugations running vertically with a minimum of 2.5 corrugations overlap. The edge of the sheet shall terminate in a valley. Circumferential overlap shall be 4 inches.

7.3.2 For stucco embossed jacketing on horizontal equipment, longitudinal and circumferential joints shall be lapped 3 inches and arranged to shed water.

7.3.3 Each section of metal jacketing shall be supported from the next lower section with "S" clips. The bottom section of covering shall be supported by "J" clips attached to the insulation support.

7.3.4 The covering shall be banded with 3/4 inch wide bands over circumferential laps with intermediate bands on 12 inch maximum centers. For resistance to high winds, band spacing shall be 9 inches with 2 bands located on circumferential overlaps.

7.3.5 Bands over rigid insulation and jacketing without corrugations shall have expansion devices as specified for the outer layer of insulation in Table 7.2.

7.3.6 Bands without springs shall be tensioned sufficiently to remove all slack.

7.3.7 Bands shall be supported by a minimum of two "S", "U", or "J" clips with a maximum spacing of 6 feet between supports. Springs, if present, shall be located away from jacketing laps.

7.3.8 On vertical vessels, metal screws shall be installed on 6 inch maximum centers in longitudinal seams. For resistance to high winds, screws shall be installed on 4 inch maximum centers.

7.3.9 Head gore segments shall be fastened to each other with screws on 6 inch centers and bands placed over each gore. For resistance to high winds, screws shall be installed on 4 inch maximum centers.

7.3.10 Flashing and a heavy fillet of silicone caulk shall be used to seal around all projections through the jacketing and all longitudinal seams. Jacketing shall be cut to fit tightly around all penetrations while allowing adequate room for expansion and contraction over the operating temperature range. All penetrations must be designed and flashed so that water will not enter.

10.0 Documentation and Submittals

10.1 SELLER shall submit detailed installation procedures complete with detailed sketches showing methods of applying insulation, particularly for valves, flanges, fittings, expansion joints, and metal jacketing.

10.2 All materials used must be completely described as to manufacturer and type. The SELLER shall furnish a certificate from the manufacturer confirming compliance with all requirements of Sections 2.0 and 3.0.

10.3 SELLER's procedures must describe how materials will be stored, handled, mixed, and used in accordance with the manufacturer's printed instructions.

10.4 SELLER shall maintain a copy of their procedures properly revised and used by site supervision to control the execution of the work. The procedures and revisions thereof must be submitted for the BUYER's review and authorization to proceed prior to use.

11.0 Inspection

The BUYER reserves the right to inspect the insulation prior to and after jacketing installation. The SELLER shall replace or correct any materials or installations that do not meet the requirements of this specification and reference drawings.

Appendix A
Insulation Thickness Tables

Table A-1

Insulation Thickness for Heat Conservation (HC), Process Stability (PS), Electric Traced (ET), and Steam Traced (ST) Function Codes

Pipe Size (inches)	Normal Operating Temperature of Process Fluid (°F)						
	≤ 140	140-230[1]	231-320	321-410	411-500	501-590	591-680
	Insulation Thickness (inches) [1]						
0.5	1.0	1.0	1.0	1.5	1.5	2.0	2.5
0.75	1.0	1.5	2.0	2.5	2.5	3.0	3.0
1	1.0	1.5	2.0	2.5	2.5	3.0	3.0
1.25	1.0	2.0	2.0	2.5	3.0	3.0	3.0
1.5	1.0	2.0	2.0	2.5	3.0	3.0	3.0
2	1.5	2.0	2.5	2.5	3.0	3.0	4.0
3	1.5	2.5	2.5	3.0	3.0	4.0	4.0
4	1.5	2.5	3.0	3.0	3.0	4.0	4.0
6	1.5	2.5	3.0	4.0	4.0	4.0	4.0
8	1.5	2.5	3.0	4.0	4.0	4.0	4.0
10	1.5	2.5	3.0	4.0	4.0	4.0	4.0
12	1.5	2.5	4.0	4.0	4.0	4.0	4.0
14	2.0	3.0	4.0	4.0	4.0	4.0	4.0
16	2.0	3.0	4.0	4.0	4.0	4.0	4.0
18	2.0	3.0	4.0	4.0	4.0	4.0	4.0
20	2.0	3.0	4.0	4.0	4.0	4.0	4.0
24	2.0	3.0	4.0	4.0	4.0	4.0	6.0
30	1.5	3.0	4.0	4.0	4.0	4.0	6.0
36	1.5	3.0	4.0	4.0	4.0	6.0	6.0
48	1.5	3.0	4.0	4.0	4.0	6.0	6.0
Flat	2.0	4.0	4.0	4.0	6.0	6.0	6.0

[1] HC insulation is not required for normal process fluid temperatures below 70°F (for outdoor or unheated locations) and 100°F (for indoor, heated locations).

Table A-2

Insulation Thickness for Personnel Protection (PP) Function Code

Pipe Size (inches)	Maximum Operating Temperature of Process Fluid (°F)					
	140-230[1]	231-320	321-410	411-500	501-590	591-680
	Insulation Thickness (inches) [1]					
0.5	0.5	0.5	0.5	1.0	1.0	1.5
0.75	1.0	1.0	1.0	1.5	1.5	2.0
1	1.0	1.0	1.0	1.5	1.5	2.0
1.25	1.0	1.0	1.0	1.5	2.0	2.0
1.5	1.0	1.0	1.0	1.5	2.0	2.0
2	1.0	1.0	1.0	1.5	2.0	2.5
3	1.0	1.0	1.5	2.0	2.0	2.5
4	1.0	1.5	1.5	2.0	2.5	3.0
6	1.0	1.5	1.5	2.0	3.0	3.5
8	1.5	1.5	2.0	2.5	3.0	3.5
10	1.5	1.5	2.0	2.5	3.5	4.0
12	1.5	1.5	2.0	2.5	3.5	4.5
14	1.5	1.5	2.0	3.0	3.5	4.5
16	1.5	1.5	2.5	3.0	4.0	5.0
18	1.5	1.5	2.5	3.0	4.0	5.0
20	1.5	1.5	2.5	3.5	4.0	5.0
24	1.5	2.0	2.5	3.5	4.0	5.0
30	1.5	2.0	2.5	3.5	4.5	5.5
36	1.5	2.0	3.0	3.5	4.5	6.0
48	1.5	2.0	3.0	4.0	5.0	6.0
Flat	1.5	2.5	3.5	4.5	6.0	7.5

[1] Insulation thickness is based on maintaining 140°F jacket temperature; for process fluid temperatures below 140°F, insulation is not required for personnel protection (PP).

ATTACHMENT PS02

LAW TCO CUSTOMIZED PS02

Per 24590-WTP-3PS-PS02-T0001, Rev. 10
ENGINEERING SPECIFICATION FOR SHOP FABRICATION OF PIPING

This attachment defines the requirements and the work necessary for fabrication of piping subassemblies (pipe spools) in accordance with the requirements of ASME B31.3, Process Piping, other codes and standards, and documents as referenced in this specification. This specification applies to all quality levels as specified by the purchase order. For continuity and maintaining configuration control, the section numbers from the specification noted above have been retained.

1.2 Work Included

1.2.1.14 Perform Positive Material Identification (PMI) on completed fabrication in accordance with specification 24590-WTP-3PS-G000-T0002, *Engineering Specification for Positive Material Identification (PMI) for Shop Fabrication.*

1.4 Codes and Standards

1.4.1 ASME B321.3-1996; *Process Piping,* is the piping code for the WTP Project.

For Q applications, the editions of reference codes, standards and specifications shown in Appendix E of ASME B31.3-1996 listed below, and those listed in 24590-WTP-3PS-PB01-T0001, *Engineering Specification for Technical Supply Conditions for Pipe, Fittings, and Flanges,* are acceptable for use. If the Supplier wants to use a later edition or addenda of a reference code, standard, or specification then the Supplier shall submit an SDDR.

When using ASTM material specifications for commercial material (CM) items, any version more recent than the ASTM version listed in Appendix E of ASME B31.3 1996 is acceptable. An SDDR is not required for these commercial material (CM) item ASTM material specification edition changes.

ASME materials identified in ASME Boiler & Pressure Vessel Code, Section II Material Specifications as being identical to the ASME B31.3, Appendix E listed ASTM Material Specifications, for the year, alloy, type and / or grade, (if applicable), are acceptable for use.

See Specification 24590-WTP-3PS-PB01-T0001, Section 2.1 for ASTM Material Specifications table for acceptable years.

1.4.1.1 The American Society of Mechanical Engineers (ASME)

ASME B16.11-1991; *Forged Fittings, Socket-Welding and Threaded*

ASME B16.25-1986; *Buttwelding Ends*

ASME B16.28-1986; *Wrought Steel Buttwelding Short Radius Elbows and Returns*

ASME B16.36-1988; *Orifice Flanges*

ASME B16.47-1990; *Large Diameter Steel Flanges NPS 26 through NPS 60*

ASME B16.5-1988; *Pipe Flanges and Flanged Fittings NPS 1/2 through NPS 24 Metric/Inches*

ASME B16.9-1986; *Factory-Made Wrought Buttwelding Fittings*

ASME B36.10M-1985; *Welded and Seamless Wrought Steel Pipe*

ASME B36.19M-1985; *Stainless Steel Pipe*

1.4.1.2 ASME Boiler and Pressure Vessel Code (B & PV)

ASME B & PV Code Section V- latest edition, *Nondestructive Examination*

ASME B & PV Code Section VIII, Division 1, latest edition, *Rules for Construction of Pressure Vessels*

ASME B & PV Code Section IX- latest edition, *Welding and Brazing Qualifications*

1.4.1.3 American Society for Testing and Materials (ASTM) Material Specifications

For ASTM material designations, refer to 24590-WTP-3PS-PB01-T0001, *Engineering Specification for Technical Supply Conditions for Pipe, Fittings, and Flanges*

1.4.1.4 Pipe Fabrication Institute (PFI) Standards

ES-7 - 1962 (R1984), *Minimum Length and Spacing for Welded Nozzles*

1.4.1.5 Manufacturers Standardization Society

MSS SP-25-1978 (R1988), *Standard Marking System for Valves, Fittings, Flanges, and Unions*

MSS SP-83-1987, *Class 3000 Steel Pipe Unions Socket Welding and Threaded*

MSS SP-95-1986 (R1991), *Swaged Nipples and Bull Plugs*

MSS SP-97-1987, *Integrally Reinforced Forged Branch Outlet Fittings*

1.4.2 Other Standards

The following standards are not reference standards of ASME B31.3, 1996, but are acceptable for use to facilitate ASME B31.3 piping fabrication, or are used for pipe fabrication that is not within the scope of ASME B31.3.

1.4.2.1 Pipe Fabrication Institute (PFI) Standards

ES - 3, Fabricating Tolerance

ES - 5, Cleaning of Fabricated Piping

ES - 16, (Deleted)

ES - 24, Pipe Bending Methods, Tolerances, Process, and Material Requirements

ES - 31, Standard for Protection of Ends of Fabricated Piping Assemblies

1.4.2.2 International Association of Plumbing & Mechanical Officials

Uniform Plumbing Code (UPC), 1997 Edition

1.4.3 In case of a conflict between the requirements of the referenced codes, standards, specifications, regulations, and procedures, the Supplier shall submit a recommended resolution to the BUYER via a Supplier Deviation Disposition Request (SDDR) for review and permission to proceed prior to implementation.

1.5 Reference Documents and Drawings

The entire list of documents below may or may not apply in all cases. Refer to the purchase order for a listing of those documents that are applicable.

1.5.1 24590-WTP-3PS-PB01-T0001, *Engineering Specification for Technical Supply Conditions for Pipe, Fittings, and Flanges*

1.5.3 24590-WTP-3PS-NWP0-T0001, *Engineering Specification for General Welding and NDE Requirements for Supplier Fabricated Piping*

1.5.9 24590-WTP-3PS-G000-T0002, *Engineering Specification for Positive Material Identification (PMI) for Shop Fabrication*

1.7 Cleaning and Coating

See Attachment AFPS for additional clarification.

1.7.1 Cleaning

1.7.1.1 Perform cleaning after fabrication has been completed. Cleaned piping shall be free of loose rust or mill scale, blisters, grease, sand, oil, dirt, and other foreign materials.

1.7.1.2 Fabricated spools shall be cleaned in accordance with the standard cleaning method described in PFI-ES-5.

1.7.1.3 Clean austenitic stainless steel, nickel alloy, and titanium piping in a protected area that is free from airborne chloride contamination. Prevent contamination from non-stainless steel, non-nickel alloy or non-titanium particles such as machine chips, grinding dust, weld spatter, and other debris during fabrication by shielding or other suitable means.

1.7.1.4 Only austenitic stainless steel brushes not previously used on other material may be used on austenitic stainless steel piping.

Stainless steel wire brushes that have not been used on other materials shall be used to clean nickel alloy or titanium.

1.7.1.5 Where solvent is required to remove grease or oil from austenitic stainless steel piping, acetone, or alcohol (ethyl, methyl, or isopropyl) shall be used. Alternatively, a detergent flush may be used in lieu of solvent cleaning with prior permission to proceed from BUYER.

- Cleaning solvents used for cleaning titanium materials are methyl alcohol, acetone, or other chlorine-free solvents.
- Titanium weld preparation includes removing any oil, grease, dirt, or grinding dust from surfaces to be joined. Steam cleaning or an alkali dip in a dilute solution of sodium hydroxide can remove most of these contaminants. To remove the last remaining organic compounds just before welding, use a lint-free glove and methyl alcohol, acetone, or other chlorine-free solvent.

1.7.1.6 Final cleaning materials in contact with austenitic stainless steel shall contain less than 200 ppm chlorides. If detergent cleaning is used, rinse austenitic stainless steel with potable water having no more than 100 ppm chloride content. After rinsing, the piping shall be drained out completely such that no standing pockets/puddles of water remain that may later concentrate by evaporation. Removal of excess rinse water may be augmented by swabbing, use of a "squeegee," or air blowing.

1.7.1.7 After cleaning, blow dry the interior surfaces of all piping with clean, filtered, oil-free air.

1.7.3 External Surface Coating

1.7.3.1 Apply external surface coating in accordance with Attachment AFPS, Appendix D, Number 8.20, System Code D.

1.7.3.4 Do not paint the gasket seating surface of flange faces. The gasket seating surface of flange faces shall be cleaned and coated with a one of the following rust preventives:

1.7.3.4.1 Grease (manufacturer's standard)

1.7.3.4.2 Lectra Shield and SP-400, CRC Industries

1.7.3.4.3 Mobilarma 247, Mobil

1.7.3.4.4 Any preservative listed in Attachment AFPS

1.8 Packaging, Storage, Handling, and Protection

Packaging, handling, and storage of pipe spools are as list below. These requirements are based on the applicable requirements listed in Specification 24590-WTP-3PS-G000-T0003.

1.8.1 Sealing Openings

1.8.1.1 Comply with the minimum end protection requirements criteria outlined in PFI-ES-31 to protect all openings and/or as required in the purchase order. The BUYER must provide review and give permission to proceed prior to use of each specific type of desiccant material. Fabrications must be clearly marked indicating desiccant inside.

1.8.1.2 Cover all pipe openings with metal, polyethylene, or nonmetallic end caps, flange protectors, or plugs. Polyethylene or nonmetallic end caps and plugs shall be friction fit, (e.g., Niagara series) or secured by other means. At a minimum, one of the caps or plugs on each spool shall be provided with a 1/8-inch max diameter vent hole to preclude the buildup of internal pressure. Avoid placing the cap or plug with the vent hole on a spool that is oriented in an upward, vertical position. Tape shall not be used to secure end caps or plugs. Clamps used for securing end caps, on stainless steel or alloy spools, shall be made of stainless material.

1.8.2 Marking

1.8.2.3 Any marking material and packing tape used on stainless steel or alloy material is required to be made from low chloride (less than 200 ppm) and low sulfur (less than 400 ppm) type material. The Supplier shall provide a chemical analysis report of the marker/tape for each lot or typical representative sample. The chemical analysis report shall be submitted for BUYER's review and permission to proceed. A copy of the report is not required with each shipment of pipe spools.

2.1.2 Material Traceability

2.1.2.1 Material traceability (such as identification of the item to applicable material specification, heat, batch, lot, part, or serial number or specified inspection, test, or other records) also includes transferring material identification mark(s) prior to subdividing material for all piping material. Traceability is being able to trace the piping material to the applicable MTR. All piping material, regardless of quality level, requires traceability.

2.1.5 Positive Material Identification (PMI)

To ensure material is correctly supplied as specified, the Supplier shall perform Positive Material Identification (PMI) tests in accordance with Specification 24590-WTP-3PS-G000-T0002. The Supplier shall submit their PMI test procedure for BUYER's review and permission to proceed. Note that PMI is not applicable for carbon steel materials and titanium materials. PMI is not to be performed on BUYER furnished valves unless otherwise stated in the purchase order.

2.1.6 Material Commitment

The Supplier shall submit to the BUYER a complete itemized listing of all materials purchased or reserved from the Supplier's inventory for each project. The Supplier shall also provide, upon request, the current status of pre-bought or BUYER-furnished material.

2.1.7 Material Substitutions

All materials shall be in accordance with the BUYER-furnished drawings, the purchase order, and specifications, unless written permission to proceed is granted by the BUYER via the SDDR in accordance with the purchase order requirement.

2.1.8 Material Identification and Marking

2.1.8.1 All materials shall be marked with the information and using marking materials required by the specific ASTM or ASME material specification.

2.1.8.2 Labeling with a marking pen on stainless steel and nickel based alloy material shall be done by any permanent method that will neither result in harmful contamination or sharp discontinuities, nor infringe upon the minimum wall thickness. All marking materials other than material manufacturer's marks shall be of the low chloride (less than 200 ppm) and low sulfur (less than 400 ppm) type. It is acceptable to use a rounded, low stress, vibro-etch tool for this marking.

2.1.8.3 Weld identification symbols must be recorded on detailed spool sheets and extended spool sheets (as applicable) with a cross-reference to any NDE report numbers.

2.1.8.4 Any piece of material not readily identifiable during fabrication shall be rejected, including other components welded thereto.

2.1.8.5 Deleted

2.1.9 Damaged Materials

2.1.9.4 The Supplier shall not make any base metal material repairs using welding.

3 Execution

3.1 Fabrication

3.1.2 Weld Joint Preparation

3.1.2.2 Do not use backing rings.

3.1.7 Flanges

Furnish flanges for flanged connections in accordance with the piping material classes and as shown on design drawings.

3.1.7.1 All slip-on flanges shall be double welded in accordance with paragraph 328.5.2 of ASME B31.3 unless directed otherwise by design document(s).

3.1.10 Valves

3.1.10.1 Install all valves in accordance with the manufacturer's recommended instructions and design drawings. BUYER shall furnish valve manufacturer's installation/disassembly instructions for Supplier's use and reference. The Supplier shall notify the BUYER if they have not been sent the applicable valve manufacturer's installation/disassembly instructions.

3.1.10.2 In addition to manufacturer's instructions, the following apply for valve installation:

3.1.10.2.1 Valve stems shall be positioned in accordance with the isometric and is normally not be inclined below the horizontal. Also, flow arrows, when present on the valve, must align with the flow arrow shown on the isometric.

3.1.10.2.2 Before conducting any welding on diaphragm valves or other soft-seated valves, the bonnet assembly and diaphragm, and any other heat-sensitive components shall be disassembled and valve body cooled, if required by vendor instructions. Particularly for stainless steel valves, care shall be exercised to ensure that contact with cooling medium (e.g., water-soaked wick) is not harmful. Water used for cooling of stainless steel valves shall have a maximum chloride content of 200 ppm.

3.1.10.2.3 To prevent damage or distortion to valve seat and disc, follow the vendor's instructions with respect to position of the valve stem and the disc during installation and welding.

3.1.10.2.4 If disassembly beyond the vendor's standard installation instruction is required, valves and actuators shall be disassembled and reassembled only after documented concurrence has been obtained from the BUYER that doing so will not compromise the warranty and performance of the valve.

3.1.10.2.5 Manual valves shall be disassembled and reassembled, if required, in accordance with the manufacturer's disassembly and reassembly procedures.

3.1.10.2.6 Valves shall be handled and supported with care to preclude damage to handwheels and appurtenances. Lifting lugs shall be used whenever they are provided on a valve. In no case shall a valve be picked up by the valve actuator.

3.1.11 Rework of Fabricated Spools

3.1.11.1 Reworked spools being shipped to the jobsite shall be provided with a Certificate of Conformance (C of C) stating the spools identified are the same spool number(s) originally delivered and received. The C of C shall state that the re-worked spools are in strict accordance and fully comply with the purchase order and all procedures and specifications. The C of C shall also state the re-work performed on each spool.

If additional materials are added, or if additional documentation is provided (NDE reports, MTRs, etc.) a complete documentation package for that spool shall be furnished.

3.2 Inspection and Testing

3.2.1 General

3.2.1.1 The Supplier is responsible for nondestructive examination and testing of piping furnished under this specification.

3.2.1.2 All examination, inspection, and testing shall be in accordance with this specification and other governing codes and standards, as applicable. This includes nondestructive examination of the piping spools in accordance with the requirements for Normal Fluid Service piping in ASME B31.3-96.

3.2.1.3 BUYER's representative shall be provided free access to the Supplier's and Supplier's subcontractor's or Supplier's facilities, to witness, inspect, and report progress of work.

3.2.1.4 Note: No sub-supplier shall perform NDE work without prior submittal of the sub-supplier's NDE procedure and BUYER's review and permission to proceed.

3.2.2 Examination of Fabrication Welds

3.2.2.1 Examine all completed pressure boundary welds in accordance with the ASME B31.3-96 and/or standard, including the requirements listed below, as applicable. Weld repair shall be examined according to the requirements used for the original weld.

3.2.2.2 Perform and evaluate examinations in accordance with procedures and acceptance standards prepared in accordance with the ASME B31.3-96 and/or standard, and the *ASME Boiler & Pressure Vessel Code*, Section V.

Summary Table of Non-Destructive Examinations (NDE) of Pipe & Tubing Shop Welds

Table 2 Piping Weld Examination Requirements

See sections 3.2.2.2 for applicable shop weld NDE, inspection, and acceptance criteria requirements.

Type of Weld	Piping Outside Black Cells and Hard-To-Reach areas
All Girth and Miter Welds	100% VT 5% RT or 5% UT
All Pipe and Integral Attachment Fillet Shop Welds - including thermowell socket welds, integral support welds, non pressure & non load bearing piping attachment welds	100% VT
All integrally reinforced forged branch fittings welded to main piping run.	100% VT

Legend: VT = Visual Examination per ASME B31.3 para 344.2
RT = Radiographic Examination per ASME B31.3 para 344.5
UT = Ultrasonic Examination per ASME B31.3 para 344.6
PT = Liquid Penetrant Examination per ASME B31.3 para 344.4
MT = Magnetic Particle Examination per ASME B31.3 para 344.3

ATTACHMENT AFPS

LAW TCO CUSTOMIZED AFPS

Per 24590-WTP-3PS-AFPS-T0001, Rev. 4

ENGINEERING SPECIFICATION FOR SHOP APPLIED SPECIAL PROTECTIVE COATINGS FOR STEEL ITEMS AND EQUIPMENT

Only the sections and appendices contained in this Attachment AFPS apply to the LAW Thermal Catalytic Oxidizer/Reducer (TCO). For continuity and maintaining configuration control, the section numbers from the AFPS specification noted above have been retained. Additional clarifications have been added to Sections 1.1 and 6.4.1, identified by an asterisk.

1 Scope

1.1 This specification defines the minimum requirements for Special Protective Coating (SPC) materials/coating systems, surface preparation, application, and inspection of protective coatings to be shop applied. Items and surfaces to be coated shall be coated in accordance with Appendix D of this specification. Unless indicated otherwise in the base technical specification/material requisition or purchase order, all coats will be shop applied. Finish color shall be *ANSI 70 Gray unless indicated otherwise in Section 2.0 of the Material Requisition (MR).

1.2 All Special Protective Coatings (SPC's) are designated as Commercial Grade (CM) and non-safety.

2 General

2.1 Responsibility

2.1.1 The SELLER shall supply all personnel, coating materials and all necessary surface preparation, application, inspection and other equipment as required.

2.1.2 The SELLER shall unload, inspect, and store all inbound steel items and equipment scheduled for coating when manufactured by others. Items found to be damaged or otherwise unsuitable for coating shall be identified and segregated for evaluation by the SELLER.

2.1.3 The SELLER shall store all coating materials, perform surface preparation, coating application and inspection in accordance with this specification and Buyer reviewed procedures. The coating systems and associated coating materials used shall be in accordance with Appendix D Coating Schedule or the Material Requisition (MR) when coatings are specifically identified.

2.1.4 The SELLER shall perform all inspections and tests contained in this specification as necessary prior to verification by the BUYER.

2.1.5 The SELLER shall provide application and inspection documentation for all coating Work in accordance with this specification.

2.1.6 The SELLER shall provide environmental control equipment as necessary for coating application and curing.

2.1.7 The SELLER shall provide erection marking. Marks for color-coding of bulk materials and erection marking shall be fully compatible with the coating system specified.

2.1.8 The SELLER shall touch-up and repair defective or damaged coating in accordance with procedures submitted and reviewed by the BUYER.

2.1.9 The SELLER shall protect all coated surfaces prior to shipment and provide suitable coverings, padding and strapping to protect coated items during shipment.

2.1.10 The SELLER shall only use inspection equipment that is currently (in date) calibrated.

2.2 Surfaces Not To Be Coated

2.2.1 Hold back coating from weld areas-

2.2.1.2 Three (3) to Four (4) inches for **shop** welds when using epoxy or other types of organic coatings

2.2.1.4 Note - The above coating hold back dimensions are only for items previously coated prior to welding. These coating hold back dimensions do not apply to shop welds that will be coated after welding is completed. This Section of the shop coating spec does not have anything to do with coating cold back requirements associated with visual inspection of welds during hydro testing. Coating hold back requirements associated with weld inspection must come from the prevailing code.

2.2.1.6 The coating hold back shall be sufficient to expose the entire shop weld for visual inspection on items fabricated prior to coating.

2.2.2 Name and instruction plates, etc.

2.2.3 Rubber or similar nonmetallic parts.

2.2.4 Machined surfaces.

2.2.5 Non-Ferrous metals unless otherwise specified.

2.2.6 Stainless Steel surfaces, unless specifically required by the BUYER (areas where stainless steel is welded to carbon steel the coating overlap onto the stainless steel shall be approximately 1" or as otherwise specified.)

2.3 Definitions

2.3.1 Batch- A quantity of coating made in one production run. A unique batch number is assigned for each production run of the coating material, curing agent, zinc powders, fillers and thinner.

2.3.3 Dry Film Thickness (DFT)- The thickness of an applied coating, once dry or cured. Usually expressed in mils (each mil is 1/1000 of an inch).

2.3.4 Fish Eyes (cratering)- Formation of holes or visible depression in the coating film. Usually from a contaminated particle on the surface prior to applying the coating.

2.3.5 Holiday- A Pinhole, skip, discontinuity, or void in the applied coating film.

2.3.7 Mfg. Std. Coating- A manufacturers standard coatings system applied to off the shelf items or standard line items of routine manufacture that are not specifically manufactured for the WTP project.

2.3.8 NIST- National Institute of Standards and Technology.

2.3.10 Pinholes- Minute holes visible in the applied coating without magnification that appears to penetrate one or more layers of the coating film.

2.3.11 Profile- The surface roughness resulting from surface preparation by abrasive blasting or other authorized methods. (Refer to Section -7.3.6).

2.3.13 Sag- The running of freshly applied coating on a vertical surface due to being applied too thick. (Same definition for runs and drips)

2.3.16 Training and Certification- Training shall include an understanding of the specification, work procedures and manufacturers published instructions. Certification shall include a documented performance test demonstrating quality work verifiable by the BUYER. (Refer to Sections 4.8, 5.1.7, 7.1.2, and 8.1.1.1)

2.4 Safety

2.4.2 The SELLER shall comply fully with OSHA Hazard Communication Standard 29CFR 1910. Material Safety Data Sheets (MSDS) for all materials, including thinners and cleaning solvents, shall be obtained from the materials manufacturer and upon request made available, at the place and time of Work, for review.

2.4.3 The Volatile Organic Compound (VOC) content of all materials shall comply with Federal, State and Local or other Regulatory requirements.

3 Applicable Documents

3.1 Codes and Standards

The latest applicable edition of the following codes, standards, specifications or WTP procedures form a part of this specification.

3.1.1 American Society for Testing and Materials (ASTM)

ASTM E337- R96; 02	Test for Relative Humidity by Wet-and-Dry Bulb Psychrometer
ASTM D3276- 00; 05	Standard Guide for Painting Inspectors (Metal Substrates)
ASTM D4285- 99	Test Method for Indicating Oil or Water in Compressed Air
ASTM D4417- 99; 03	Field Measurement of Surface Profile of Blast Cleaned Steel
ASTM D4537- 96; 04; 04a	Standard Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work Inspectors in Nuclear Facilities.
ASTM D4940- 98; 03	Test for Conductimetric Analysis of Water Soluble Ionic Contaminants of Blasting Abrasives
ASTM D5064-01	Standard Practice for Conducting a Patch Test to Assess Coating Compatibility

3.1.2 The Society for Protective Coatings (SSPC)

SSPC-AB1 6/1/97;7/1/07	Mineral Slag Abrasive
SSPC-PA2 5/1/04	Measurement of Dry Paint Thickness with Magnetic Gages
SSPC-SP1 11/1/82;11/1/04	Solvent Cleaning
SSPC-SP10 11/1/04	Near White Metal Blast Cleaning
SSPC-SP11 11/1/87; 11/1/04	Power Tool Cleaning to Bare Metal
SSPC-VIS 1 6/1/02; 11/1/04	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

3.1.3 Occupational Safety and Health Administration (OSHA)

OSHA 29 CFR 1910	Occupational Safety and Health Standards

4 Submittals

4.1 SELLER shall prepare detailed written procedures for material receiving, marking, storage, handling, surface preparation, environmental control, application, curing, inspection, testing, touch-up/repair, application personnel qualification, inspector qualification, (G321- E , category 28.0) and proposed documentation forms as described within this specification. The final procedure and documentation forms shall be submitted and

reviewed with BUYER's permission to proceed prior to the start of coating Work. (G321-E category 15.0). Submittal requirements for manufacturers standard coating are found in Section 6.0.

4.2 The SELLER shall submit all procedures and verification documents in accordance with the purchase order (e.g., Appendix J, Form G-321-E. & V, Exhibit "D" located in the purchase order.).

4.4 The SELLER shall identify the specific products by manufacturer and catalog number and shall submit the coating manufacturer's latest published product data sheet, application instructions and Material Safety Data Sheets (MSDS). Conflicts, if any, between the SELLER's normal procedures, the coating manufacturer's recommendations, and this specification shall be brought to the attention of the BUYER for resolution and written permission to proceed. (G321-E category 11.0)

4.5 The SELLER shall submit original or copies of original Coating Manufacturer's Product Identity Certification Records for each and every batch of coating material used on the WTP project (Appendix F). (Refer to G321V category 13.0)

4.6 The SELLER shall submit a daily inspection record as part of the Work procedures that includes all the elements provided in Appendix G as a minimum. An entry for Wet Bulb is not required when the accepted device used to measure humidity and dew point does not require a wet bulb. (Refer to Section 8.1.9 and 10.2) (G321V category 15.0)

4.8 The SELLER shall provide a personnel training and certification plan for applicators and inspectors. (Refer to Section 2.3.16, 5.1.7, 7.1.2 and 8.1.1.1.).

5 Quality Plan

5.1 General

5.1.1 The SELLER shall control the quality of items and services to meet the requirements of this specification, applicable codes and standards, associated procurement documents, referenced herein. The SELLER shall prepare and maintain documentation to provide evidence of compliance with reviewed procedures and this specification. A copy of the coating inspection documentation shall be included in the shipping documentation.

5.1.2 The SELLER, including any lower-tier organizations engaged by him, shall be subject to surveillance inspection by the BUYER representative until completion or termination of the procurement. This surveillance inspection does not relieve the SELLER from the responsibility for conformance to the requirements of procurement documents, this specification and authorized procedures.

5.1.4 The BUYER representative shall be provided with a work activity schedule and shall be notified of all required inspection points prior to the scheduled date for coating activities (Refer to MR Section 5.0).

5.1.5 If the SELLER's proposed Work plan or procedures differ from the requirements of this specification, the SELLER shall specifically identify and explain all differences in writing and submit them to the BUYER for review and verification prior to the start of Work (e.g., Supplier Deviation Disposition Request-SDDR).

5.1.6 All pre-established witness and hold points shall be witnessed by the BUYER unless a written waiver has been issued.

5.1.7 The SELLER's coating inspectors shall have previous experience in coating inspection and shall receive documented training in the specific project coating requirements, ASTM standards and other relevant standards including the reviewed work procedures. All coating inspectors working on steel items or equipment shall be trained and qualified meeting the requirements of Section 8.1.1.1.

6 Materials

6.1 Coating Materials

6.1.2 Coating materials including the primer, intermediate and finish coat on a given item, shall all be from the same manufacturer. One exception to this rule is when upgrading a Manufacturer's Standard (Mfg. Std.) coating using a compatible epoxy tie-coat and suitable topcoat coating system (refer to Section 6.2).

6.1.3 Appendix D Coating Schedule and Appendix C Tables contain the specified Special Protective Coatings for the WTP project. Appendix C contains the generic coating systems and approved coating materials.

6.1.4 Repair materials shall be the same as those originally used. Repair materials shall be in pre-measured units, and only complete kits shall be mixed. Splitting or breaking down pre-measured units of multi-component coating materials may be considered if the SELLER prepares a procedure that requires accurate measurement of all materials and Seller's QC inspector monitoring/verification of each and every mix. This procedure must be submitted to the BUYER for review and permission to proceed.

6.2 Manufacturer's Standard Coating

6.2.1 Components and equipment which are normally mass-produced, inventoried, and supplied from stock generally have been coated with the Manufacturer's Standard Coating (Mfg. Std.) system. Included are small valves, pumps and rotating equipment, filters and electrical equipment such as switchgear, control panels, instrumentation, motors, transformers and electrical enclosures. Items and equipment which are specifically fabricated for the WTP project shall be coated per this specification unless the item is shown to be too delicate to properly coat per Appendix D or the specific requirements contained in the MR.

6.2.1.1 The SELLER may submit an alternate coating to the specified or Mfg. Std. System, by identifying the coating materials, surface preparation, application and inspection on Appendix H including the coating material's latest published technical data sheet and MSDS, to the BUYER for review and permission to proceed.

6.2.1.2 All Mfg. Std. coatings must be identified on an Appendix H and submitted to the BUYER along with technical data sheets and MSDS'. A small, easily replaceable item where coating touch-up is not practical (e.g., very small, too delicate, low cost and easily replaceable) and can only be purchased with the manufacturer's standard coating, an Appendix H Manufacturer's Standard Coating Data Sheet is not required.

6.2.1.3 Deleted

6.3 Machined-Surfaces Coating

6.3.1 Machined surfaces not specified to be coated with a specific coating system shall be protected with a solvent cutback asphalt temporary preservative (Daubert Chemical Tectyl 891, EF Houghton Chemical Rust Veto 342 or authorized equivalent). Temporary preservative applied to carbon steel that is overlapped onto stainless steel must meet the same chemical requirements as listed in Section 6.4. All equivalents must be identified on an Appendix H form and submitted along with the manufacturer's latest published data sheet and MSDS for review and permission to proceed by the BUYER.

6.4 Coating Over Stainless Steel

6.4.1 All coating materials, thinners, solvents and cleaning materials used on SS shall be shown to comply with the following requirements:

Leachable halogen content shall not exceed 200 ppm

The total sulfur content shall not exceed 400 ppm

The total of low melting point metals such as lead, zinc, copper, tin, antimony and mercury shall not exceed one (1) percent. Of this, mercury should not exceed 50 ppm. These low melting metals shall not be intentionally added during the manufacture of the coating.

* (ADDED for LAW TCO MR): Sherwin Williams Macropoxy 646 and Carboline Carboguard 890 have been tested and meet the requirements above. Only these materials are approved for direct contact with stainless steel.

6.5 Batch Information

6.5.1 Each container of coating material used by the SELLER shall be marked with the following:

- The manufacturer's name
- The product designation
- Batch or lot number
- Location and date of manufacture
- The shelf life expiration date

6.6 Abrasives

6.6.1 Abrasives for blast cleaning shall be clean, free of oil or contaminants, and dry. The particle size shall be capable of producing the specified surface profile. Mineral and slag abrasives shall meet the requirements of SSPC AB-1. The first batch/lot of bulk, non-packaged, abrasives shall be tested for water-soluble contaminants and the conductivity shall not exceed 500 micro siemens/cm when tested in accordance with ASTM D4940. As an alternate, a chloride ion test kit, such as the Chlor*Test "A" manufactures by Chlor Rid International Inc, or BUYER accepted equal may be used. The maximum allowable chloride level is 200ppm.

6.6.2 When using reclaimed steel grit/shot abrasive, the particle size shall be capable of producing the specified angular surface profile (minimum 50% steel grit in original mix and all adds shall be 100% steel grit). Reclaimed abrasives already in use and the first batch/lot of new abrasive shall be tested for water-soluble contaminants and conductivity. Conductivity shall not exceed 500 micro siemens/cm when tested in accordance with ASTM D 4940. As an alternate, a chloride ion test kit, such as the Chlor*Test "A" manufactures by Chlor Rid International Inc, or BUYER accepted equal may be used. The maximum allowable chloride level is 200ppm.

7 Application

7.1 General

7.1.1 It shall be the SELLER's responsibility to stop the surface preparation and coating at any time when conditions exist that might adversely affect the quality. The BUYER representative may reject any prepared or coated surfaces not in compliance with this specification.

7.1.2 All painters (e.g., surface preparation personnel and paint/coating material application personnel), shall be individually qualified and certified in accordance with the SELLER's written description that includes classroom training and capability demonstration using the WTP project specification, and the SELLER's procedures as reviewed by the BUYER.

7.1.3 Care shall be taken to avoid blasting or grinding away critical markings, which identify welders, joint numbers, or other markings, which identify the item. Where such data appears in the area to be coated, it shall be protected. SELLER's are responsible for assuring their Sub-Suppliers are instructed concerning these requirements.

7.2 Pre-Surface Preparation

7.2.1 Prior to mechanical cleaning, the surfaces to be coated shall be cleaned in accordance with SSPC SP1 to remove oil, grease, dirt, and other foreign matter that can interfere with the proper bonding of the coating. Any remaining sharp edges, weld spatter, or burrs found after the start of coating Work shall be completely removed by grinding or other means. Pneumatic tools shall not be used unless they are fitted with effective oil and water traps on the exhaust air. If the steel items or equipment was shipped or stored so that the surface could have been contaminated with soluble salts (e.g., above deck ship transport, truck transport on dirt roads close to ocean, storage), the area shall be pressure water washed (2,000-5000psi) with demineralized water to remove as much soluble salt contamination as possible prior to abrasive blasting.

7.3 Surface Preparation

7.3.1 Prior to the start of Work, the SELLER shall examine all surfaces to be coated to determine their acceptability for the specified coating application. If the surfaces are found to be unacceptable, the SELLER shall return the surface to an acceptable condition. Coating work shall not commence until corrective action has been taken. Commencement of coating work prior to the taking of correctable action shall preclude any subsequent claim by the SELLER. The BUYER may require corrective action at the SELLER's expense.

7.3.2 Prior to blast cleaning items to be coated, they shall be visibly dry with the surface temperature of at least 5°F above the dew point. When using automatic blasting equipment that recycles steel abrasive, the steel need only be visibly dry.

7.3.3 All surfaces to be coated shall be pre-cleaned per SSPC SP 1 where oil, grease, and other contaminants are present.

7.3.4 Abrasives shall meet the requirements of Section 6.6.

7.3.5 Surfaces to be coated shall be blast cleaned in accordance with the surface preparation requirements specified in Appendix D (e.g., SSPC SP10). Where abrasive blasting will damage the items or is impractical, SSPC-SP11 Power Tool Cleaning to bare Metal may be substituted only in limited areas and only with BUYER's permission to proceed (e.g. SDDR).

7.3.6 Abrasive blasting carbon steel shall result in an angular surface profile 1.5 to 3.0 mils deep as measured using a profile comparator or Testex Press-O-Film replication tape, in accordance with ASTM D4417 method A or C.

7.3.6.1 Methods established for measuring surface profile produced by abrasive blast cleaning are not valid or conclusive on surfaces that are excessively rough prior to blast cleaning (e.g. rough mill finishes, heavy rusting or pitting [SSPC-VIS 1 Condition D or rougher], cast surfaces, weld beads or physically damaged surfaces). Therefore, to accurately determine the surface profile produced by blast cleaning, profile measurements shall be taken in areas exhibiting the least surface roughness. For example, SSPC-VIS 1 pre-blast Conditions A, B or C typically result in a blasted surface that is acceptable for surface profile measurement.

7.3.6.2 If excessive surface roughness covers the entire item, then a smooth, clean ASTM A36 steel plate (e.g., SSPC-VIS 1 Condition A, B or C), approximately 6" square and at least 1/4" thick, shall be blasted using the identical abrasive, pressure, nozzle, blasting equipment and method used on the actual item. The surface profile measured on the smooth plate is regarded as an accurate measurement of the profile produced by that blasting method, and shall be recorded as the surface profile for the actual item. A new plate shall be blasted and measured at a frequency accepted in the SELLER'S procedures (refer to Section 8.1.9).

7.3.7 Recycled abrasive blasting using a steel grit/shot mix is acceptable. The maximum amount of shot in the original mix shall be 50%. All additions of abrasive shall be steel grit. The stabilized working mix shall be maintained by frequent small additions of new grit abrasive commensurate with consumption.

Infrequent large additions of grit shall be avoided. Steel grit or shot is not acceptable for use on stainless steel surfaces.

7.3.7.1 The working abrasive mix shall be maintained clean of contaminants by continuous effective operations of cleaning machine scalping and air wash separators. Reclaimed grit used for abrasive cleaning shall be tested for the presence of oil/grease by immersing a sample in clean tap water and checking for oil flotation. Tests shall be made at the start of blasting and at a minimum of every four (4) hours thereafter. If oil is evident, the contaminated abrasive shall be cleaned or replaced. All surfaces blasted since the last successful test shall be completely cleaned of contamination then re-blasted using clean abrasive.

7.3.8 Blast cleaning shall not be performed in the immediate area where coating or curing of coated surfaces is in progress. All surfaces and equipment, which are not to be coated, shall be suitably protected from blast cleaning.

7.3.9 Burrs, slivers, scabs, lamination, and weld spatter which become visible after blasting shall be removed. The tools and manner employed to remove weld defects and sharp edges shall not burnish or destroy the profile. If the profile or roughness is reduced, it shall be re-blasted to produce the profile and roughness as required. The exhaust of pneumatic grinders shall not impinge on the cleaned surface. If the surface becomes contaminated, it shall be cleaned of contamination and re- blasted. Carbon steel tools or implements specifically employed for coating surface preparation shall not be used on stainless steel surfaces.

7.3.10 If visible rust occurs or if the cleaned surface becomes wet or otherwise contaminated, these surfaces shall be re-cleaned to the degree specified. Cleaned surfaces remaining uncoated overnight shall be visually reinspected 100% for required cleanliness prior to coating or shall be re-cleaned to the specified cleanliness prior to applying the coating.

7.3.11 After surface preparation is complete and before coating, pressurized air or a vacuum shall be used to remove all dust and abrasive residue. The air shall be clean and dry as verified in accordance with Section 8.1.6 so as not to contaminate the prepared surface.

7.3.12 Machined surfaces shall be wiped with clean solvent before the application of coating and shall be protected from damage due to blasting and coating operations.

7.3.13 Machined portions of pipe flanges and other machined mating faces which will not be exposed after final fit-up shall be masked or covered and protected from surface preparation and coating activities. The remaining part of the flange face and exposed surfaces shall then be blasted and coated (bolt holes need only to be sufficiently coated for visible coverage. No dry film thickness required.).

7.3.14 Equipment shall have all openings plugged, masked, and/or blinded sufficiently to protect internals before abrasive blasting. After the coating operation is complete all internals shall be blown clean and/or vacuumed to remove any dust or abrasive blast media that may have entered the coated equipment.

7.3.15 The abrasive mixture and the compressed air shall be clean, dry and oil free. Moisture traps, in addition to oil and water extractors mounted on the compressor, shall be used in compressed air lines to remove oil and moisture from air close to the point of use. (Refer to Section 7.3.7.1 and 8.1.6)

7.3.16 All valves, valve actuators and motors that will be shop coated shall be blasted and coated prior to assembly. Areas of assembled items that are not coated prior to assembly and subject to damage during blasting must be carefully protected from abrasive damage or abrasive contamination.

7.4 Coating Application

7.4.1 The coating shall be applied in accordance with reviewed procedures (refer to Section 4.1). The coating manufacturer's recommendations for the application temperature and the curing temperature and times (between coats and after last coat) of the specified material shall become a part of this specification.

Application and curing temperatures above or below the limits allowed by this specification (Refer to Section 7.4.4) shall be submitted to the BUYER for review (e.g., SDDR).

7.4.2 Coatings shall be applied using properly sized and type of equipment for the size & complexity of the item being coated. The equipment shall be clean with all components in good working order.

7.4.3 Surfaces that will become inaccessible shall be coated before assembly, tagging, fitting, or welding. Inaccessible surfaces includes lap joint flanges, nozzle necks, lap joint stub ends, lap rings, bolt holes, flanges for exchangers and vessels, and welded joints that become inaccessible after assembly.

7.4.4 Coatings shall be applied only when the surface to be coated is clean and dry. The substrate temperature shall be a minimum of 5°F above the dew point during coating application and until the applied coating is no longer moisture sensitive per the coating manufacturer's published data or written recommendations. The substrate and air temperature during coating application and curing shall be a minimum of 50°F (Inorganic zinc primers 40°F) and a maximum of 110°F. The relative humidity during coating application shall not exceed 85 percent. Measure humidity in accordance with ASTM E 337 (Sections 1.0-19.0) or using an alternate method reviewed and accepted by the BUYER. Deviations from the above listed minimum and maximum substrate/air temperature and humidity limits may be allowed when in accordance with the coating manufacturer's published or written recommendations and are accepted by the BUYER. The one firm limit is that the minimum substrate or air temperature shall not be less than 35 °F regardless of the coating manufacturer's published or written recommendations.

7.4.5 The SELLER shall record all batch numbers for each coating component used along with other information necessary for the BUYER to relate the batch to the item for which it was applied. (Refer to Appendix G)

7.4.6 All coatings shall be thoroughly mixed until they are smooth and free from lumps, then strained through a screen of at least 30 mesh. Zinc filled coatings shall be continuously agitated from the time initially mixed and while being applied. Other coating materials shall be mixed in accordance with the coating manufacturer's published recommendations. All multi-component coating materials shall be in pre-measured units. Splitting or breaking down pre-measured units is not permitted. See Section 6.1.4 for requirements for mixing repair materials.

7.4.7 Alternating coats shall have a visible color difference to insure full coverage over previous coats. Touch-up of individual small spots < 6 sq. in, do not require a visible color difference when individually marked for repair and the mark remains in place until the repair is accepted.

7.4.8 Dry film thickness of each coating shall be in accordance with Appendix C/Table 1 Acceptable Coating Materials or as specified in the MR. (Refer to Section 8.3.2 & 8.3.3).

7.4.9 Relative to the ambient and surface temperatures the minimum and maximum drying times between coats shall be in strict accordance with the coating manufacturer's latest published technical data sheets.

7.4.10 Runs, sags, voids, drips, overspray, loss of adhesion, bubbling, peeling, or inadequate cure are not permitted. Where possible, defects shall be corrected as detected during application of the coating.

7.4.11 Spray equipment, brushes and rollers shall be cleaned using only manufacturer recommended solvents/cleaners.

7.5 Remedial Work

7.5.1 The completed coating on each item shall have the correct dry film thickness and shall be free of damage and visible defects.

7.5.2 Repair of Dry Film Thickness (DFT) deficiencies

7.5.2.1 Defects such as runs, sags, overspray and embedded particles shall be corrected by sanding to remove the defect. When the defects are in the finish coat, all areas sanded must be overcoated with the finish coat. If the DFT of primer or intermediate coat is reduced to less than the specified

minimum, the area shall be abraded with 80 grit sand paper or flapper wheel and an additional layer of coating shall be applied until sufficient thickness is achieved. If noticed during application, the sags or runs may be brushed out.

7.5.3 Repair of Damage

7.5.3.1 All damaged and loosely adhering coating shall be removed and the surface thoroughly cleaned using 80 grit sanding disc, 80-grit flapper wheel or 3M Clean-N-Strip. Edges of the breaks shall be feathered and the resulting surfaces shall be roughened. The designated number of prime and finish coats shall be applied.

7.5.4 Loss of adhesion, delamination blisters, bubbling and fish eyes in the applied coating require the coating to be removed and reapplied in accordance with this specification.

8 Inspection

8.1 General

8.1.1 The SELLER shall have the full responsibility for the coating application quality in accordance with this specification and shall be responsible for stopping Work activities when conditions develop that could adversely affect the quality of the completed work. All Work is subject to the BUYER's inspection surveillance.

8.1.1.1 All coating Work inspection personnel shall be trained, qualified and certified in accordance with the SELLER's reviewed procedures. The inspectors shall meet or exceed the minimum capability requirements for a Level I coatings inspector as described in ASTM D4537 Section 6.2. The SELLER's inspector training, qualification and certification procedures and plan shall include classroom training on the WTP project specification, and the SELLER's reviewed procedures using the guidelines provided in ASTM D5498. The SELLER's inspector must demonstrate his/her capability of using the inspection equipment and performing all the required inspections. Additional coating work inspection guidance is found in ASTM D3276 and ASTM D6237 which may also be used in developing procedures for training and certifying coating work inspectors.

8.1.2 The BUYER representative shall be the final authority on the specification compliance for surface preparation and material application. Any coating, which in the BUYER representative's judgment, has not been applied in conformance with this specification, shall be rejected.

8.1.3 The BUYER representative shall have access to each part of the process and shall have the right and opportunity to witness any of the Quality Control Tests.

8.1.4 The SELLER shall furnish the necessary testing and inspection instruments, properly calibrated and maintained. If equipment is suspected of being out of calibration, it shall be re-calibrated and certificates made available for verification to the BUYER. Such equipment shall be available for use by the BUYER in conducting surveillance of the work. Calibration of testing and Inspection instruments shall be traceable to NIST or Buyer authorized alternative standards.

8.1.5 The SELLER shall halt the coating Work and make corrections to the procedures, as necessary to correct repetitive faults found in the Work.

8.1.6 Prior to using compressed air, the quality of the air downstream of the separator shall be tested in accordance with the requirements of ASTM D4285 by blowing the air onto a clean white blotter or cloth for two (2) minutes at a distance of no more than (12) inches to check for any contamination, oil, or moisture. "This test shall be performed at the start of work and every 4 hours thereafter". The test shall also be made after any interruption of the air compressor operation or as required by the BUYER. The air shall be used only if the test indicates no visible contamination, oil, or moisture. If contaminants are evident, the equipment deficiencies shall be corrected and the air stream shall be re-tested. Moisture separators shall be bled continuously. All lines shall be tested individually prior to use. Surfaces

determined to have been blown down or blasted with contaminated air shall be cleaned of all contamination then re-blasted with clean air and abrasive. Coatings determined to have been applied using contaminated air shall be removed and reapplied using clean air.

8.1.7 Inspection points shall be established as follows:

- Prior to the start of Work.
- Immediately following the surface preparation
- Immediately prior to the coating application
- Following the application of each coat
- Following the curing of the coating
- Final inspection and sign-off, in accordance with the project requirements

8.1.8 Any defects disclosed by inspection shall be re-inspected after correction.

8.1.9 The SELLER shall keep the records indicated below, and submit these records to the BUYER (refer to Section 4.6 and Appendix G). The following lists the frequencies:

Coating/Inspection Step		Required Frequency
1.	Pre-Surface Prep Surface Preparation Profile	100% visual on Pre- Surface 100% on Surface Prep/Cleanliness Profile first item of each type per shift and every 20 items thereafter or other frequency as BUYER accepted in SELLER's procedures.
2.	Environmental/Air Quality	At the start of each work and every 4 hours thereafter or more often during changing conditions.
3.	Recirculated Abrasive	At the start of work and every 4 hours thereafter
4.	Thickness Per SSPC PA2	On large items five (5) spot reading per 100 sq.ft. On items < 100 sq.ft. four (4) spot readings On items less than 4" (valves, fittings, components, etc) two (2) spot readings, For repair spots < 6 sq. inches and > 1 sq. inch. Two (2) spot readings For repair spots < 1 sq. inch one (1) spot reading For small chips/nicks/scratches and pinhole size repair spots need only a visual. For complex surfaces such as structural steel (steel beams) the frequency of dry film thickness readings shall be in accordance with SSPC-PA2 Appendix 3 section A3.4.1 excluding any readings on the flange toes. In accordance with figure A.3 "The Surface of a Steel Beam" the following locations are acceptable for the test readings- 1, 3, 4, 5, 7, 9, 10 and 11; and the following locations are excluded from test readings- 2, 6, 8, 12. For beams less than 20'-0" two (2) sets of 8 spot readings shall be taken.

		For beams 20'-0" thru 60'-0" three (3) sets of 8 spot readings shall be taken.
5.	Visual on Applied Coating.	100% of all items

8.2 Surface Preparation Inspection

8.2.1 Verify environmental conditions and compressed air quality (refer to Section 7.3.2, 8.1.6).

8.2.2 Verify recirculated grit is grease and oil free (refer to Section 7.3.7).

8.2.3 Verify surface cleanliness and profile (refer to Sections 7.3.5, 7.3.6 and 8.1.9).

8.2.4 Grease free chalk shall be used to mark local areas, which do not meet the specified requirements (e.g., soapstone and crayons are not acceptable).

8.3 Coating Application

8.3.1 Environmental conditions and compressed air quality shall be verified per Sections 7.3.2, 7.4.4, 8.1.6 and 8.1.9.

8.3.2 Dry coating thickness (DFT) shall be measured with a magnetic film thickness gage such as an Elektro-Physik "Mikrotest" or Positector 2000, Positector 6000 or BUYER authorized equal in accordance with SSPC PA2. The number and location of dry film thickness readings shall be in accordance with section 8.1.9.4.

8.3.2.1 The gage shall have an appropriate range that is suitable to measure the thickness expected and record calibration accuracy in accordance with SSPC PA 2 at the start of work, against certified coating thickness calibration standards for non-magnetic coating of steel, traceable to NIST or BUYER authorized alternative standards. The calibration standards shall be in date, and 1.5 mil to 20.0 mil range, unless otherwise specified.

8.3.3 Any surface with a measured thickness outside of the limits described in Section 7.4.8 shall be rejected. These areas shall be reworked or re-cleaned and re-coated at the SELLER's expense. The average of the required number of readings shall be within the specified dry film thickness range. Any of the required spot readings may be as low as 80% of the minimum specified or 120% of the maximum specified as long as the average of all the readings is within the specified range. An individual spot reading that conforms to this criteria conforms to the specified dry film thickness.

9 Storage, Handling and Shipping

9.1 Coating Materials

9.1.1 Coating materials shall not be stored in direct sunlight or exposed to inclement weather (e.g. rain, snow, sleet, freezing rain, dew point condensation, see also Section 9.1.5). Materials shall remain under cover until ready to use.

9.1.3 Coating material shall be delivered in manufacturer's original unopened containers. Each container shall be clearly identified with the manufacturer's name, product designation, batch number, date of manufacture and shelf life expiration date.

9.1.4 The maximum shelf life allowed for coating materials used on the WTP project is 24 months from the date of their manufacture. Coating materials that are older than 24 months or that exceed the manufacturer's published shelf life, if less than 24months, shall not be used and shall be placed on HOLD and segregated from other coating materials. A one-time shelf life extension of no less than three (3) months and no more than six (6) months, may be issued by the coating manufacturer. The shelf life extension shall be based on

laboratory testing of retain samples taken at the time of manufacture or by testing a sample provided from the actual coating material in question. Where testing verifies an outdated coating material still complies with its original design criteria, it is acceptable for shelf life extension. Expiration date stickers, provided by the coating manufacturer, shall be affixed to each container prior to release from HOLD. The stickers shall include the product number, batch/lot number, the new expiration date and suitably marked to indicate that they came from the coating manufacturer. A new Appendix F shall be provided by the coating manufacturer that includes the test results and specifically indicates it was provided to document shelf life extension including new expiration date. Coating materials that have not been stored or handled in accordance with Sections 9.1.5, 9.1.6, 9.1.7 and 9.1.8, may not have their shelf life extended.

9.1.5 Coating material shall be protected from moisture, direct sunlight and temperatures below 40°F or above 100°F unless otherwise allowed by the coating manufacturer's latest published instructions and verified by the BUYER.

9.1.6 Coating material containers where the airtight seal has been broken or any of the contents are lost, shall not be used and shall be clearly marked and segregated from useable coating material.

9.1.7 Coating material containers shall not be opened except for immediate use.

9.1.8 Unused material shall be returned to storage as soon as possible at the end of each Workday. Materials left out for more than eight (8) hours in an uncontrolled storage area (areas without environmental controls that are exposed to ambient weather) shall not be used and shall be clearly marked and segregated from useable coating material.

9.1.9 All required coating material certifications (Appendix F forms) for each batch of material delivered to the SELLER shall be available at the time of material receipt. Materials delivered to the shop without the required documentation shall not be used and the SELLER shall tag and place discrepant materials into a hold area clearly separated from acceptable material. Once required documentation is received or otherwise corrected and found to be acceptable, the discrepant material may then be taken off hold status and used.

9.2 Steel Items and Equipment

9.2.1 The SELLER shall be solely responsible for the condition of the steel items and equipment from the time they are received until they have been delivered to the BUYER.

9.2.2 All booms, hooks, clamps, forks, supports, and skids used in handling or storing coated items shall be designed and maintained in such a manner as to prevent any damage to the items or to the coating and shall be reviewed by the BUYER's representative. Chains and wire rope in direct contact with the coated items are not acceptable. Fabric lifting and tie down straps shall be used.

9.2.3 The SELLER shall inspect all items upon receipt for shipping and handling damage. Any visible damage observed at this point shall be noted on the receipt inspection report.

9.2.4 All coated steel items and equipment shall be stored on padded supports as necessary to preclude damage to the coating. The supports shall be properly spaced and leveled.

9.2.5 The BUYER's representative will have authority to stop any storage or handling activity, if there is a possibility of damage to the coating.

9.2.6 All steel items and equipment damaged by the SELLER shall be repaired in accordance with the specification at the SELLER's expense. Only repair procedures reviewed by the BUYER shall be used.

10 Documentation

10.1 The SELLER shall provide a record of all materials used (related to individual batch number- refer to Appendix F).

10.2 The SELLER shall provide a record of all required daily inspections (Example- Appendix G) that includes pre-surface preparation, compressed air cleanliness, environmental conditions, surface preparation and roughness, location of field repairs coated, application, visual inspection, dry film thickness, holiday testing and all touch-up/repair. This record shall include the coating and thinner materials used and the ID of the items coated to provide traceability.

10.3 All quality documentation shall be available for review by the BUYER representative within 24 hours from the time it is generated.

10.4 SELLER documentation forms or the way that the actual Work will be documented shall be provided by the SELLER as part of the procedures submittal for review by the BUYER.

10.5 Documentation shall be submitted in accordance with the requirements listed in Section 3 of the Material Requisition (MR).

APPENDIX C
Coating Materials/Coating Systems

TABLE 1 - PREQUALIFIED COATING PRODUCTS

Coating Number	Generic Products	Dry Film Thickness (mils)	Ameron	Carboline	Devoe	Dudick	Inter-national	Sherwin Williams
P02	Organic Zinc Epoxy Primer	3.0-5.0	Amercoat 68HS	Carbozinc 859	313	None	Interzinc 52	Zinc Clad IV
P04	High Build Epoxy	4.0-6.0	Amercoat 385	Carboguard 890	224HS	Protecto-Coat 330 or 300	Intergard 475HS	Macropoxy 646

NOTES to Table 1, Appendix C:

1) All versions of the above coating materials shall comply the WTP project VOC requirements of 3.8 lbs./gal and shall also comply with more restrictive local VOC requirements where the work is being performed. In the event the listed coating materials or acceptable versions of the listed coating materials do not meet the local VOC requirements an alternate VOC compliant material may be submitted for review.

TABLE 2 – COATING SYSTEM CODES

SYSTEM CODE	D
COAT 1	P02
COAT 2	P04
COAT 3	P04
COAT 4	

NOTES to Table 2, Appendix C:

1) The surface preparation for all coating systems shall be SSPC SP10 Near White Blast with a surface profile of 1.5 to 3.0 mils unless otherwise noted in this specification or the material requisition.

Appendix D
Coating Schedule

No.	Item – Component	System Code	Surface Prep. SSPC		1st Coat	DFT in mils	2nd Coat	DFT in mils	3rd Coat	DFT in mils	Color
			Initial	Repair							
7.0	**Skid Mounted Equipment**										
7.10	Skid Mounted Equipment-interior	All items on the skid shall be individually coated.									
8.0	**Miscellaneous Steel Items and Equipment**										
8.20	Miscellaneous Mechanical Equipment-Interior	D	SP10	SP11	P02	3.0-5.0	P04	4.0-6.0	P04	4.0-6.0	ANSI 70 GRAY

NOTES TO APPENDIX D

5. Flange surface (except gasket surfaces) & boltholes shall be cleaned and coated the same as the adjacent component.
8. Individual components of skid-mounted units shall be coated as noted for each individual item listed in Appendix D.
9. Complete details of the Manufacturer's Standard coating system shall be submitted for review. Refer to Section 6.2.
18. To minimize the potential of cracking or chipping where bolts are torqued onto precoated surfaces and within the bolted connection itself, a three coat coating system may be reduced to the prime coat and one finish coat directly under the bolt head, washer and nut up to 1/2" beyond.

Appendix F

Coating Manufacturer's Product Identity Certification Record

Project Name: _____ Coating Manufacturer: _____

Project Number: _____ Purchase Order Number: _____

Project Location: _____ Contract Number: _____

Coating Applicator: _____ Generic Coating Type: _____

Product Name: _____ Product Number: _____

(For multi-component products, provide data for all components on one or more Appendix F forms).
(Provide the standard range and actual batch values for each test)

TEST RESULTS		**Component A Batch No.**		**Component B Batch No.**	
Test	**Test Method Used**	**Standard Range**	**Batch Actual**	**Standard Range**	**Batch Actual**
Weight per Gallon					
Viscosity					
Flash Point (Typical)					
% Solids by Volume (Typical)					
Cure to recoat time @ 50F, 70F, & 90F (typical)					
Batch Size					
Date of Mfg.					
Shelf Life					
Expiration Date					

COMMENTS:

I hereby certify that the coating materials described above were manufactured with the same formulation, raw materials, production methods, and quality control standards as the coating materials originally tested and/or accepted for use at the River Protection Project-Waste Treatment Plant (WTP) Project site, located in the 200 East Area of the Hanford Site in Washington State in accordance with the requirements of WTP specification 24590-WTP-3PS-AFPS-T0001, 24590-WTP-3PS-AFPS-T0003,24590-WTP-3PS-AFPS-T0004, 24590-WTP-3PS-AFPS-T0006 and 24590-WTP-3PS-PX04-T0004.

Signed: _____ Date: _____

Title: _____ Company: _____

Appendix G
Surface Preparation and Coating Inspection Form

Page __ of ___

REPORT NO:_____ DATE:_____
PROJECT:_____ DAY: M T W T F S S
SUBCONTRACTOR/SELLER:_____ SHIFT:_____
EQUIPMENT/AREA:_____ INSPECTOR:_____
SUBSTRATE: STEEL/CONCRETE/OTHER-_____ COATING SPEC NO/REV:_____
ENVIRONMENTAL CONDITIONS:

WORK ACTIVITY						
TIME						
DRY BULB TEMP. °F						
WET BULB TEMP. °F						
RH %						
DEW POINT °F						
SURFACE TEMP. °F						
BLOTTER TEST						

PRE-SURFACE PREPARATION:
SP-1:_____ MASKING/PROTECTION:_____ SURFACE DEFECTS:_____

SURFACE PREPARATION:
METHOD:_____ ABRASIVE TYPE/SIZE/STORAGE:_____
CLEANLINESS SPEC:_____ ACTUAL:_____PROFILE SPEC:_____ ACTUAL:_____
EQUIPMENT:_____

COATING MATERIALS & MIXING:
PRODUCT(S)_____
BATCH NO(S)/QUANTITIES/EXPIRATION DATE:_____/_____/_____
THINNERS/THINNING RATIO:_____/_____/_____
STORAGE:_____ MIXING: _____ INDUCTION TIME:_____
MATERIAL TEMPERATURE:_____ POT LIFE EXPIRATION TIME:_____
COATING/LINING APPLICATION START TIME:_____ FINISH TIME:_____
COAT: PRIMER/PRIMER T.U./SECOND/SECOND T.U./THIRD/THIRD T.U./OTHER
METHOD:_____ WFT:_____ RECOAT TIME/TEMP:_____ CURE TIME/TEMP:_____
EQUIPMENT:_____

APPLIED COATING:
VISUAL INSPECTION (FILM IMPERFECTIONS):_____
DRY FILM THICKNESS: SPEC:_____ ACTUAL:_____ METHOD:_____
HOLIDAY TEST:_____ METHOD:_____ OTHER TESTING:_____ METHOD:_____
TOUCH-UP AND REPAIR:_____ FINAL CURE:_____

COMMENTS: (*Use reverse side or attach extra pages*)

_____/_____
INSPECTOR'S SIGNATURE/DATE

Appendix H
Manufacturer's Standard Coating Data Sheet

The SELLER proposes the following Manufacturer's Standard (Mfg. Std.) or alternate coating system that is suitable for the exposure conditions of steel items and equipment in radiation and non-radiation areas.

1. **^Equipment Description:** _____
   - A. Tag Number _____
   - B. Part(s) i.e. skirt, shell, channels, lugs, etc.* _____
   - C. Design/Operating Temperatures, designate °F or °C ..... _____ °F _____ °C
   - D. Does Equipment Receive Steam out (Yes/No), Temperature _____ °F _____ °C
   - E. Insulated/Uninsulated _____
   - F. Fireproofing (Yes/No) _____
   - ^G. Carbon Steel (CS), Stainless Steel (SS), other (List) _____
2. **^Seller:** _____
3. **^Surface Preparation:** SSPC No./Profile _____ / _____
4. **Coating System Designation:** (Code)

	First Coat	Second Coat	Third Coat
^A. Type of Coating			
^B. Coating Mfg./No.**			
^C. Dry Film Thickness (Min/Max in mils)/(µm) ...			
D. Wet/Film Thickness (Min/Max in mils)/(µm)			
E. Curing Method			
^F. Color			
G. Dry to Recoat			
H. Pot Life			
L. Thinner / %			

5. **Total DFT of System:** (Mils/µm)(Min/Max) ..... _____ / Min. _____ / Max.
6. **Material Storage:** Temperature Requirements (Min/Max) _____ / _____
7. **Shelf Life:** _____ Months
8. **Application Environmental Limits:**
   - A. Temperature Ambient and Surface (Min/Max) ..... _____ / _____ _____ / _____
   - B. Humidity (Min/Max) ..... _____ / _____
   - C. Surface Temp ≥5°F above Dew Point temp. (Yes/No) ..... _____
9. **Protection of surfaces that will be inaccessible after equipment installation (such as underside of base plates, interior of fans, vessels or equipment housings)** _____
10. **Rust Preventative for machined faces:** (**Mfg./No.) _____
11. **Quantity of touch-up coating supplied:** *None* _____
12. **Additional information:** (attach extra page as necessary) _____

* Use additional copies of this form for each part described in 1 above that requires a different coating system. A completed copy of this data sheet shall be submitted to CONTRACTOR/BUYER with the initial vendor data submittal.

** Include manufacturer's technical data sheets and MSDS for each proposed coating & preservative.

^ Mandatory data entry. Other entries should be completed where information is available from sub vendor or from coating material technical data sheets.

ATTACHMENT EEQ

LAW TCO CUSTOMIZED EEQ GUIDANCE

Environmental Equipment Qualification Requirements for SS-Chemical Toxicity Equipment in the LAW Facility

Environmental Equipment Qualification Requirements for SS-Chemical Toxicity Equipment

1. The equipment shall be designed under applicable codes and standards to withstand the effects of its environmental and process conditions and perform its safety function under the applicable Design Basis Event (DBE) conditions.

2. The Seller shall establish and document the ability of the supplied safety equipment to perform its safety function under the most severe environmental and process conditions to which it is subject during its installed life.

   The evaluation necessary for this purpose may be based on testing, analyses or operating experience. The necessary data shall have been obtained under quality assurance requirements imposed elsewhere in the procurement documents.

   The environmental service conditions considered shall be those contained in the Equipment Qualification Datasheets (EQD) applicable to the supplied equipment and are provided as part of the procurement documents. The process conditions considered shall be those stated in the equipment datasheets or elsewhere in the procurement documents.

   Testing performed to establish adequate performance under Design Basis Event (DBE) conditions, including Seismic testing, need not be performed on an aged test specimen.

3. The Seller shall consider the aging effects of the environmental and process conditions.

   The Seller shall consider the effects of temperature (thermal aging), radiation and wear as aging mechanisms. For radiation exposure evaluations, a total radiation dose of less than 1.0E03 Rad is not a significant radiation aging mechanism for electronic components. A total dose of less than 1.0E04 Rad is not a significant radiation aging mechanisms for organic compounds.

   The results of the aging evaluation shall be documented as recommended maintenance, replacement and/or surveillance actions which are required in response to the aging effects.

   The desired qualified life for the supplied equipment for the WTP is 40 years. However, if agreed to by the BUYER, the equipment/component qualified life may be less than 40 years.

4. Components not involved in the equipment's safety function(s) may be excluded from the Seller's qualification process if it can be shown, through a documented means such as analysis that assumed failures, including spurious operation, have no adverse effect on the stated safety function(s) or by way of interfaces, on the safety function(s) of other equipment.

5. The results of the qualification evaluations required above shall be specific to the equipment items supplied to WTP. Any modifications made to the equipment after the evaluations are complete shall also be evaluated in accordance with the above requirement and the results shall be similarly documented.. Modifications to the equipment include changes in its design, materials, manufacturing process, clearances, lubricant, or mounting conditions.
6. Documentation of Qualification
    a. The Seller shall provide a signed Certificate of Conformance to the specified performance requirements. The certificate shall be in the form shown in Attachment 11 of the primary specification 24590-LAW-3PS-MBTV-T0001, *Engineering Specification for LAW Thermal Catalytic Oxidizer/Reducer.*
    b. Passive Equipment
        i. The Seller shall provide a documented evaluation confirming that the applicable bounding normal, abnormal, accident and post accident environmental and process conditions will not degrade non-metallic component/subcomponent performance in such a manner as to prevent the equipment from performing its required passive safety function(s).
    c. Active Equipment (including all electrical, instrumentation and controls equipment)
    d. The Seller shall either: a) document recommended replacement (whole equipment or parts) or maintenance actions which are required in response to the aging effects and include a specific statement that the recommended replacement (whole equipment or parts) or maintenance actions are based on the aging considerations, or b) provide a statement that no maintenance / components replacements are required due to aging considerations if the equipment is not susceptible to aging,
    e. All qualification documentation shall be submitted to WTP under document category 35 of BNI Form G-321-E.

34.0 ANSI K61.1, American National Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia

Revision: 1999
Sponsoring Organization: Compressed Gas Association, Inc.

WTP Specific Tailoring

The following tailoring of ANSI K61.1 is required for use by the WTP project as an implementing standard for the safety related systems design.

Page 9; Section 5.1 Equipment and systems

Revise Section 5.1 as follows:

Not Applicable

Justification: Section allows the continued use or reinstallation of containers and systems designed and installed under earlier versions of codes and ANSI standards. WTP does not plan on using previously installed or design equipment. Therefore, Section 5.1 of this standard will not be implemented for this project.

Page 11; Section 5.2 Requirements for new construction and original test, repair, and alterations of containers (including DOT portable tanks), other than refrigerated storage tanks

Revise the first sentence of Section 5.2.2.2 as follows:

Steels used in fabricating pressure containing parts of a container shall not exceed a specified ASME Code Minimum Yield Strength of 70 ksi (483 MPa) (does not apply to Sections 8, 9, and 10).

Justification: Section 5.2.2 states that containers designed and construction in accordance with the ASME Code shall comply with the following requirements. In the wording of Section 5.2.2.2, the term "shall not exceed a specified tensile strength of 70 000 psi" is ambiguous.

ANSI K61.1 - 1989, paragraph 5.2.2.2 states that "Steels used in fabricating pressure-containing parts of a container shall have a tensile strength no greater than a nominal 70,000 psi (480 MPa) (does not apply to Sections 8, 9, and 10)." This paragraph is interpreted to mean that materials with a tensile strength range of 65,000 to 80,000 psi or 70,000 to 95,000 psi would be suitable for this fabrication. A material with a tensile strength range of 80,000 to 105,000 would not be acceptable.

CGA-2 - 1995, paragraph 18.2.1 states that "Steels used to fabricate the pressure-retaining parts of a container must not exceed 70,000 ksi **minimum specified tensile strength** in order to minimize the potential for the development of stress corrosion cracks during service". Again, this paragraph is interpreted to mean that a material with a specified range of 70,000 to 95,000 psi would be acceptable for this fabrication.

ANSI K61.1 - 1999 / CGA G-2.1 - 1999, paragraph 5.2.2.2, states "Steels used in fabricating pressure containing parts of a container shall not exceed a specified tensile strength of 70,000 psi (483 MPa) (does not apply to Sections 8, 9, and 10)." Exception: Implements of husbandry may be fabricated from steel having a specified tensile strength of 75,000 psi (517 MPa)".

From the sequence of the code issue dates, it appears that the CGA recognized the ambiguity of the word "nominal" when referring to the tensile strength in ANSI K61.1 - 1989, Section 5.2.2.2, and corrected it in CGA-2 - 1995 to indicate the minimum specified tensile strength. In ANSI K61.1 - 1999 / CGA G-2.1 - 1999, Section 5.2.2.2, it appears that the CGA revised its terminology to be more consistent with the terminology used in the ASME codes for the specified tensile strength, which are the minimum tensile strengths. The purpose of tailoring Section 5.2.2.2 is to remove any ambiguity and provided consistency between the ASME Code and ANSI K61.1 -1999.

This tailoring is per DOE Letter 10-NSD-068 dated September 24, 2010 (CCN 225818).

Page 19; Section 6.3 Pressure relief devices

Revise Section 6.3.2 as follows:

Not Applicable

Justification: Section specifies relief valve design for underground containers. WTP does not plan to install underground containers. Therefore, Section 6.3.2 of this standard will not be implemented for this project.

Revise Section 6.3.3 as follows:

Not Applicable

Justification: Section specifies manhole design for relief for underground containers. WTP does not plan to install underground containers. Therefore, Section 6.3.3 of this standard will not be implemented for this project.

Page 19; Section 6.4 Installation of storage containers

Revise Section 6.4.4 as follows:

Not Applicable

Justification: Section specifies design requirements for the installation of underground containers. WTP does not plan to install underground containers. Therefore, Section 6.4.4 of this standard will not be implemented for this project.

Revise Section 6.4.5 as follows:

Not Applicable

Justification: Section specifies design requirements for the installation of underground containers. WTP does not plan to install underground containers. Therefore, Section 6.4.5 of this standard will not be implemented for this project.

Revise Section 6.4.7 as follows:

Not Applicable

Justification: Section specifies design requirements for the installation of underground storage systems. WTP does not plan to install underground storage system. Therefore, Section 6.4.7 of this standard will not be implemented for this project.

Revise Section 6.4.8 as follows:

Not Applicable

Justification: Section specifies design requirements for the installation of underground tanks. WTP does not plan to install underground tanks. Therefore, Section 6.4.8 of this standard will not be implemented for this project.

Page 20; Section 6.5 Reinstallation of containers

Revise Section 6.5 as follows:

Not Applicable

Justification: Section specifies requirements for reinstallation of containers. WTP does not plan to use previously used containers. Therefore, Section 6.5 of this standard will not be implemented for this project.

Pages 21-26; Section 7 Refrigerated storage

Revise Section 7 as follows:

Not Applicable

Justification: This section establishes design requirements for system using tanks for the storage of anhydrous ammonia under refrigerated conditions. WTP does not plan on a system using tanks for the storage of anhydrous ammonia under refrigerated conditions. Therefore, Section 7 of this standard will not be implemented for this project.

Pages 26-28; Section 8 Systems mounted on railcar structures (tank cars), other than DOT class 106A, for transportation of ammonia

Revise Section 8 as follows:

Not Applicable

Justification: This section establishes design requirements for tank cars for the rail transportation of ammonia. WTP does not plan to receive anhydrous ammonia by rail car. Therefore, Section 8 of this standard will not be implemented for this project.

Pages 31-32; Section 10 Systems using DOT portable tanks and cylinders

Revise Section 10 as follows:

Not Applicable

Justification: This section establishes requirements for cylinders (less than 1000 pounds), DOT portable tanks and DOT containers. WTP does not plan to receive anhydrous ammonia by container or cylinder. Therefore, Section 10 of this standard will not be implemented for this project.

Pages 32-34; Section 11 Systems mounted on farm wagons (implements of husbandry) for the transportation of ammonia

Revise Section 11 as follows:

Not Applicable

Justification: This section establishes requirements for equipment mounted on farm wagons for the transportation of ammonia. WTP does not plan to use farm wagons for the transportation of ammonia. Therefore, Section 11 of this standard will not be implemented for this project.

Pages 34-35; Section 12 Systems mounted on farm wagons (implements of husbandry) for the application of ammonia

Revise Section 12 as follows:

Not Applicable

Justification: This section establishes requirements for equipment mounted on farm wagons for the application of ammonia. WTP does not plan to use farm wagons for the application of ammonia. Therefore, Section 12 of this standard will not be implemented for this project.

Pages 35-37; Section 13 References

The references listed shall be constrained to the approved versions listed in the SRD or approved changes and equivalencies.

The following references shall be excluded:

ANSI/ASHRAE 15, American National Standard Safety Code for Mechanical Refrigeration

ANSI/IIAR 2, American National Standard for Equipment, Design and Installation of Ammonia Mechanical Refrigeration Systems

ANSI/ASME B31.5, American National Standard for Refrigeration Piping

ANSI/SAE J1513f, Refrigeration Tube Fittings

API Standard 620, Design and Construction of Large Welded Low-Pressure Storage Tanks

Justification: The above references are for the design of refrigerated storage systems. WTP does not plan to use a refrigerated anhydrous ammonia storage system. Therefore, these references will not be implemented for this project. **The exception is ANSI/ASME B31.5 which provides a basis for utilizing certain materials in lower temperature applications considered compliant with the intent of ANSI K61.1 requirements for Piping, Tubing, and Fittings.**

Limitations of Tailoring: The use of ASME B31.5 in WTP systems required to be compliant with ANSI K61.1 is limited to isolation valves on the ammonia storage vessels. ASTM A536 material is considered compliant with the intent of ANSI K61.1 paragraph 5.6.6, but its use is limited to ammonia storage vessel isolation valve bonnets.

The following references shall be excluded:

40 CFR Part 280, Technical standards and corrective action requirements for owners and operators of underground storage tanks (UST)

Justification: The above reference is for underground storage tanks. WTP does not plan to use underground storage tanks for anhydrous ammonia. Therefore, these references will not be implemented for this project.

The following references shall be excluded:

CGA G-7, Guide to the Preparation of Precautionary Labeling and Marking of Compressed Gas Containers

ANSI/CGA V-1, American National Standard Compressed Gas Association Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections

Justification: The above references are for the use of cylinders and small (less than 1 ton) containers. WTP does not plan to use cylinders or small containers for anhydrous ammonia storage. Therefore, these references will not be implemented for this project.

The following references shall be excluded:

ANSI/ASAE S276, Slow Moving Vehicle Identification Emblem
ANSI/ASAE S338.2, Safety Chain for Towed Equipment

Justification: The above references are for the use of ammonia systems mounted on farm equipment. WTP does not plan to use farm equipment for anhydrous ammonia storage. Therefore, these references will not be implemented for this project.

26.0 ASME B31.3-1996, Process Piping

Revision: 1996
Sponsoring Organization: ASME

WTP Specific Tailoring

The following tailoring of ASME B31.3, *Process Piping*, is required for use by the WTP contractor as an Implementing Standard for: (1) the fabrication and installation of those portions of the C5V ductwork that are being embedded in concrete, (2) the use of ASME B31.3-2010, Appendix P, Alternative Rules for Evaluating Stress Range for evaluating stress ranges due to pressure cycling and operational load cycling, (3) the use of ASME B16.9 welding tees in accordance with ASME B31.3-2002, (4) use of vacuum box leak testing, (5) the ASME B31.3-1998, paragraph 345.2.3(c), allowance for not leak testing closure welds outside of a closed cell (black cell) and/or hard-to-reach area, (6) the test pressure that is used for piping systems subjected and designed to HPAV events, and (7) design for HPAV Detonation/Deflagration loads and associated thermal gradients.

- The tailored sections of ASME B31.3 applicable to embedded ductwork will only be utilized to the extent that it will cover the fabrication, installation, and inspection (and associated testing) of Category D fluid service piping being used as C5 ductwork. Air testing requirements for this ductwork will be compliant with ASME AG-1. Below is a description of those portions of ASME B31.3 that apply to fabrication, installation, and inspection of Category D fluid service piping and the sections of the SRD that they will apply to.
- The tailored sections of ASME B31.3 applicable to welding tees will only be used for ASME B16.9 welding tees. As long as the stress intensification factors from ASME B31.3-2002 are used in the stress analysis for the welding tees, welding tees fabricated to either the 1996 or the 2002 edition of ASME B31.3 can be used. Below is a description of those portions of ASME B31.3, Appendix D, Table D300, that apply to welding tees and the section of the SRD to which they will apply.
- The tailored paragraphs of ASME B31.3 applicable to vacuum box leak testing, in lieu of hydrostatic or pneumatic leak testing, will only be used to leak test full penetration circumferential piping field butt welds inside a closed cell (black cell) and/or hard-to-reach area as defined in Appendix M, out to the first isolation component outside the closed cell (black cell) and/or hard-to-reach area. Further, if the 100 % volumetric inspection using ultrasonic examination per ASME B31.3 paragraph 344.6, is conducted for welds to be vacuum box tested, then the ultrasonic examination shall be conducted using a method that creates and maintains a reproducible computerized image(s) of the entire weld in the axial and radial direction.
- The tailored paragraphs of ASME B31.3 adopting the provisions of ASME B31.3 (c) - 1998 Addendum paragraph 345.2.3(c) are applicable to all ASME B31.3 piping in all facilities except for closure welds in closed cells (black cell) and/or hard-to-reach areas.

Piping providing a confinement function in accordance with SRD 4.4-3 and 5.1-2 will comply with the following sections of ASME B31.3-1996, *Process Piping*. These sections of ASME B31.3 are applicable for embedded ductwork.

Chapter 3, Materials

Chapter 5, Fabrication

Table 341.3.2, Visual acceptance criteria for Category D fluid service piping

Justification: Due to wall thickness requirements of duct embedded in concrete, piping materials are required. ASME B31.3 will apply to materials, fabrication, and inspection standards as appropriate. Testing requirements for nuclear air treatment systems will be consistent with ASME AG-1.

Piping providing a confinement function in accordance with SRD 4.4-2 will comply with the following sections of ASME B31.3-1996, *Process Piping* with the following modification.

ASME B31.3-2010 Appendix P: Alternative Rules for Evaluating Stress Range will be used to evaluate stress ranges due to pressure cycling and operational load cycling to address ASME B31.3-1996 Section 301.10: Cyclic Effects.

Justification: ASME B31.3-1996 Section 301.10 specifies that fatigue due to pressure cycling, thermal cycling, and other cyclic loadings shall be considered in the design of piping. No additional methodology is provided by code of record. Therefore, consideration of cyclic loading other than displacement controlled loading shall be achieved through the alternative rules provided in ASME B31.3-2010 Appendix P. This alternate rule does not apply to HPAV affected confinement piping systems as addressed separately in this Appendix to the SRD.

Piping providing a confinement function in accordance with SRD 4.2-2 will comply with ASME B31.3-1996, *Process Piping*, with the following modification:

In Table D300, the description of welding tee per ASME B16.9 shall be revised so it is consistent with that shown in Table D300 of ASME B31.3-2002:

		Stress Intensification Factor [Notes (2), (3)]			
Description	**Flexibility Factor k**	**Out-of-Plane, i_o**	**In-Plane i_i**	**Flexibility Characteristic, h**	**Sketch**
Welded tee per ASME B16.9 [Notes (2), (4), (6), (11), (13)]	1	$\frac{0.9}{h^{2/3}}$	$3/4\ i_o + 1/4$	$3.1\frac{T}{r_2}$	Same as ASME B31.3-1996

This means that for welding tees per ASME B16.9, note 11 in Table D300 is also changed to:

(11) If $r_x \geq 1/8D_b$ and $T_c \geq 1.5\overline{T}$, a flexibility characteristic of $4.4\overline{T}/r_2$ may be used.

Justification: The use of a lower flexibility characteristic for welding tees per ASME B.16.9 in accordance with ASME B31.3-2002 will increase both the out-of-plane and in-plane stress intensification factors. The increased stress intensification factors will reduce the allowable out-of-plane and in-plane moments that can be applied to the welding tee and keep the calculated stress below the stresses allowable by ASME B31.3-1996.

Safety piping within the scope of SRD 4.2-2 shall comply with ASME B31.3-1996, Chapter V, Paragraph 345, using the following approach for vacuum box leak testing. Vacuum box leak testing, in lieu of hydrostatic or pneumatic leak testing, may be used to leak test full penetration circumferential piping, field butt welds inside a closed cell (black cell) and/or hard-to-reach area as defined in Appendix M, out to the first isolation component outside the closed cell (black cell) and/or hard-to-reach area, only under the following conditions:

Vacuum Box Leak Test Method - The vacuum box leak test shall be in accordance with a Bubble Test - Vacuum Box Technique method specified in ASME BPV Code, Section V, Article 10, Appendix II, subject to the requirements listed below:

(a) Sensitivity of the test shall be demonstrated to be not less than 1E-3 atm-ml/sec at 15 psig.

(b) The test pressure shall be a partial vacuum of at least 7 psi below atmosphere, applied to the outside of the weld.

(c) The required partial vacuum shall be maintained for at least 20 sec examination time.

In addition, the following limitations and restrictions shall apply to the application of vacuum box leak testing in lieu of a hydrostatic or a pneumatic leak test:

- Vacuum box leak testing will only be used to leak test circumferential piping field welds inside a closed cell (black cell) and/or hard-to-reach area (as defined in SRD Appendix M). This includes any welds in extensions of piping systems contained or originating in accessible areas between the closed cell (black cell) and/or hard-to-reach area boundary and the first isolation valve or device beyond the closed cell (black cell) and/or hard-to-reach area boundary;
- It shall only be used for piping field welds where required to avoid damage to components, ensure the safety to construction workers, perform leak tests of field welds where physical limitations prevent hydrostatic or pneumatic leak testing as prescribed in ASME B31.3-1996 paragraph 345.4 and paragraph 345.5 respectively;
- Pipe welds that are to be vacuum box leak tested will be assessed for suitability. The number of welds to be vacuum box leak tested shall be limited to a maximum of three welds between termination points (two termination or closure welds and one intermediate weld) on a given pipe

system except where physical limitations prevent examination by hydrostatic or pneumatic leak testing. DOE will be informed of such exceptions, and may at its discretion and within 48 hours of being informed, respond to BNI on the suitability of the use of vacuum box leak testing for such instances. Termination points may be tanks, vessels, valves, etc. (Specifically excluded from the definition of termination points are junctions where the piping changes design class). This could be either the last two closure welds in a closed cell (black cell) and/or hard-to-reach area or the last closure weld in the closed cell (black cell) and/or hard-to-reach area and the last closure weld outside the closed cell (black cell) and/or hard-to-reach area. In addition, vacuum box leak testing would be permitted for the connection welds between construction modules if this is limited to one module-to-module weld per piping run within the cells. This is in addition to termination welds on the piping run. A module is defined as a pre-leak-tested subassembly containing multiple pipe spools;

- Vacuum box leak testing shall be limited to full penetration girth butt welds, on straight pipe or between straight pipe and pipe components of the same nominal pipe size and same wall thickness on both sides of the weld at the weld location. The following configurations are candidates for vacuum box testing:

  (a) Straight pipe to straight pipe connection butt welds

  (b) Straight pipe to 90° elbow connection butt welds

  (c) Straight pipe to 45° elbow connection butt welds

  (d) Straight pipe to concentric reducer connection butt welds

  (e) Straight pipe to eccentric reducer connection butt welds

  (f) Straight pipe to butt welding tee connection butt welds

  (g) Straight pipe to butt welding reduced outlet tee connection butt welds

  (h) Straight pipe to valve nozzle connection butt welds

  (i) Straight pipe to tank or vessel nozzle connection welds

  (j) Straight pipe to safe-end of a weldolet connection butt welds - full penetration butt welded connection only

  (k) Straight pipe to pipe cap connection butt welds

  Prior to the application of vacuum box testing using any of the candidate configurations on piping butt welds at the WTP, the Contractor must successfully demonstrate to the DOE, for the candidate configuration, that (1) all portions of the weld to be inspected are visible and can be inspected in accordance with the ASME Boiler and Pressure and Vessel Code, Section V, Article 10, Appendix II - 1995; (2) the vacuum box can adequately maintain a partial vacuum of 7 psid; and (3) vacuum box leak testing can be accomplished in the time limits and other requirements established by this procedure. The DOE shall be advised at least 7 days in advance of any demonstration to qualify a new weld configuration so that they can witness the demonstration. The Contractor shall document any demonstration relied upon to justify the use of vacuum box leak testing on a new configuration. Further, vacuum box leak testing shall be conducted with a vacuum box that completely encapsulates the weld, at the test location;

- All welds shall be 100 % volumetrically inspected in accordance with ASME B31.3-1996, paragraphs 344.5 or 344.6. If the 100 % volumetric inspection is conducted using ultrasonic examination per ASME B31.3-1996 paragraph 344.6, then the ultrasonic examination shall be conducted using a

method that creates and maintains a reproducible computerized image(s) of the entire weld in the axial and radial direction;

- It shall be limited to welds made using the Orbital welding machines. The only exception is that vacuum leak box testing may be used on manual welds if the 100 % volumetric inspection was conducted by radiography per ASME B31.3-1996 paragraph 344.5;
- The piping systems and or components on both sides of the weld to be vacuum box leak tested shall have been subjected to a hydrostatic leak test in accordance with ASME B31.3-1996 paragraph 345.4, a pneumatic test in accordance with ASME B31.3-1996 paragraph 345.5, a combination pneumatic-hydrostatic leak test in accordance with ASME B31.3-1996 paragraph 345.6, or in the case of components, leak tested in accordance with the Code or Standard applicable to the design of the component;
- At a minimum, a flexibility analysis in accordance with ASME B31.3-1996 paragraphs 319.4.2 (a) and (b) shall be required on any piping systems that contain welds that are to be vacuum leak box tested. In addition, a comprehensive flexibility analysis in accordance with ASME B31.3-1996 paragraphs 319.4.2 (c) and (d) shall be performed on any piping systems that contain welds that are to be vacuum box leak tested when the piping systems have a design temperature greater than or equal to 150 °F;
- For manual welds, the requirements of ASME B31.3-1996 paragraph 344.7.1 (a) through (g) shall be invoked on any weld to be vacuum box leak tested with the exception that the requirement of subparagraph 344.7.1 (e) "... aided by liquid penetrant or magnetic particle examination when specified in the engineering design" shall not be required. For welds made using Orbital welding machines, the requirements of ASME B31.3-1996 paragraph 344.7.1 (a), (b), (c), (d), and (g) shall be invoked. The requirements of 344.7.1 (e) and (f) shall not be required. The implementation of these requirements shall be documented in the weld inspection report;
- Pipe welds and the associated line numbers that are to be vacuum leak box tested shall be identified in advance of the testing. This identification shall be documented in the controlled document Weld List, which must include this information prior to the initiation of any vacuum box leak testing associated with those welds and line numbers. It is understood that the controlled document Weld List may need to be revised and updated periodically through the construction phase of the WTP Project; and
- The following special requirements shall be placed on the training programs used to certify the technicians that will be conducting the vacuum box leak tests:
  1. The BNI Construction Manager shall pre-approve the technician qualifying examination(s) for vacuum box leak testing;
  2. The BNI Construction Manager shall pre-approve the qualifications of each Level III technician preparing or giving the examinations for vacuum box leak testing;
  3. DOE ORP at their discretion shall reserve the right to observe any and/or all practical leak test examinations and review of the results of any and/or all written vacuum box leak test examinations;
  4. The minimum topical content of each Level II examination shall be specified by BNI, and approved by DOE;
  5. The 80 % correct criteria for passing the examination shall apply to each part of the three part examinations that are to be given;

6. BNI shall provide reasonable assurance that they will take adequate measures to assure the integrity of written examination is maintained; and
7. There shall be several versions of each examination in use to assure Level II knowledge and ability concerning vacuum box leak testing is confirmed.

Justification: The requirement for the vacuum box leak test sensitivity is consistent with the ASME B31.3 requirement for a sensitive leak test as given in ASME B31.3-1996 paragraph 345.8 and for at least 7 psi vacuum and an examination time of at least 20 seconds. The limitations in using vacuum box leak testing better define when this method can be used. DOE ORP may further change the definition and application of these special vacuum box leak testing criteria based on the Contractor's experience with their use, or the Contractor's request for a change.

Piping system closure welds outside of a closed cell (black cell) and/or hard-to-reach area as defined in SRD Appendix M, shall comply with the requirements of ASME B31.3-1998, subparagraph 345.2.3(c). When ASME B31.3-1998, subparagraph 345.2.3(c) is invoked the following restrictions shall apply:

- It shall not be invoked on any closure welds on piping systems in a closed cell (black cell) and/or hard-to-reach area as defined in SRD Appendix M. This includes any welds in extensions of piping systems contained or originating in a closed cell (black cell) and/or hard-to-reach area, between the closed cell (black cell) and/or hard-to-reach area boundary and the first isolation valve, or device beyond the closed cell (black cell) and/or hard-to-reach area boundary;
- It shall only be invoked on full penetration butt welds in straight pipe, full penetration butt welds at the safe-end of an equipment nozzle, or full penetration butt welds at the safe-end of branch connections. [The safe-end is defined as the piping to equipment nozzle connecting weld or the branch connection to branch piping connecting welds.];
- The requirements of ASME B31.3(c) - 1998, subparagraph 345.2.3 (c) shall be met;
- The piping systems and or components on both sides of the closure weld shall have been subjected to a hydrostatic leak test in accordance with ASME B31.3-1996 paragraph 345.4, a pneumatic leak test in accordance with ASME B31.3-1996 paragraph 345.5, a combination pneumatic-hydrostatic leak test in accordance with ASME B31.3-1996 paragraph 345.6, or in the case of components leak tested in accordance with the Code or Standard applicable to the design of the component;
- For manual welds, the requirements of ASME B31.3-1996 paragraph 344.7.1 (a) through (g) shall be invoked with the exception that the requirement of subparagraph 344.7.1 (e) "...aided by liquid penetrant or magnetic particle examination when specified in the engineering design" shall not be required. For welds made using the Orbital welding machines, the requirements of ASME B31.3 -1996 paragraph 344.7.1 (a), (b), (c), (d), and (g) shall be invoked. The implementation of these requirements shall be documented in the weld inspection report;
- Piping welds and the associated line numbers for which the closure weld classification is invoked shall be documented in a controlled document Weld List;
- Piping components may include mechanical elements other than piping; and

- In addition, BNI shall incorporate these requirements into the appropriate specification. DOE-ORP may further change the definition and application on the use of closure welds based on the Contractor's experience with their use or the Contractor's request for a change.

Justification: This change does not change the safety function of any pressure boundary components. The requirement to leak test pressure boundary field welds is primarily to ensure the reliability of the welds in addition to the reliability provided by the other required examinations. The exception allowed by ASME B31.3-1998, paragraph 345.2.3 that the final weld connecting piping systems or components which have been successfully tested in accordance with paragraph 345 need not be leak tested provided the weld is examined in-process in accordance with paragraph 344.7 (a), (b), (c), (d), and (g) and passes with 100 % radiographic examination in accordance with paragraph 344.5 or 100 % ultrasonic examination in accordance with paragraph 344.6 provides adequate assurance that the weld is reliable and leak tight. The change continues to provide adequate safety since it requires that all piping closure welds that are not leak tested are in-process examined and 100 % volumetrically examined which exceeds the requirements of ASME B31.3-1996 for closure welds that are leak tested. The inability to hydrostatically or pneumatically leak test these closure welds does not affect the soundness of the welds.

Exception to B31.3 Paragraph 302.2.4

Piping subjected to HPAV events, as defined in Appendix A, Section 5.4, and designed to withstand those events without controls will be leak tested at a pressure equal to the system design pressure (from the Mechanical line list) multiplied by the applicable factors in Section 345 of ASME B31.3-1996, *Process Piping*. The HPAV pressure will be permitted to exceed the test pressure, which is an exception to Paragraph 302.2.4.

Justification: ASME B31.3 does not address highly impulsive pressure loading, and does permit the designer to perform detailed analysis for unusual situations, as indicated in Paragraph 304.7.2 for Unlisted Components. The design rules developed in Report 24590-WTP-RPT-ENG-07-011, Revision 2, ensure that the piping system will maintain pressure boundary under all conditions.

Design for Hydrogen Detonation/Deflagration Loads and Thermal Gradients

This section provides design criteria to determine the acceptable responses of piping systems and components to occasional loads that may result from HPAV events. Piping routes that fail to meet these criteria require preventive controls. The development of such criteria is permitted by B31.3 and is, therefore, not a deviation from it.

A best-estimate design tool may be used to determine the number of cycles for defined classes of HPAV events that differ in applicable structural design considerations for their accommodation subject to the following constraints to ensure consistency with safety analysis expectations:

1. The route specific factors that affect the potential for significant quantities of combustible gases to accumulate must be considered, including the maximum expected waste characteristics (i.e., combustible gas generation rate, temperature, viscosity), the proposed configuration of the route, and the related human and equipment failure rates.

2. An ignition probability of one is to be assumed at each maximum bubble size unless a technical basis for a lower probability is submitted to DOE-ORP and receives their concurrence.
3. The design tool shall not be used to exclude limiting events such as PRC-DDT that can occur for credible gas configuration conditions.
4. A defined class of events may be designated as structurally insignificant provided the included events are shown not to affect compliance with these Appendix C, B31.3 tailoring provisions.
5. Documentation of the model must be provided including the process for its application, the defined event classes, the parameters chosen, and the results.

For HPAV events, analysis will use 100/sec strain-rate dependent stress-strain curves for austenitic stainless steels (SS 304, 304L, 316 and 316L), which are used in the construction of WTP piping systems. Strain rate dependent properties will be developed based on a literature survey of academic, National Laboratory and industry information, covering the range of experimental test data to which the material in question will be subjected in service. Specifically, the experimental data requirements shall provide:

(a) A lower-bound estimate for strength over the strain rate and temperature regime of interest,

(b) Variation of yield strength with strain-rate and temperature,

(c) Variation of the rate of strain-hardening with strain-rate,

(d) Determination of a loading path-dependence to both the quasi-static (QS) and rate-dependent yield behavior,

(e) A loading path-dependence to both the quasi-static (QS) and rate-dependent strain-hardening behavior, and

(f) Development of an equation (or mathematical model) that describes the strength properties over the regime of interest.

(g) Scaled to the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, static, room temperature true stress-true strain curve.

Events Affecting Piping Located in Black Cells or Designated as Hard-To-Reach

Deflagrations events must meet the criteria of ASME B31.3-1996, *Process Piping*, and B31.3 Code Case 178, with appropriate consideration of deflagration pressure, sustained loads, and thermal gradients.

In evaluating Code Pressure Boundary for detonation events (including deflagration to detonation [DDT] transitions and reflected DDTs [PRC-DDT]), the straight pipe equivalent through-wall average strain will be limited to 0.2 % plastic strain using the 100/sec strain-rate dependent stress-strain curves, finite element time-history analysis, and end-of-life wall thickness.

For bends fabricated from straight pipe, the equivalent through-wall average strain will be limited to 0.2 % plastic strain using the 100/sec strain-rate dependent stress-strain curves, finite element time-history analysis, and end-of-life wall thickness.

Fittings (tees, elbows, reducers) manufactured in accordance with B31.3 Paragraph 303 and the standards listed in B31.3 Table 326.1 are considered to be as strong as the matching pipe, due to the burst test requirements of the standards. BNI will verify that burst test methods (in lieu of calculation methods) have been used to validate representative fitting designs.

Fatigue damage from high frequency oscillations, bar waves, thermal gradients, pressure changes, and traveling detonation waves must be evaluated.

B31.3 302.3.5 limits the sum of longitudinal stresses due to pressure, weight, and other sustained loads to S_h, the basic Code allowable at maximum temperature. Combining only longitudinal stresses, as is done in B31.3 paragraph 302.3.6, does not consider the possible combination of hoop and longitudinal (axial) effects. For highly dynamic pressures during a traveling wave detonation event, the axial and hoop effects due to pressure are not necessarily both tensile, so a departure from the normal B31.3 methods (sum of longitudinal stresses) must be made to allow for the possible combination of hoop and axial effects. Therefore, for traveling wave detonation events, the combination of hoop and axial effects must be considered without exceeding the 100/sec strain-rate dependent yield; the dynamic interaction ratio added to the dead weight interaction ratio shall not exceed 1. Since DDT and PRC-DDT events are point events, the requirement to combine hoop and axial effects does not apply.

Events Affecting Piping Not Located in Black Cells or Designated as Hard-To-Reach

Except as noted below, all HPAV requirements in the BC/HTR apply. The criteria below are limited to affected piping systems and components located in the HLW Process Cells, or in the Pretreatment facility Hot Cell and C3 area bulges that serve as extensions of the Hot Cell.

For HPAV events that are anticipated to result in a PRC-DDT, detonation, or DDT, the maximum pressure that produces a straight pipe (or 3D bend, whichever is limiting) equivalent through-wall average strain of 0.2 % plastic strain, as determined above for the BC/HTR, will be permitted to be 1.5 times higher. This results in a plastic through-wall average strain estimated to be less than 2.5 %.

Other Components

Stresses in the nozzle/vessel intersection or in the dipped line due to the traveling detonation wave loading will be combined with stresses due to normal loads (PJM operation, if applicable, thermal expansion, internal pressure, weight) and the primary results limited to 1.2 times the normal condition allowable stress for that type of stress, as permitted by the ASME Boiler and Pressure Vessel Code, Sections VIII-1 and VIII-2, for occasional loads.

Stresses in pipe supports inside BC/HTR areas under combined weight, thermal expansion, and detonation loading will be limited to B31.3 allowable stress (if a catalog support) or the AISC allowable stress (if a structural shape), for occasional loads.

Stresses in pipe supports outside BC/HTR areas under combined weight, thermal expansion, and detonation loading will be limited to 1.6 times the B31.3 or AISC normal condition allowable stress. The basis for the 1.6 is AISC N690, Table Q1.5.7.1 for extreme and higher loading.

In-line instrumentation, such as pressure transducers, will be shown to be acceptable up to DDT loading by limiting the maximum pressure to the maximum rated pressure of the instrumentation pressure boundary. Since these items are replaceable, i.e., there are none in Black Cells, their possible failure to function after a PRC-DDT is acceptable.

Components such as jumper connectors, valves, jet pump pairs, etc., whose function cannot be demonstrated by analysis alone may be qualified by a combination of analysis and test as follows:

1. Analyses per the criteria above as applicable for the component boundary.
2. Demonstrate other significant design aspects such as leak tightness of jumper connectors or valve operability, closure function and stem leakage by performing a bounding impulsive load test. Provide test acceptance criteria similar to those that would be used for the same functions in a seismic test.

Justification: ASME B31.3 does not address detonation pressure loading, but does permit the designer to perform detailed analysis for unusual situations, as indicated in Paragraphs 300(c)(3) and 304.7.2. The purpose of the criteria described above is to implement that provision.

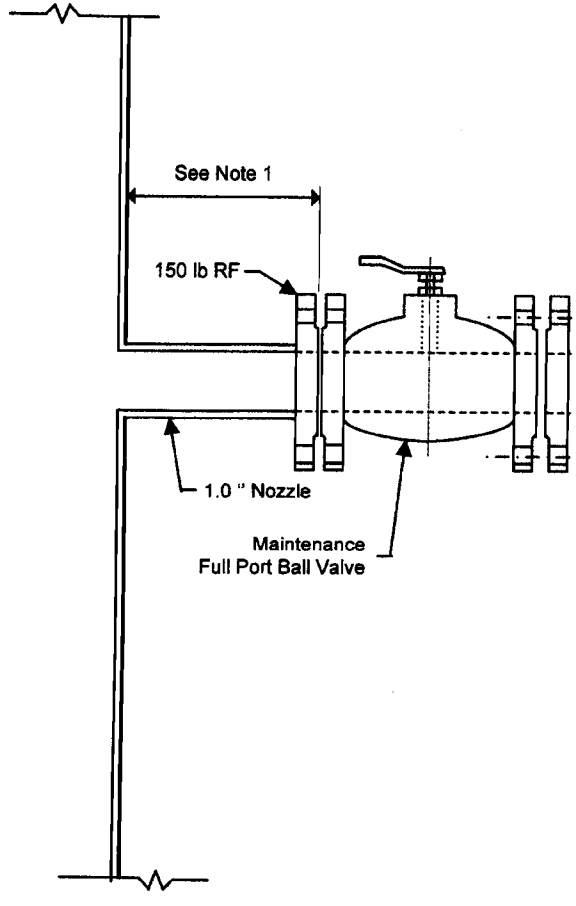
ATTACHMENT 3

Deleted

ATTACHMENT 4

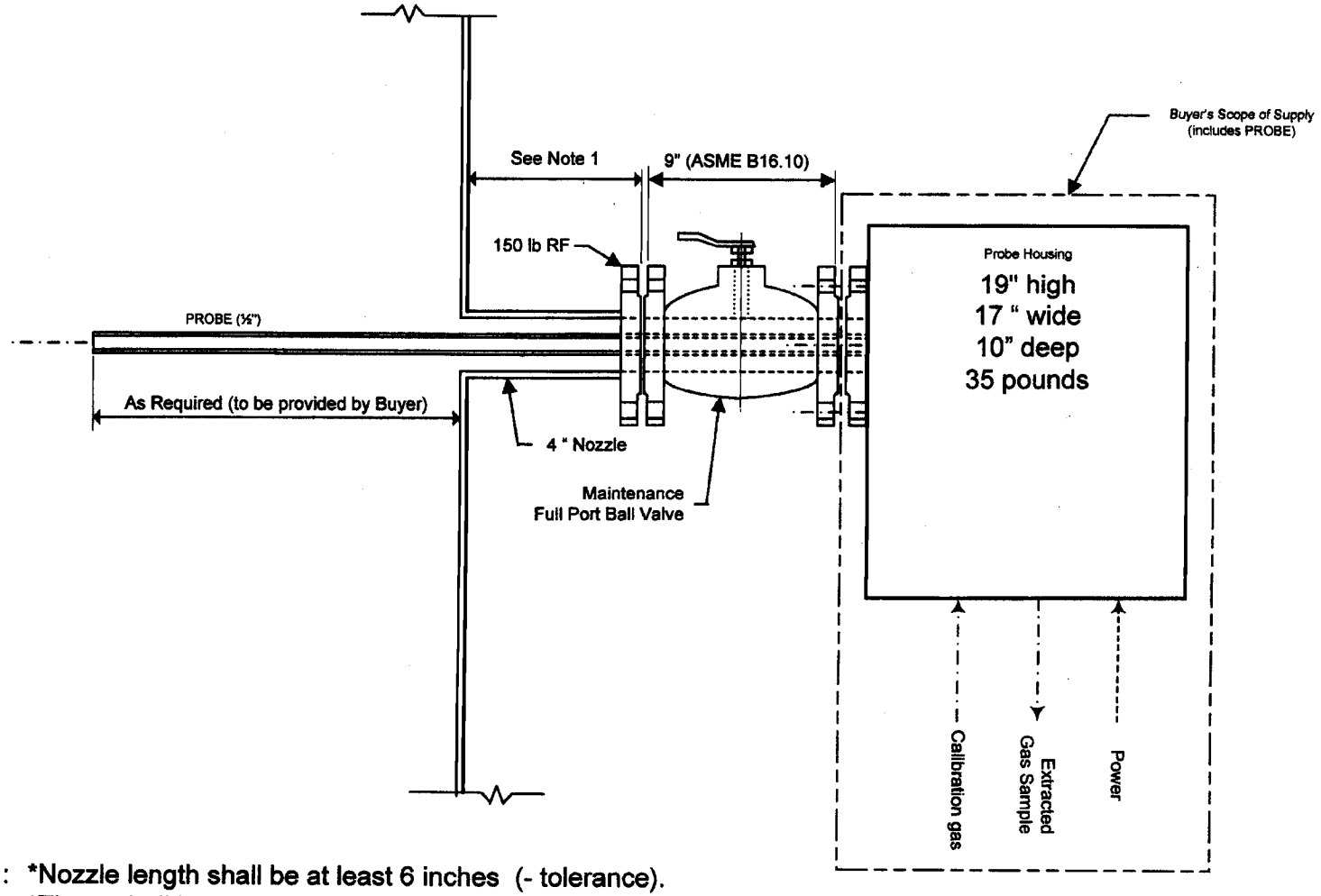
LAW SKID INTERFACE CONNECTIONS

SERVICE	NOZZLE	SIZE	INTERFACE
LVP-SKID-00002			
PROCESS GAS IN	N01	18"	FLG WN, A182-F316/316L, CL150, RF
PROCESS GAS OUT	N02	18"	FLG WN, A182-F316/316L, CL150, RF
AMMONIA/AIR IN	N03	8"	FLG WN, A182-F316/316L, CL**300**, RF
LVP-SKID-00003			
AMMONIA/AIR OUT	N04	8"	FLG WN, A182-F316/316L, CL **300**, RF
AMMONIA GAS IN	N05	2"	FLG SW, A350LF2, CL300, XS, RF
C3 DUCT AIR IN	N01	8"	FLG WN, A182-F316/316L, CL150, SCH 10, RF
C3 DUCT AIR IN	N02	8"	FLG WN, A182-F316/316L, CL150, SCH 10, RF



Note 1: *Nozzle length shall be at least 6 inches (- tolerance).
*There shall be at least 3 inches (- tolerance) of clearance, for tightening bolts, between the surface of the insulation jacketing and the underside of the flange.

Scale: None
Connection for Non-Routine Sample Extraction



Note 1: *Nozzle length shall be at least 6 inches (- tolerance).
*There shall be at least 3 inches (- tolerance) of clearance, for tightening bolts, between the surface of the insulation jacketing and the underside of the flange.

Scale: None
Connection for Sample Extraction-Permanent Typical
Secondary Offgas Flange Connection for Gas Monitor Probe with Ball Valve for Maintenance
Gas Extraction Connection

Attachment 7

Certificate of Analysis for BASF Catalysts, LLC (VOCat 300S)

This Certificate of Analysis (COA) for VOCat 300S is representative of VOCat 300S catalyst used by Catholic Vitreous State Laboratory (VSL). Seller's use of the COA is described in Section 10.2.5.3.

Form #0697
Rev. 1

BASF
ENVIRONMENTAL CATALYST GROUP
9800 KELLNER ROAD
HUNTSVILLE, ALABAMA 35824
Main Phone # (256) 772-9373

CERTIFICATE OF ANALYSIS

LOT CONTROL NO: 3642401500 HSV PART NO: 166204-001 Customer Part Numt N/A

PART SIZE: 5.91 X 5.91 X 3 CPSI: A200 Customer P/O Numt **CUA-0000016866**

THIS IS TO CERTIFY THAT CATALYSTS DELIVERED MEET REQUIREMENTS OF:

CATALYST DRAWING: **PS - 1118** REV. 3 SPECIFICATION: **PS - 057** REV. 8

FINAL INSPECTION PROC. **SOP - 0231** REV. 8

PRECIOUS METAL CONCENTRATION (SAMPLE OF ALL) IN g/ft3

TOTAL PM CONCENTRATION	SPEC	SAMPLE
MAX. AVERAGE	NR	
MIN. AVERAGE	32.51	35.53
MIN AVERAGE TPM	NR	NR
MIN INDIVIDUAL TPM	28.31	33.88

DRY GAIN	SPEC	SAMPLE
MAX. AVERAGE	2.15	
MIN. AVERAGE	1.29	1.72

DIMENSIONAL (AS PER AQL) IN INCHES

WASHCOAT ADHESION (% LOSS)

SAMPLE OF 1	SPEC	SAMPLE
MAX. INDIVIDUAL	2.0	1.0

BET SURFACE AREA IN mm2/cc

SAMPLE OF 1	SPEC	SAMPLE
MIN. INDIVIDUAL	4.0	11.9

MIN. FLOW (AFCM)

	SPEC	SAMPLE
MIN. INDIVIDUAL	TBD	381

CATALYTIC ACTIVITY IN DEG F

SAMPLE OF 1	SPEC	SAMPLE
MAX HEXANE T 20	289	200.0
MAX HEXANE t 50	387	347.0
MIN HEXANE CONV. @ 450c	92	98.0

VISUAL (AT 1.5 AQL): ALL REQUIREMENTS FOR FLATNESS, CHIPS, WORKMANSHIP, GOUGES, CRACKS, WEB DEFECTS, AND PASSAGE DEFECTS HAVE BEEN MET OR EXCEEDED AS DEFINED ON THE APPROPRIATE DRAWING.

COMMENTS: _____

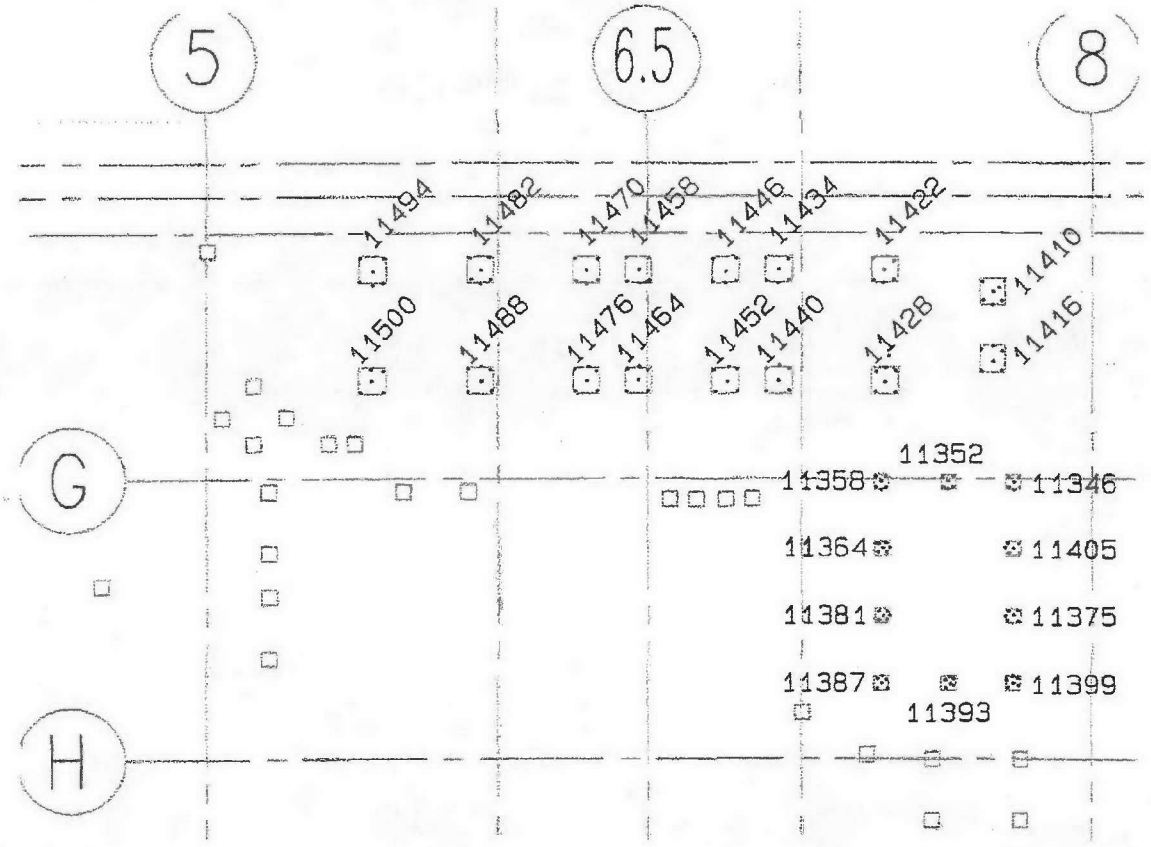
Jason Weber 6-1-09

PROCESS QUALITY REPRESENTATIVE DATE

Attachment 8

LAW TCO & Ammonia/Air Dilution Skid Embed As-Built Elevations

[Reference Drawing 24590-LAW-DB-S13T-00135]



Embed #	Elevation	Embed #	Elevation
11346	47.984	11434	47.978
11352	47.986	11440	47.993
11358	47.998	11446	47.976
11364	47.994	11452	47.992
11375	47.991	11458	47.969
11381	47.993	11464	47.967
11387	47.995	11470	47.964
11393	47.978	11476	47.972
11399	47.986	11482	47.969
11410	47.963	11488	47.976
11416	47.973	11494	47.976
11422	47.963	11500	47.967
11428	47.973		

ATTACHMENT 9

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ATTACHMENT 10

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ATTACHMENT 11

SAMPLE Certificate of Conformance

I (Signer's Name) , (Signer's Title) of (SELLER), being duly authorized by (SELLER) to make this certification, do hereby certify that:

1) The (Equipment descriptive name - Example: Pressure Transmitter), Model No.(s) (or Equivalent Identification), supplied to the WTP Project for application as Nuclear Safety item(s) under (MR /P.O. No., or equivalent Buyer's purchase document no.) is (are) environmentally and seismically qualified in accordance with the requirements in the standards, specifications, data sheets and technical notes in said purchase documents and will meet the acceptance criteria stated for its safety function.

2) The said environmental and seismic qualification are based on the tests, analyses and results documented in: (List of documents establishing Environmental and Seismic Qualification to WTP requirements)

3) The particular items (Equipment descriptive name(s), Model (Model designation(s) and List of serial numbers or other identification of the particular items supplied for Nuclear Safety application to the WTP project) supplied for Nuclear Safety application at the WTP Project are identical to, or have been shown to be sufficiently similar to, the test sample(s) subjected to qualification testing/analyses documented in the qualification documents listed above, such that the data and results in the said documents are specifically applicable to the particular items supplied to the WTP project. (If necessary) Sufficient similarity between the test sample(s) and the safety related items supplied to WTP is documented in (Document title).

4) All modifications to the test sample and manufacturing methods which were necessary to establish qualification have been effected in the particular items supplied to the WTP Project.

5) All maintenance, surveillance requirements necessary to maintain the qualified status of the equipment in the installed configuration and service conditions at the WTP Project are stated in (Document Title).

6) All replacements of parts necessary to maintain the qualified status of the equipment in the installed configuration and service conditions at the WTP Project are stated in (Document Title).

Seller (Company name) _____

Signature of Authorized Representative _____

_____
Date Signed

Name of Authorized Representative _____

Title of Authorized Representative _____

ATTACHMENT 12

Deleted

ATTACHMENT 13

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RIVER PROTECTION PROJECT – WASTE TREATMENT PLANT

ENGINEERING SPECIFICATION

FOR

Pressure Vessel Design and Fabrication

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA) are regulated at the U. S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts that pursuant to AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

Content applicable to ALARA? ☒ **Yes** ☐ **No**

ADR No.
24590-WTP-ADR-M-03-008

Rev
2

Specification changes retroactive? ☐ **Yes** ☒ **No**
☐ **N/A (alpha revision or revision 0)**

NOTE: Contents of this document are Dangerous Waste Permit affecting.

Quality Level
Q
DOE Contract No. DE-AC27-01RV14136

REV	DATE	BY	CHECK	REVIEW	NSE	APPROVER
5	2/9/15	Mohan Arulampalam	Hassan Ziada	Mike Seed	~~Dan Jolly~~	Sean Sweeney
4	27Sept09	Mohan Arulampalam	Bart Makadia	Mike Seed	R. Carlstrom	J. Julyk
3	23Apr07	R. Simmons	Mike Seed	William Eaton	Merl Rosenthal	J. Julyk
2	3Nov04	R. Tiwari	C. Slater	N/A	N/A	M. Hoffmann
1	7Jan03	R. Simmons	C. Slater	M. Hoffmann	N/A	M. Hoffmann for G. Duncan
0	22Apr02	R. Simmons	C. Slater	N/A	N/A	G. Duncan

SPECIFICATION No.
24590-WTP-3PS-MV00-T0001

Rev
5

Revision History

Revision	Reason for Revision	Q Specification Revision Only Margin Reduced?		CM Only
		YES	NO	N/A
0	Issued for Design	N/A	N/A	N/A
1	Rewritten, Incorporates Design Changes: 24590-WTP-3PN-MV00-00001 24590-WTP-3PN-MV00-00002 24590-WTP-SDDR-PROC-02-0145 24590-WTP-SDDR-PROC-02-0155 24590-WTP-SDDR-PROC-02-0183 24590-WTP-SDDR-PROC-03-0023 24590-WTP-SDDR-PROC-03-0053 24590-WTP-SDDR-PROC-03-0075 24590-WTP-SDDR-PROC-03-0082 24590-WTP-SDDR-PROC-03-0083 24590-WTP-SDDR-PROC-03-0086 24590-WTP-SDDR-PROC-03-0100 Issued for Use	☐	☒	☐
2	Incorporates Design Changes: 24590-WTP-3PN-MV00-00009 24590-WTP-3PN-MV00-00011 Added Black cell and Primary Confinement Definitions and requirements Revised Radiographic Acceptance Requirements Revised Reference to ADR Issued for Use	☐	☒	☐
3	Incorporates Change Documents Listed in Section 11 Revised Section 3.7 to Support Nozzle Loads other than Appendix A Changed to 'Design Level' grading system Issued for Use	☐	☒	☐
4	Incorporated relevant requirements from Appendix L Section of SRD, SCN, and SDDR design changes	☐	☒	☐
5	Incorporated requirements from MR technical notes, clarifications and SDDR and design changes noted in Section 11	☐	☒	☐

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1 Scope

1.1 Project Description and Location

This specification is included in the Purchase Order, Material Requisition or in the scope of work of subcontract packages. It defines the technical requirements for the design, fabrication, and testing of pressure vessels for the Hanford Tank Waste Treatment and Immobilization Plant (WTP) project located in the southeastern part of Washington State.

1.2 Acronyms and Definitions

1.2.1 **Black Cell:** Shielded cells for which no maintenance or entry planned for the 40-year design life of the plant.

1.2.2 **Containment:** Components that contain active process fluids inside the plant process system. Refer to the MDS for the containment classification of components.

- Primary Confinement: The boundary within which the process fluids, gases, and vapors are contained and confined during the plant process operation. In this document, the entire process vessel and nozzle walls are generally referred to as the Primary Confinement.
- Primary Containment: The part of the Primary Confinement that is in contact with the process fluid. This is typically the wetted portion of the vessel wall below the top of the overflow.
- Auxiliary Containment: This term is used in this document to identify the portion of a Primary Confinement that is not subject to a static pressure head of liquid but may be in contact with splashing liquid, vapor, or gases. This is typically the vessel components above the prescribed high operating liquid level.
- Secondary Containment: The boundary that will contain process liquid if the Primary Containment is breached. This boundary will not normally be in contact with the process liquid. Typically, this is the cell liner or wall structure of the facility.

1.2.3 **CV:** Charge Vessel

1.2.4 **DBE:** Design Basis Event

1.2.5 **Design Level:** Determines allowable nozzle reinforcement methods and nondestructive examination (NDE) requirements. Buyer assigns Design Levels on the MDS or Drawings.

1.2.6 **Drawings**: The Buyer's Drawings include the vessel general outline drawing and any associated standard drawings

1.2.7 **ECDS:** The section of the MDS titled Equipment Cyclic Data Sheet. If components of a vessel are subjected to cyclic loads, those loads will be detailed in the ECDS.

1.2.8 **EQD**: Equipment Qualification Data Sheet.

1.2.9 **Hard to Reach Areas:** Facility areas located in rooms not designed for manual or remote access, replacement, or repair.

1.2.10 **MDS**: The Buyer's mechanical data sheet.

1.2.11 **NDE**: Nondestructive Examination

1.2.12 **PJM:** Pulse Jet Mixer

1.2.13 **Quality Level:** Establishes the quality assurance program requirements. Formerly, Quality Level also determined allowable nozzle reinforcement methods and NDE requirements. Refer to the Design Level for these requirements. Buyer assigns Quality Levels on the MDS or Drawings.

1.2.14 **SDDR**: Supplier Deviation Disposition Requests

1.2.15 **Seismic Category:** Classification of vessels defining the required condition, status, and operating function during and after a seismic event. The Seismic Category determines the analysis method and acceptance criteria appropriate for the intended service and safety function of the vessel. Buyer assigns Seismic Category on the MDS.

1.3 Conflicts

In cases of conflicts between this specification and other drawings or specifications, the Seller shall call attention to the conflict and request an interpretation by the Buyer.

1.4 Buyer's Responsibilities

Process parameters of the vessel for performance, capacity, or configuration are the Buyer's responsibility, and are not part of this specification.

1.5 Seller's Responsibilities

1.5.1 Seller shall assume complete responsibility for the design, fabrication, testing, inspection, and documentation as required by the Buyer and detailed in the purchase order.

1.5.2 Buyer's review of the Seller's drawings, or release of the vessel for shipment by the Buyer's representative, shall in no way relieve the Seller of the responsibility for complying with all the requirements of this specification and the purchase order.

1.5.3 The Seller shall substantiate any necessary changes to the MDS, Drawings, specifications and purchase order and obtain approval from the Buyer.

2 Applicable Documents

2.1 General

2.1.1 Work shall be in accordance with the referenced codes, standards, and documents listed below, which are integral parts of this specification.

2.1.2 When specific chapters, sections, parts, or paragraphs are listed following a code, industry standard, or reference document, only those chapters, sections, parts, or paragraphs of the document are applicable and shall be applied. When more than one code, standard, or referenced document covers the same topic, the requirements for all must be met with the most stringent governing.

2.2 Codes and Industry Standards

2.2.1 The Seller shall apply the latest issue, including addenda, at the time of request for quote or award as applicable for the following codes and industry standards with exceptions as noted.

2.2.1.1 ASME Section VIII, Division 1, *Rules for Construction of Pressure Vessels*, American Society of Mechanical Engineers

2.2.1.2 ASME Section II, *Materials*, American Society of Mechanical Engineers Use of later version of the code or standard directly comparable and equivalent in approach, Buyer approval is NOT required. If the later version of the code or standard is not directly comparable and essentially equivalent use of the later version requires AI's approval

2.2.1.3 ASME Section V, *Nondestructive Examination*, American Society of Mechanical Engineers

2.2.1.4 NBIC, *National Board Inspection Code*, National Board of Boiler and Pressure Vessel Inspectors

2.2.1.5 WRC-107, *Local Stresses in Spherical and Cylindrical Shells due to External Loading*, Welding Research Council

2.2.1.6 WRC-297, *Local Stresses in Cylindrical Shells due to External Loadings on Nozzles–Supplement to WRC Bulletin No. 107*, Welding Research Council

2.2.1.7 PFI Standard ES-24, *Pipe Bending Methods, Tolerances, Process and Mechanical Requirements*, Pipe Fabrication Institute, Engineering and Fabrication Standard

2.2.1.8 ASME Section VIII, Division 2, *Rules for Construction of Pressure Vessels - Alternative Rules*, American Society of Mechanical Engineers, *(Note: Code year not later than 2004 Edition with 2005 and 2006 Addenda)*.

2.2.1.9 ASME B31.3, *Process Piping*, 1996, American Society of Mechanical Engineers

2.2.1.10 AISC M016, *ASD Manual of Steel Construction, 9th Edition*, American Institute of Steel Construction

2.2.1.11 ANSI/AISC N690, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities*, American Institute of Steel Construction

2.2.1.12 SNT-TC-1A, *Recommended Practice No. SNT-TC-1A*, American Society for Nondestructive Testing, Inc.(Note: Refer to the Quality Assurance Program Requirements Data Sheet in the Purchase Order for acceptable editions).

2.2.1.13 ANSI/AWS D1.1, D1.6 Structural Welding Code

2.2.2 The Seller shall apply the issue and addenda as referenced in Table U-3 of ASME Section VIII, Division 1 for the following codes and industry standards:

2.2.2.1 ASME B16.5, *Pipe Flanges and Flange Fittings NPS 1/2 through NPS 24*

2.2.2.2 ASME B16.47, *Large Diameter Steel Flanges NPS 26 through NPS 60*

2.2.3 The Seller shall apply the issue and addenda as stated for the following codes and industry standards:

2.2.3.1 ASCE 7-98, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers

2.2.3.2 ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, 1989, 2000 Edition

2.3 Related Documents

Other project specifications, standards, and standard details as listed or referenced in Section 2 of the purchase order shall be used as applicable for the design and fabrication of the vessels.

2.4 Project Documents

2.4.1 24590-WTP-3PS-MV00-T0002, *Engineering Specification for Seismic Qualification Criteria for Pressure Vessels*

2.4.2 24590-WTP-3PS-MV00-T0003, *Engineering Specification for Pressure Vessel Fatigue Analysis*

2.4.3 24590-WTP-3PS-G000-T0002, *Engineering Specification for Positive Material Identification (PMI) for Shop Fabrication*

2.4.4 24590-WTP-MV-M59T-00001, *Pressure Vessel Tolerances Standard Details*

2.4.5 24590-WTP-3PS-MVB2-T0001, *Engineering Specification for Welding of Pressure Vessels, Heat Exchangers and Boilers*

2.4.6 Deleted

2.4.7 24590-WTP-3PS-G000-T0003, *Engineering Specification for Packaging, Handling and Storage Requirements*

2.4.8 24590-WTP-3PS-FB01-T0001, *Engineering Specification for Structural Design Loads for Seismic Category III and IV Equipment and Tanks*

3 Design Requirements

3.1 Basic Requirements

3.1.1 Unless otherwise specified, all vessels shall be designed and fabricated in accordance with ASME Section VIII, Division 1, any additional requirements of this specification, MDS, and the referenced Drawings.

3.1.2 Pressure vessels shall be U-stamped and registered with the NBIC. Any exceptions are indicated on the MDS.

3.1.3 Seller shall consider design details and material thickness shown on Drawings and MDS as the minimum requirements.

3.1.4 Seller shall not scale Drawings

3.1.5 Pulse Jet Mixers and Charge Vessels are not required to be U-Stamped

3.2 Loadings

3.2.1 Seismic analysis shall be performed per the requirements of 24590-WTP-3PS-MV00-T0002.

3.2.2 If wind or snow loadings are specified on the MDS, the design for such loadings shall be based on the requirements of the ASCE 7, using the indicated wind and snow loading parameters.

3.2.3 If the MDS contains an ECDS, the Seller shall analyze for fatigue per the requirements detailed in the 24590-WTP-3PS-MV00-T0003. Seismic loadings shall not be considered when performing a fatigue analysis.

3.2.4 Unless indicated otherwise on the MDS or Drawings, the Seller shall design the vessels to support process liquid filled to the top of the overflow.

3.3 Corrosion/Erosion Allowance

3.3.1 Corrosion allowance is specified on the MDS and shall be applied to each surface exposed to process vapor or liquid. Internal piping, charge vessels, and pulse jet mixers shall have the specified corrosion allowance applied to both internal and external surfaces.

3.3.2 Unless otherwise specified, corrosion allowance shall not be applied to external vessel surfaces.

3.3.3 Erosion allowances, where required, will be specified in the MDS.

3.4 Heads

The Seller shall use head shapes as specified on the vessel drawing. Deviations from this profile may be considered for economic, space or fabrication concerns. Any change, however, requires the approval of the Buyer via SDDR.

3.5 Supports and Anchors

3.5.1 Seller shall provide vessel supports as illustrated on the Drawings.

3.5.2 Supports and anchors shall be designed to secure the buoyant vessel in case the vessel is empty and submerged to the level indicated in the MDS or EQD.

3.5.3 Criteria

Detail design of vessel supports shall be in accordance with the recommendation of ASME Section VIII, Division 1, Appendix G, except as noted below.

3.5.3.1 For safety equipment (SC or SS) the abnormal and design basis event (DBE) conditions, as defined on the EQDs, are to be used when evaluating the load combination per AISC N690, Table Q1.5.7.1. For vessel item temperatures, see appendix "E"

For Load Combinations 5, 7 and 8 from N690, the "T_o" value is to be from the EQD "abnormal" room temperature section.

For Load Combination 9 from N690, the "T_a" value is to be from the EQD "DBE" room temperature section.

For Load Combination 11 from N690, the "T_o" value is to be from the EQD "DBE" room temperature section

The thermal environmental boundary condition may also be determined through a more detailed analysis by the Seller with prior approval by the Buyer.

Note: When the T_a value from the EQD indicates that it is due to a high energy line break (HELB) then the T_a thermal environmental condition is additive to the seismic event. When the Ta value from the EQD is not due to a HELB (typical) then the thermal condition and seismic event may be evaluated separately (i.e. non-simultaneous).

3.5.3.2 For SC-III and SC-IV vessels, the stresses for carbon steel vessel supports shall not exceed the allowable stress value for the material of construction per AISC M016, *Manual of Steel Construction* as tailored, and included in Appendix C. For combined loadings, see 24590-WTP-3PS-FB01-T0001, *Engineering Specification for Structural Design Loads for Seismic Category III & IV Equipment and Tanks*.

3.5.3.3 SC-III and SC-IV stainless steel vessel supports are to be designed in accordance with the allowable stresses from N690 to the load combinations from 24590-WTP-3PS-FB01-T0001, *Engineering Specification for Structural Design Loads for Seismic Category III & IV Equipment and Tanks*.

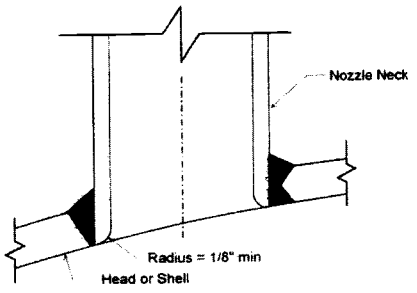
3.6 Nozzles and Manways

3.6.1 Nozzle wall thickness shall be per ASME Section VIII, Division 1 and at least that specified on the Drawings. Seller shall understand that minimum nozzle thicknesses indicated on the Drawings may not support the nozzle loading requirements listed in Appendix A.

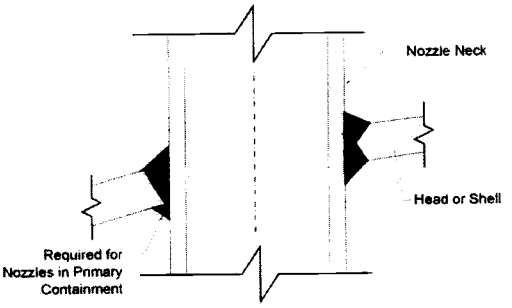
3.6.2 Nozzles and manways and their reinforcements located on the head shall be located fully within the crown region of the head unless noted otherwise on the Drawing.

3.6.3 All nozzles shall be set-in type or through type with full penetration welds. All nozzles, which are flush with the inside surface of the vessel, shall be rounded to 1/8 inch minimum radius as shown below. Nozzles for pressure relief devices, vents, and drainage shall be flush with the inside surface of the vessel. Nozzles with internal projection in primary containment shall have an additional fillet weld between the internal projection and the inside surface of the shell or head.

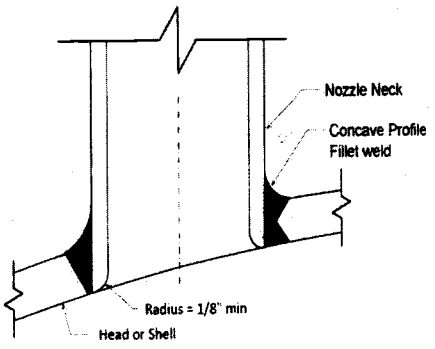
3.6.4 **The following illustrates acceptable and unacceptable nozzle configurations and welding:**



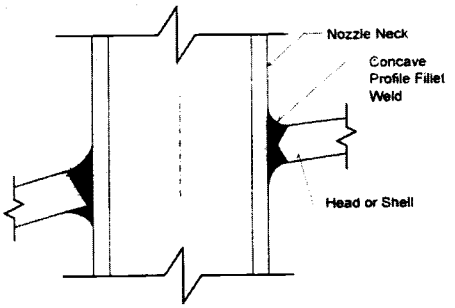
Set-in Nozzle with Full Penetration Weld



Through Nozzle with Full Penetration Weld

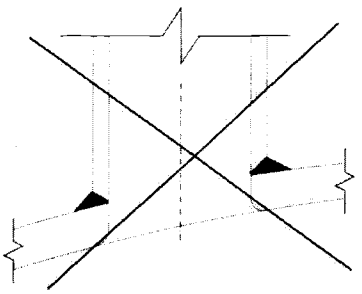


Optional Set-in Nozzle with Full Penetration Weld for Fatigue Service

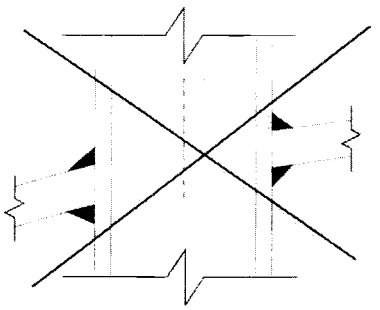


Optional Through Nozzle for Fatigue Service

Unacceptable Nozzle Connections



Set-on Nozzle with Full Penetration Weld



Through Nozzle with Double Fillet Weld

3.6.5 Flange boltholes shall straddle natural vessel centerlines unless otherwise specified.

3.7 Nozzle Loading

3.7.1 Unless otherwise specified, Seller shall design nozzles for the minimum nozzle design loads listed in the applicable table of Appendix A for the connected pipe size. For Safety (SC/SS) and Black Cell and/or Hard-to-Reach Area Vessels, nozzles are to be designed in accordance with Appendix 4 of ASME VIII, Division 2, using the allowable stress (S) from Division 1 in lieu of design stress intensity (S_m) of Division 2. Nozzles/shell on other vessels are to be designed according to the methods of WRC-107, WRC-297 as a minimum.

3.7.1.1 For Safety (SC/SS) vessels outside Black Cell/Hard-to-Reach (BC/HTR) areas, if the fatigue exemption rules are met per specification 24590-WTP-3PS-MV00-T0003, Section 8.3, then the primary local membrane (PL) and primary membrane plus primary bending (Pl+Pb) stresses in the vessel shell (or head) at nozzle and support connections shall be evaluated and limited to 1.5S for normal loads and 1.8S for normal plus seismic loads. This requirement can be satisfied using WRC-107 or WRC-297 method. Detail stress analysis per Finite Element Modeling may be used but is not required.

3.7.2 Appendix A lists minimum design nozzle loads by nozzle size, connecting pipe material, and Seismic Category for weight, seismic, and thermal expansion cases. The coordinate system conforms to the 'right hand rule'. Loads provided in Appendix A do not have a sign convention; Seller must ensure that the direction of load application provides the most conservative stresses at the nozzle to shell or head junction. The Y-axis is vertical and in the direction of gravity regardless of the orientation of the nozzle. Loads act at the juncture of the nozzle and shell.

3.7.3 Nozzle load combinations to be considered for Primary and Secondary Stress in the design shall be:

Weight + Seismic+ Operating Pressure+ Thermal Load (Appendix A)

Note: Thermal Loads listed in Appendix A are from the loads resulting from the restrained free end movement of the attached pipe and are considered as primary loads per paragraph 4-138 of Appendix 4 of ASME VIII Division 2.

With regard to the radial load. the internal pressure shall not be used to oppose the compressive stress due to the force acting inwards; for this load condition a null pressure condition is to be considered to exist.

Nozzle load combinations to be considered for Secondary Stress in the design shall be:

Weight + Operating Pressure+ Thermal Load (Appendix A)
+ General Thermal (per code definition)

3.7.4 The nozzle loads provided are for the piping connected to the external nozzle. If a nozzle projects and is loaded internally to the vessel. design the nozzle for the sum of the internal and external loads.

3.7.5 The nozzle loads due to thermal expansion listed in Appendix A are estimated based on the operating temperature of 350° F. If the maximum operating temperature of the attached pipe is less than 350° F. the nozzle thermal loads may be reduced by a scale factor of the absolute value.

$$\text{of } \frac{|X-70|}{|350-70|}$$

Where X is the maximum vessel operating temperature of the attached pipe.

3.7.6 The MDS shall indicate if a particular nozzle on a particular vessel has an interface with a jumper. The nozzle to jumper interface loading shall follow the tables of Appendix B.

3.7.7 The coordinate system conforms to the 'right hand rule'. Loads provided in Appendix B do not have a sign convention; supplier ensures that the direction of load application provides the most conservative stresses at the nozzle to shell or head junction. The V- axis is vertical (Appendix B. "V" for vertical) and in the direction of gravity regardless of the orientation of the nozzle. Loads and moments act at the junction of the nozzle and shell.

3.8 Nozzle Reinforcement

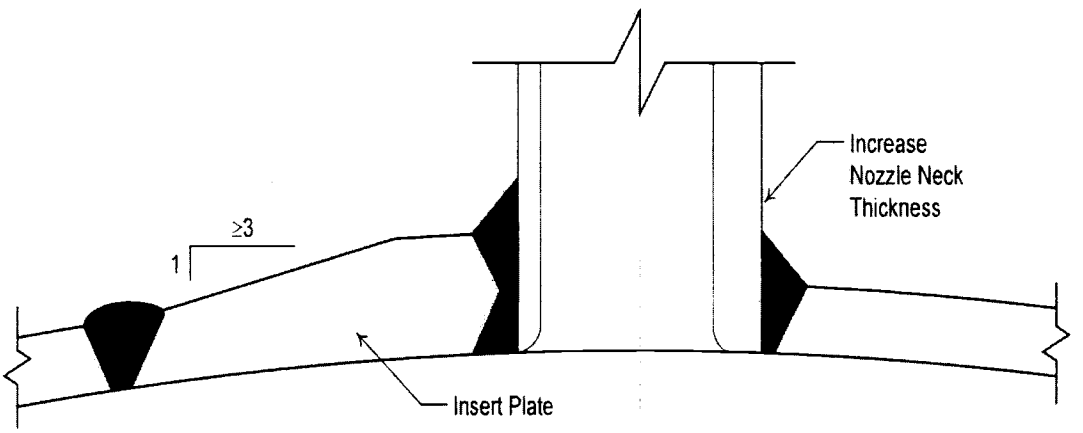
3.8.1 When required. suitable nozzle reinforcements must be provided. Reinforcement methods are limited depending on the assigned Design Level and cell designation. Refer to Section 6 for allowable reinforcement methods. If the wall thickness of the nozzle neck is greater than that of the connecting piping. the requirements of ASME Section VIII. Division 1. and Figure UW-13.4 shall be satisfied.

3.8.2 Nozzle reinforcing pads. where permitted. shall have one-piece construction (not segments). Nozzle insert plates (integral pads) shall be in accordance with ASME Section VIII with a 3 to 1 taper.

3.8.3 For external nozzle reinforcing pads. the pad thickness shall not exceed 1.5 times the thickness of the penetrated shell. To meet nozzle loading requirements. pad diameter may exceed the limits of reinforcement per ASME Section VIII. Division 1. Pad width shall be at least 2 inches but shall not exceed ten times the thickness of the pad. Each pad shall have single 1/8 inch nominal pipe size (NPT) telltale hole for testing purposes. On completion of all

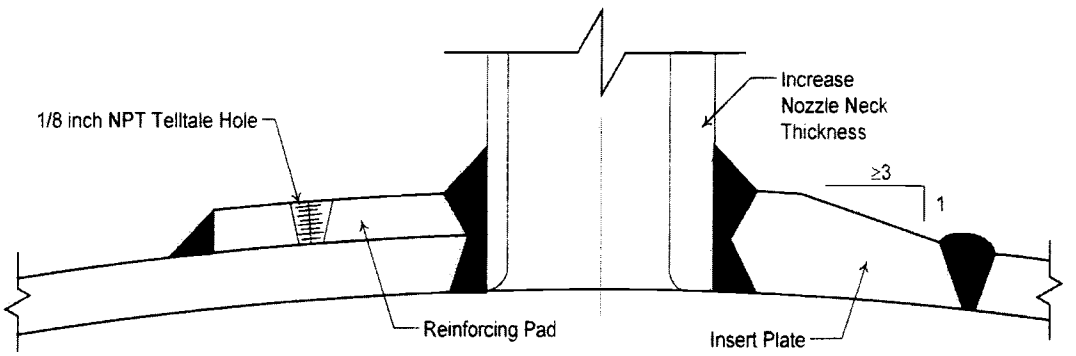
fabrication activities. the hole shall be fitted loosely with a screwed plug of the same material as the reinforcement plate.

3.8.4 The following illustrates acceptable reinforcement practices for nozzles irrespective of Design Level:



Nozzle Reinforcement Methods
for All Design Levels

3.8.5 Nozzles on Commercial Grade vessels not located in a BC or HTR area may use external reinforcing pads (See figure below). As a warning, the nozzle loads specified in Appendix A may exceed the practical use of repads. In such cases, the Seller should consider locally increasing the thickness of the shell or head with an insert plate or increasing the nozzle neck thickness as required. The following illustrates acceptable reinforcing practices with full penetration welds for nozzles on Commercial Grade vessels not located in a BC or HTR area.



Nozzle Reinforcement Methods
Only for Commercial Grade Vessels
Not Located in a Black Cell

3.8.6 Material used for nozzle reinforcement shall be the same as the parent vessel unless approved by the Buyer as stated on the MDS.

3.8.7 Structural reinforcing elements such as reinforcing rings or pads (integral or non-integral) can be used as necessary to accommodate new design load combinations on fabricated and

partially fabricated vessels. Any butt-weld seams to be covered by the pads shall be ground flush and radiographically examined, in accordance with ASME Section VIII, Division 1, subdivision UW-51, before the reinforcing pads are welded in place. Reinforcing pads may be formed to the required shape by any process that will not unduly impair the physical properties of the material. Reinforcing pads shall be fitted to conform to the curvature of shell, head, or other surfaces to which they are attached to minimize flat spots and horizontal surfaces that could collect solids. Edges of non-integral pads shall be tapered 3 to 1 minimum to match the height of the legs of the attaching fillet welds. The fillet welds shall fully seal the dead space between the pad and the shell, head, or other surfaces to which the pad is attached.

3.9 Internal Components and Supports

3.9.1 Design of support members for vessel internals shall be the responsibility of the Seller. For pulse jet mixers, charge vessels, and their supports, the Seller shall submit a preliminary layout for review prior to detail design.

3.9.1.1 Piping Internal to the Vessel

Piping internal to the vessel is to be designed in accordance with ASME B31.3-1996, Process Piping with following modification:

In Table D300, the description of welding tee per ASME B16.9 shall be revised so it is consistent with that shown in Table D300 of ASME B31.3-2002:

		Stress Intensification Factor [Notes (2), (3)]			
Description	**Flexibility Factor k**	**Out-of-Plane, i_o**	**In-Plane i_i**	**Flexibility Characteristic, h**	**Sketch**
Welded tee per ASME B16.9 [Notes (2), (4), (6), (11), (13)]	1	$\frac{0.9}{h^{2/3}}$	3/4 i_o + 1/4	$3.1\frac{\overline{T}}{r_2}$	Same as ASME B31.3-1996

This means that for welding tees per ASME B16.9, note 11 in Table D300 is also changed to:

(11) If $r_x \geq 1/8 D_b$ and $T_c \geq 1.5\overline{T}$, a flexibility characteristic of $4.4\overline{T}/r_2$ may be used.

3.9.1.2 Support Structures for Components Internal to the Vessel

Support structures for SC-I and SC-II components within the vessel that connect and support items such as the internal piping, Pulse Jet Mixers, charge vessels, or other internal components, that are away from the discontinuity shall be designed to meet the requirements of either AISC N690 or ASME Section VIII, Div-2. The tailoring of ANSI/AISC N690 in

Appendix D of this specification is required for use by the WTP contractor as an Implementing Standard for structural design. The support at the connection discontinuity is within the code pressure boundary shall be designed per ASME Section VIII.

3.9.1.3 SC-III and SC-IV carbon steel support structures within the vessel that connect and support items such as the internal piping, pulse Jet Mixers, charge vessel, or other internal components, that are away from the discontinuity shall be designed in accordance with AISC M016 to the load combinations from 24590-WTP-3PS-FB01-T0001, *Engineering Specification for Structural Design Loads for Seismic Category III & IV Equipment and Tanks*. The support at the connection discontinuity with the vessel is within the code pressure boundary and shall be designed per ASME Section VIII.

3.9.1.4 SC-III and SC-IV stainless steel support structures within the vessel that support items such as the internal piping, pulse Jet Mixers, charge vessel, or other internal components, that are away from the discontinuity shall be designed in accordance with the allowable stresses from N690 to the load combinations from 24590-WTP-3PS-FB01-T0001, *Engineering Specification for Structural Design Loads for Seismic Category III & IV Equipment and Tanks*. The support at the discontinuity with the vessel is within the code pressure boundary and shall be designed per ASME Section VIII.

3.9.2 Pulse Jet Mixers and Charge Vessels.

Pulse Jet Mixers and Charge Vessels are to be designed to the same criteria as the parent vessel; requires no code stamping

3.9.3 Seller shall design support members to avoid the column of space directly below the manway.

3.9.4 The design of internal supports shall consider stresses caused by differential thermal expansion.

3.9.5 If indicated on Drawings, the internal surface of the head or shell subjected to direct impingement of process fluid shall be protected by a wear plate. See the MDS for the wear plate material.

3.9.6 Internal process piping which opens to the vessel contents shall be designed for the vessel design pressure and temperature or greater. Internal process piping which is connected to equipment internal to the vessel (e.g., Charge Vessel, Pulse Jet Mixer), shall be designed to that internal equipment design pressure and temperature.

3.10 External Components and Supports

3.10.1 If the MDS specifies insulation, the Seller shall provide and install insulation supports per the Drawings.

3.10.2 Lifting and tailing lugs shall be provided and installed by the Seller per the Drawings. The Seller may propose alternate designs and submit SDDR for Buyer approval prior to detail design.

3.10.3 The Seller is responsible for determining the necessity of stiffening rings. The material shall match the material of the shell and attachment welds shall be continuous on both sides of the ring. Reinforcement Pads for nozzles, guides etc., shall match the material of parent vessel.

3.10.4 If specified on the Drawings, Seller shall provide and install support clips for piping or platforms. The materials welded to the shell shall match the material of the shell.

3.10.5 If indicated on the Drawings, Seller shall provide and install grounding lugs.

3.10.6 Seller shall provide all vessels with a nameplate of Type 300 stainless steel attached securely on a bracket welded to the vessel at the location indicated on the Drawings. The bracket shall be the same material type as the adjoining vessel shell. The nameplate shall be in accordance with the specified Drawing.

3.10.7 The base of the vertical vessel support skirt shall be marked, using a line of welding bead, at the 0 degree orientation as shown on the Drawings.

3.10.8 If a separate ring beam support is specified on the vessel drawing, the top flange shall be marked, using a line of welding bead, at the 0 degree orientation as shown on the Drawings. Vendor shall include ring beam geometry in their vessel/skirt analysis and shall provide forces and moments at the bottom of ring beam at embed location/interface.

3.10.9 The external supports skirts, legs, saddle, lugs etc., shall be designed in accordance with AISC M016 for carbon steel or N690 for Stainless Steel Structures. The support at the discontinuity and with vessel is within the code pressure boundary and shall be designed per ASME Section VIII.

4 Materials

4.1 General

4.1.1 Materials shall be new and free from defects. Classification of fabrication materials shall be in accordance with ASME Section II. The Seller shall furnish legible copies of the mill test reports from the manufacturer for materials comprising the Primary Confinement, internals, supports, and welded attachments. Other materials shall be provided with certified statements that the material meets the requirements of ASME Section II.

4.1.2 Material shall be furnished to the specification and grade shown on the MDS. The fabricator shall not substitute materials without written approval from the Buyer.

4.1.3 Contact materials including marking materials, temperature indicating crayons, adhesive backed and pressure sensitive tape, and barrier and wrap materials may be used only under the following limits:

- The total halogen content shall not exceed 200 parts per million (PPM)
- The total sulfur content shall not exceed 400 PPM
- No intentionally added low melting point metals such as lead, zinc, copper, tin, antimony, and mercury.

Anti spatter compounds shall not contain chlorine, fluorine, sulfur, mercury or other low melting point metals.

Materials and residue shall be completely removed when no longer required. Cleaning materials may be non-halogenated solvents or potable water containing no more than 50 PPM chloride. Contact materials shall be controlled and documented in accordance with the Seller's inspection and test plan as approved by the Buyer.

4.1.4 Seller shall maintain a positive system of identification of materials used in the fabrication of each vessel per 24590-WTP-3PS-G000-T0002.

4.2 Pipe Fittings

Pipe fittings shall conform to the appropriate ASME and ANSI standards for materials and dimensions unless otherwise stated in the purchase order.

5 Fabrication

5.1 General

5.1.1 Seller shall, if necessary, provide temporary stiffening and jigging to prevent shell distortion during fabrication, welding processes, heat treatment, hydrostatic testing, or shipment.

5.1.2 Fabrication tolerances shall be in accordance with ASME Section VIII, Division 1 and standard drawing 24590-WTP-MV-M59T-00001.

5.1.3 The sequence of fabrication shall be planned to permit maximum access to the internal surfaces to enable examination of all welds.

5.1.4 Plates and pipes shall be cut to size and shape by machining, grinding, shearing, plasma, laser, or water jet cutting. Plates, 3/8 inch thick and above, cut by shearing, shall either be dye penetrant tested on the sheared edge or have 3/8 inch allowance left on the edges which shall be removed by machining or grinding. All thickness of plate or pipe cut by air plasma cutting shall have the edges dressed to a smooth, bright finish. Material cut by the inert gas shielded plasma, laser or water jet process will not require further dressing other than deburring. All lubricants, burrs, and debris shall be removed after cutting.

5.1.5 All stamps used for identification reference markings shall be of the low stress type. Stampings shall not be located near discontinuities.

5.1.6 If a butt welded seam is required between materials of different thickness, the thicker material shall normally be machined on the side away from the process liquid. Machining shall ensure a smooth finished profile with no sharp corners and shall be in accordance with ASME Section VIII, Division 1.

5.1.7 When rolling any austenitic stainless plate, care shall be taken to prevent carbon pickup or contamination of rolled material. The work area shall be free of carbon steel grindings and general cleanliness shall be maintained to preclude carbon contamination.

5.1.8 Only stainless steel brushes, clean iron-free sand, ceramic, or stainless steel grit shall be used for cleaning stainless steel or nonferrous alloy surfaces. Cleaning tools or materials shall not have been previously used on carbon steel.

5.1.9 Internal piping bends shall have a center line radius of four times the pipe nominal diameter. In confined spaces, the centerline radius may be reduced to three times the outside diameter of the pipe. Piping shall not be terminated or butt welded within the bend. If a circumferential butt weld in the arc of a pipe bend is necessary, the bending process shall comply with PFI Standard ES-24 and require Buyer's prior approval via the SDDR process. The circumferential butt weld shall be radiographed prior to and after bending.

5.1.10 Pipe bending methods, tolerances, processes, and material requirements shall comply with PFI Standard ES-24 and require Buyer's approval. These requirements shall apply equally to tube bending processes. Seller shall submit a pipe bending procedure for Buyer review prior to use.

5.2 Layout

5.2.1 Plate size shall be chosen to minimize welding. For horizontal vessels, the longitudinal seams in cylindrical shells and conical heads shall be located above the specified normal operating level, where practical. Longitudinal seams shall be completed before welding any adjoining circumferential seam.

5.2.2 The longitudinal seams of adjacent shell courses shall be staggered by a minimum length (measured from the toe of the welds) of 5 times the plate thickness, or 4 inches whichever is greater. Where it is considered impractical to meet this requirement, Seller shall submit a proposed layout to the Buyer for approval via the SDDR process.

5.2.3 For large diameter formed heads, where two or more plates are butt welded prior to forming, the butt welds shall be located such that the weld in the knuckle region is minimized.

5.2.4 Saddles shall be continuously welded to the shell. Welded seams under the saddle or wear plate are not permitted. Longitudinal weld seams in the shell should not be located within 15 degrees of the horn of the saddle or wear plate.

5.2.5 Plate layouts shall be arranged so that longitudinal and circumferential weld seams clear all nozzles, manways, and their reinforcing pads to the maximum extent possible. A minimum clearance of eight times the plate thickness from the toes of the welds is required. Where it is considered impractical to meet this requirement, Seller shall submit a proposed layout of all weld joints to the Buyer for approval via the SDDR process.

5.2.6 Structural attachment welds such as internal support rings or clips, external stiffening rings, insulation support rings, and ladder, platform or pipe support clips shall clear weld seams by a minimum of 2 inches. If overlap of pad type structural attachments and weld seams is unavoidable, the portion of the seam to be covered shall be ground flush and radiographically examined before the attachment is welded. The seam shall be radiographed per ASME Section VIII, Division 1, Paragraph UW-51 for a minimum distance of 2 inches beyond the edge of the overlapping attachment. Any protrusion through the weld seam when unavoidable shall be radiographically examined after completing the joint weld for at least minimum distance of 8 times the thickness of thicker material at protrusion. Radiographic examination of longitudinal weld seams is not required when single plate edge type attachments such as

tray support rings, stiffening rings, insulation support rings, ladder, platform, or pipe support clips cross such weld seams.

5.3 Nozzles, Manways, and Reinforcing Pads

5.3.1 For forged nozzles connecting to pipe of lesser wall thickness, the Seller shall prepare the nozzles per ASME Section VIII, Division 1, Figure UW-13.4.

5.3.2 If a manway is specified with a welded cover, the cover shall be tack welded to the manway neck, prepared for field welding to the manway neck, sealed to prevent dirt and water from entering the vessel using adhesive tape which meets the contact material requirements. The cover shall be marked with the plant item number of the vessel.

5.3.3 Nozzles to be butt welded to connecting pipe shall be prepared for field welding and fitted with a plastic or rubber protective cover and sealed to prevent dirt and water from entering the vessel using adhesive tape which meets the contact material requirements.

5.4 Welding Requirements

5.4.1 Seller shall comply with 24590-WTP-3PS-MVB2-T0001.

5.4.2 All welding shall be continuous. Stitch welding is prohibited.

5.4.3 Joints shall be assembled and retained in position for welding. The use of manipulators or other devices to permit welding in the flat position should be employed where practical.

5.4.4 All attachments such as lugs, brackets, nozzles, pads and reinforcements around openings and other members (when permitted) shall follow the contour and shape of the surface to which they will be attached. The gap at all exposed edges to be welded shall not exceed the greater of 1/16 inch or 1/20 of the thickness of the attachment at the point of attachment.

5.4.5 Where fillet welds only are used, the maximum gap between the components being joined shall be 1/8 inch. The components shall be clamped or otherwise maintained together during welding.

5.4.6 Attachment point of spiders, braces, or other temporary attachments shall match the material of the vessel.

5.4.7 All temporary attachments shall be removed prior to shop hydrotest unless specifically approved by the Buyer.

5.4.8 Where practical, internal structural components and piping welds shall be full penetration. If it is not practical, seller shall propose fillet welded attachments for Buyer approval via the SDDR process.

6 Design and NDE Requirements

6.1 All Design Levels

6.1.1 The shell and head sections which are subjected to concentrated or large loads through welded attachments (such as lifting and tailing lugs, PJM supports, or agitator mountings) shall, prior to welding, be ultrasonically examined over 100 percent of the areas, in accordance with the following:

- For connections or attachments directly welded to the shell or head, the area tested shall extend 3 inches beyond the extremity of the proposed weldment
- For connections or attachments welded via a reinforcement or doubler plate, the shell area tested shall extend 5 inches beyond each side of the perimeter of the proposed fillet weld attaching the reinforcing or doubler plate to the shell or head
- Not required for nozzle penetrations.

6.1.2 All full penetration welds attaching internal or external structural components to the heads or shell shall be ultrasonically tested. If fillet welds except for Lifting and Tailing Lugs are permitted by writing by the Buyer and are not readily ultrasonically tested, they may be dye penetrant tested or magnetic particle tested with approval from the Buyer via the SDDR process.

6.1.3 All full penetration welds forming part of the jacket shall be ultrasonically tested.

6.1.4 Records of the NDE and other tests shall be submitted to the Buyer as described in the purchase order.

6.1.5 Deleted

6.1.6 Additional NDE requirements are specified in the drawings and MDS

6.2 Additional Requirements for Design Level 1 (L-1) Vessels

6.2.1 All nozzle reinforcement on L-1 vessels shall be integral. Using additional reinforcing elements such as reinforcing rings or pads is prohibited. Reinforcing material shall be taken as excess thickness on the shell or head and nozzle neck. Additional reinforcing material may be provided, when required, by increasing the shell, head or nozzle thickness, or by providing a thicker insert plate of a suitable diameter, butt welded into the shell or the head.

6.2.2 The following weldments shall be subject to volumetric testing:

- All welds forming part of the primary containment, including weldments joining nozzles to the vessel shell or head.
- Where a main seam butt weld is located such that only part of its length lies within the Primary Containment, the complete length of that particular seam.
- All butt welds in internal piping.

- For multi-chambered vessels, where an adjacent chamber is categorized other than L-1, all interconnecting butt welds which provide Primary Containment between the two chambers to L-1 requirements.
- For vessels fitted with a shell-type jacket, all Primary Containment welds in the main shell enclosed by the jacket and found satisfactory prior to fitting the jacket and associated rings.

Radiography is the preferred method of volumetric testing. Where it is considered impractical to perform radiographic examination due to joint configuration, the Seller may propose ultrasonic examinations; the seller shall use the SDDR process to propose ultrasonic examinations. The SDDR shall include UT procedure reference, technical justification of UT proposal for every weldment and schematic location of every weldment proposed to be UT tested.

6.2.3 Where components attach to any part of the vessel by full or partial penetration tee weld (including a corner weld), the parent plate in the vicinity of the weld shall be ultrasonically tested prior to welding, to ensure that no defects are present that could result in laminar type tearing during welding.

In particular, the following components shall always be examined as detailed above:

- Supports for vessel internals
- Vessel supports where a small local area of the vessel takes the support load (ultrasonic inspection is not required for skirt or ring supported vessels)
- Not required for nozzle penetrations

6.3 Additional Requirements for Design Level 2 (L-2) Vessels

6.3.1 All nozzle reinforcement on L-2 vessels shall be integral. Using additional reinforcing elements, such as reinforcing rings or pads, is prohibited. Reinforcing material shall be taken as excess thickness on the shell or head and nozzle neck. Additional reinforcing material may be provided, when required, by increasing the shell, head or nozzle thickness, or by providing a thicker insert plate of a suitable diameter, butt welded into the shell or the head.

6.3.2 The following weldments shall be subject to volumetric testing:

- At least 10 percent of the length of each welder's production of welds forming part of the Primary Containment. The minimum extent of volumetric testing shall include all "T" junctions, and 10 percent of the remaining longitudinal weld with a 6 inches minimum length of volumetric testing.
- For nozzle-to-shell welds located in the Primary Containment, at least 10 percent of the number of welds made by each welder over 100 percent of its circumference, with a minimum of one nozzle to shell weld per vessel.
- All butt welds in internal piping

Radiography is the preferred method of volumetric testing. Where it is considered impractical to perform radiographic examination due to joint configuration, the Seller may propose ultrasonic examinations; the seller shall use the SDDR process to propose ultrasonic examinations. The SDDR shall include UT procedure reference, technical justification of UT

proposal for every weldment and schematic location of every weldment proposed to be UT tested.

6.3.3 Where components attach to any part of the vessel by full or partial penetration tee weld (including a corner weld), the parent plate in the vicinity of the weld shall be ultrasonically tested prior to welding, to ensure that no defects are present that could result in laminar type tearing during welding.

In particular, the following components shall always be examined as detailed above:

- Supports for vessel internals.
- Vessel supports where a small local area of the vessel takes the support load (ultrasonic inspection is not required for skirt or ring supported vessels)
- Not required for nozzle penetrations

6.4 Additional Requirements for Commercial Grade (CM) Vessels

6.4.1 Nozzles may use either a pad or integral reinforcement.

6.4.2 The following weldments shall be subject to volumetric testing unless otherwise indicated on the MDS or Drawings:

- At least 10 percent of the length of each welder's production of vessel main seams butt welds. The minimum extent of volumetric testing shall include all "T" junctions and 10 percent of the remaining longitudinal weld with a 6 inch minimum length of volumetric testing.
- For nozzle-to-shell welds located in the Primary Containment, at least 10 percent of the number of welds made by each welder over 100 percent of its circumference.
- At least 10 percent of butt welds in internal piping for the full circumference.

Radiography is the preferred method of volumetric testing. Where it is considered impractical to perform radiographic examination due to joint configuration, the Seller may propose ultrasonic examinations; the seller shall use the SDDR process to propose ultrasonic examinations. The SDDR shall include UT procedure reference, technical justification of UT proposal for every weldment and schematic location of every weldment proposed to be UT tested.

6.5 Additional Requirements for Vessels Located in a Black Cell or Hard-to-Reach Area

6.5.1 If a vessel is located in a Black Cell it shall be noted on the MDS.

6.5.2 All nozzle reinforcement shall be integral (one piece construction) and attached by full penetration welds regardless of Design Level. Using additional non-integral (external) reinforcing elements, such as reinforcing rings or pads, is prohibited unless used to accommodate occasional loads such as the revised ground motion accelerations, hydrogen in pipes and ancillary vessel loads, or multiple overblow loads, in vessels that are already fabricated. Buyer approval via the SDDR process is required for non-integral type

reinforcement. Integral reinforcing material shall be taken as excess thickness on the shell or head and nozzle neck. Additional integral reinforcing material may be provided, when required, by increasing the shell, head or nozzle thickness, or by providing a thicker insert plate of a suitable diameter, butt welded into the shell or the head. Nozzle weld details of Section 3.8.4 for integral or Section 3.8.5 for non-integral reinforcement, and Section 3.8.7 shall be followed.

6.5.3 All welds joining components of the Primary Confinement shall be subject to full volumetric testing. Radiography is the preferred method of volumetric testing. Where it is considered impractical to perform radiographic examination due to joint configuration, the Seller may propose ultrasonic examinations; the seller shall use the SDDR process to propose ultrasonic examinations. The SDDR shall include UT procedure reference, technical justification of UT proposal for every weldment and schematic location of every weldment proposed to be UT tested.

6.5.4 All welds to internal components and supports, which include pulse jet mixer and charge vessel supports, dip pipe supports, sparger supports, instrumentation piping supports, and pump discharge and return line supports shall, as a minimum be dye penetrant tested per ASME Section VIII, Division 1 requirements.

6.5.5 All welded construction shall be used for vessels and piping. There shall be no flanged, socket welded or threaded connections with the exception of socket welded thermowell nozzle connections. There shall be no non-removable soft or non-metallic parts that could be affected by high radiation doses.

7 Tests and Inspections

7.1 Hardness Testing for Austenitic Stainless Steel Components

7.1.1 Hardness testing is required when austenitic stainless steel plates are cold formed to make sections such as angles, channels, and conical sections. This requirement is not applicable to the cold forming of dished heads, which is covered by the relevant section of ASME Section VIII, Division 1.

7.1.2 Hardness testing is required when austenitic stainless steel pipe is cold formed for bends with a centerline radius less than three times the nominal pipe diameter.

7.1.3 Any cold forming process, which may significantly increase hardness, shall be in accordance with an approved procedure, which contains hardness testing. The procedure shall be submitted for Buyer's approval.

7.1.4 Hardness testing shall be performed on areas subject to the greatest deformation after cold working or any rework or rectification. The maximum permitted hardness is HRB 92 or as indicated by the material specification acceptance criteria for hardness.

7.1.5 If the maximum permitted hardness is exceeded, the Seller shall solution anneal (heat treatment) in accordance with the applicable ASME specification for that material. Heat Treatment process shall include heating and cooling rates, thermocouple locations, and type of

heating equipment. Seller shall submit a written procedure for suitable heat treatment and testing for Buyer's approval

7.2 Nondestructive Examinations

7.2.1 Radiography, ultrasonic testing, visual examination, magnetic particle, and dye penetrant examination, where specified or required, shall be performed in accordance with ASME Section VIII, Division 1 and ASME Section V, and procedures developed and submitted to the Buyer for review prior to use.

7.2.2 All mandatory nondestructive examination (visual, surface flaw, and volumetric) shall be carried out after the completion of fabrication, including any heat treatment. Where Seller carries out additional nondestructive examination prior to any heat treatment process, such examinations shall be included in the Quality Plan or Inspection Schedule. The Buyer's representative need not witness this additional nondestructive examination; however, the records of such inspection shall be made available to the Buyer's representative.

7.2.3 Nondestructive examination must be performed by an inspector certified to the requirements of SNT-TC-1A. The interpretation of the results shall be by either Level II or Level III inspectors certified to SNT-TC-1A. Visual examination is not included in this requirement.

7.2.3.1 All weld visual examinations shall be performed by personnel certified in accordance with American Society for Non-Destructive testing (ASNT) Recommended practice SNT-TC-1A, Level I, II, or III or certified in accordance with AWS QC-1 as either a Certified Welding Inspector (CWI) or a Senior Certified Weld Inspector (SCWI)

7.2.4 Ultrasonic testing, where specified by the Buyer or proposed by the Seller, shall be in accordance with Appendix 12 of ASME Section VIII, Division 1.

7.2.5 Radiographic acceptance criteria shall be in accordance with ASME Section VIII, Division 1, Paragraph UW-51 where full radiography is required or UW-52 where spot radiography as defined in this specification is per Section 6.4.2.

7.2.6 Deleted

7.2.7 Dye Penetrant testing, where specified by the Buyer or proposed by the Seller, shall be in accordance with Appendix 8 of ASME Section VIII, Division 1.

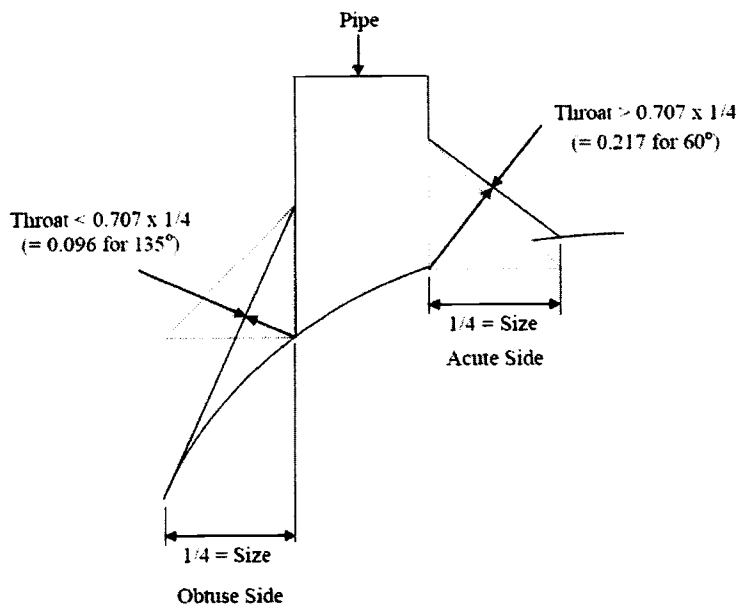
7.2.8 Magnetic Particle testing, where specified by the Buyer or proposed by the Seller, shall be in accordance with Appendix 6 of ASME Section VIII, Division 1.

7.2.9 Weld visual examination, where specified by the Buyer or proposed by the Seller, shall be in accordance with ASME Section V, Article 9

7.2.10 Fillet Weld Measurement:

- A fillet weld leg size specified on the drawing weld symbol is the minimum size required 360 degrees around the nozzle/attachment. The effective throat based on that fillet size must be fully met around that circumference, including the obtuse (downhill) location. Both leg and throat dimensions must be met as an example, for a specified fillet weld leg

size of 1/4", the throat thickness on the obtuse side as shown in the figure below is NOT acceptable (less than 0.707 x 1/4") and consequently the actual leg size must be increased on the obtuse side to meet an effective throat thickness of 0.707 x 1/4". For angles greater than 135 degrees, submit an SDDR for buyer review and approval. Fillet weld design is applicable between 60 degrees and 135 degrees (per AWS D1.1, Section 16, D1.6 Annex B) any weld outside these limits is not considered a fillet weld and shall be designed accordingly.



Off Set Nozzle Fillet Weld

7.3 Hydrotests

7.3.1 If paint is specified, the vessel shall not be painted prior to the pressure test. Coating shall not be applied to external welds of items requiring leak/hydrostatic testing prior to testing.

7.3.2 All welds shall be sufficiently cleaned and free of scale or paint prior to hydrostatic testing.

7.3.3 Testing of vessels or components made of austenitic stainless steel materials shall be conducted with potable water containing no more than 50 PPM chloride.

7.3.4 For vessels of carbon and low alloy steel, before application of the test pressure, the test water and the vessel material shall be allowed to equalize to approximately the same temperature. The temperature of the pressure resisting components during the pressure test, regardless of test media, shall be at least 30° F warmer than the minimum design metal temperature to be stamped on the nameplate, but need not exceed 120° F.

7.3.5 The final hydrostatic test pressure shall be held for a minimum of one hour.

7.3.6 After completion of the hydrostatic test, the vessel shall be drained, dried, cleaned thoroughly inside and outside to remove grease, loose scale, rust, and dirt and closed as quickly as

practicable. Test water shall not be in contact with austenitic stainless steel for more than 72 hours, unless treated with an appropriate biocide.

7.3.7 If field assembly or erection is involved, the final hydrostatic test shall be at the job site. The Seller or the field subcontractor shall provide the Buyer with a detailed test procedure for review and approval prior to testing.

7.3.8 A horizontal vessel shall be tested while resting on its support saddles without additional supports or cribbing.

7.3.9 Tall vertical vessels may be shop hydrotested in the horizontal position. The vessel shall be designed for vertical hydrotest loading. These vessel supports must be adequately designed to support the vessel (in accordance with the ASME code) during the hydrotest to prevent damage.

7.3.10 Each chamber of a multi-chamber vessel (jacketed vessel) shall be subject to a hydrotest pressure with atmospheric pressure in the adjacent chamber.

7.3.11 Parent vessels are in the Black Cell or Hard to Reach Areas, no hydrotest required for Pulse Jet Mixers and Charge Vessels.

7.3.12 Seller shall submit a hydrostatic test procedure in accordance with the requirements of Section 7.3 of this specification and ASME Section VIII, Division 1, Paragraph UG-99 for buyer review prior to use.

7.4 Leak Tests

7.4.1 If gas or pneumatic testing is specified in the MDS, Drawings or in the purchase order, the Seller shall conduct the tests in accordance with ASME Section V. Seller shall submit a test procedure for Buyer review prior to use.

7.4.2 Reinforcing pad attachment welds and accessible surfaces of inside nozzle to vessel wall welds shall be tested for leaks with 15 PSIG dry air or nitrogen and bubble forming solution. This test shall be performed prior to the final hydrostatic or pneumatic test as applicable.

7.5 Obstruction Test

7.5.1 Seller shall ensure and document that all internals, internal piping, and jacketing are free from obstructions.

7.6 Final Inspection of Completed Vessel

7.6.1 Final inspection of the completed vessel shall be the sole responsibility of the Seller. The finished dimensions and cleanliness of the vessels shall comply with the relevant Drawings and specifications after completion of all tests.

8 Preparation and Shipment

8.1 Cleaning

8.1.1 Seller shall comply with 24590-WTP-3PS-G000-T0003.

8.1.2 If specified in the purchase order and in any event following hot working or heat treatment, the equipment shall be descaled. The procedure to be used by Seller shall be submitted for Buyer's prior approval.

8.1.3 If blast (mechanical) descaling process is specified in the purchase order for stainless steel construction, clean and iron-free glass or ceramic beads, or sand of alumina or zirconia type shall be used. The type, grade, and chemical composition of the abrasive shall be submitted for Buyer's approval prior to its use. Recycling of abrasive is prohibited. Blast cleaning shall not be used on weld metal or as a final finish on fabrications.

8.2 Packaging

8.2.1 Machined carbon steel surfaces, which are not protected by blind flanges, shall be coated with rust preventative. Rust preventative coating shall be approved by Buyer.

8.2.2 All flanged openings, which are not provided with a cover, shall be protected by an ASME B16.5 or B16.47 carbon steel blind flange of the same rating as the flange, a full faced rubber gasket with a minimum thickness of 1/8 inch and carbon steel bolts with stainless steel washers.

8.2.3 For internal parts, suitable supports shall be provided to avoid damage during shipment. Temporary internal bracing shall be painted yellow and a label, located near the nameplate shall state that the vessel contains temporary bracing that must be removed.

8.2.4 Small parts, which are to be shipped loose, shall be bagged or boxed and marked with the order and plant item number of the vessel.

8.3 Shipping

8.3.1 Seller shall take all necessary precautions in loading by blocking and bracing the vessel and furnishing all necessary material to prevent damage.

8.3.2 The Seller shall verify, by calculation, that the vessel and internals will withstand loads occurring during shipping for the chosen mode of transportation. The Buyer shall inform the Seller of the chosen mode of transportation

9 Documentation and Submittals

9.1 Seller shall comply with the requirements of forms G321-E and G321-V of the material requisition or subcontract. Furnish all applicable drawings, MDS, design calculations, reports of special analyses, welding procedure specifications with procedure qualification records, test procedures, and all other required documents.

9.2 Design calculations shall include relevant ASME Section VIII, Division 1 formulas, and source paragraphs, values used in the formulas, the calculated results, and comparison with acceptable values. Where calculations are based on other than the ASME Section VIII, Division 1 formulas, the source of the formulas shall be referenced. Where a computer program is used for calculations, a brief program description shall be given, including name and version of the program. If the program is not commercially available to industry, Seller shall maintain and provide, upon request, program documentation. Calculations shall include, but not be limited to:

- Code calculations
- Nozzle neck calculation per UG45, average primary stress Pm across the nozzle wall
- Seismic calculations including base horizontal seismic force and moment and loads for anchorage and anchor bolt design
- Support calculations including empty weight, operating weight and location of center of gravity
- Calculations associated with lifting and erection of the vessel
- Nozzle load analysis for local and gross effect, per Section 3.7 above, or by other approved method
- Design of attachments, both internal and external
- Thermal and discontinuity stresses as applicable
- Fatigue analysis as applicable for vessels in fatigue services

9.2.1 Seller shall submit an Outline drawing for each item. The Outline drawing shall include the following minimum for each item:

- Shell and head thickness
- Head type
- Vessel empty weight, test weight and shipping weight
- Center of Gravity
- Lifting lugs and tailing lugs
- Diameter, tangent-to-tangent dimensions and appropriate support details
- Nozzle, flange support locations from datum point
- Nozzle schedule with nozzle marks and service conditions
- All appropriate design conditions, NDE and materials of construction
- Foundation/Mounting details
- Installations of appropriate internals

9.3 Seller shall make a complete set of Buyer approved drawings and other documents available to the Buyer's representative at the time the quality surveillance activities are being conducted.

9.4 All records pertaining to the nondestructive examination, base materials, filler materials, fabrication, and inspection shall be traceable to the area and part inspected and is accessible for Buyer's examination.

9.5 Seller shall provide ASME Section VIII. Division 1 data reports per ASME Section VIII Division 1. Paragraph UG-120.

9.6 Seller shall submit assembly drawings and shop detail drawings for buyer's review. These drawings shall include bill of materials. weld symbol. and NDE for each weld. and parts used in vessel construction. Assembly and shop detail drawings shall also include shell and head plate layout (including nozzles) for compliance with Section 5.2 of this specification.

9.7 Seller shall provide a detailed description of their work inspections and tests planned during the receipt of materials. manufacturing. testing. and conformance verification activities. This shall include identification of Bechtel and supplier witness and hold points.

9.8 Seller shall supply quality records and test results in accordance with the G321V form of the Material Requisition to include the following.

9.8.1 Document Category 16.0 – Heat Treat Reports – in accordance with section 7.1 of this specification. A complete record of any applicable heat treatment including charts.

9.8.2 Document Category 19.0 Ultrasonic Examination and Verification Reports - in accordance with Section 7.2.4 of this specification.

9.8.3 Document Category 20.0 Radiographic Examination and Verification Reports- in accordance with Section 7.2.5 of this specification.

9.8.4 Document Category 20.1 RT Film and Reader Sheets-Seller shall submit the original set of radiographic film with associated technique and reader sheets for radiographic tests performed. Radiographic film must be suitably packaged to preclude moisture and handing damage.

9.8.5 Document Category 21.0 Magnetic Particle Examination and Verification Reports-in accordance with Section 7.2.8 of this specification.

9.8.6 Document Category 22.0 Liquid Penetrant Examination and Verification Reports-in accordance with Section 7.2.7 of this specification.

9.8.7 Document Category 24.0 Pressure Testing and Verification Reports

- Hydrostatic Leak Testing I accordance with section 7.3 of this specification.
- Gas or Pneumatic Testing in accordance with section 7.4 of this specification.

9.8.8 Document Category 25.0 Inspection and Verification Report-

- Final dimensional verifications comply with Section 7.6 of this specification.
- Visual Weld Inspections in accordance with Section 7.2.9 and 7.2.10

of this specification.
- Hardness Test report (if applicable_ in accordance with Section 7.1 of this specification.

9.8.9 Document Category 26.1 Mechanical Test Report-

- Load testing.
- Pipe bending documentation in accordance with Section 5.1.9 and 5.1.10 of this specification.
- Obstruction documentation per Section 7.5 of this specification.

10 Quality Assurance

10.1 General Requirements

10.1.1 Deleted

10.1.2 Deleted

10.1.3 Seller's QAP, as a minimum, shall contain the requirements detailed in the Supplier Quality Assurance Program Requirements Data Sheets listed in Section 2 of the material requisition.

10.2 Additional Requirements for Quality Level Q Vessels

10.2.1 Seller shall have in place a QA program meeting the requirements of ASME NQA-1, marked as applicable in Supplier Quality Assurance Program Requirements Data Sheet attached to the material requisition.

10.2.2 The successful bidder must pass a pre-award survey by the Buyer. Seller shall demonstrate that its quality program is in compliance with the procurement quality requirements listed in the Supplier Quality Assurance Program Requirements Data Sheet.

10.2.3 All items shall be manufactured in accordance with the Seller's Quality Assurance Program that meets the requirements of ASME NQA-1, and has been previously evaluated and accepted by the RPP-WTP Quality Organization.

10.2.4 Seller shall submit their QAP and work plan to Buyer for review prior to commencement of work. The plan shall include documents and procedures to implement the work and include a matrix of essential quality assurance elements cross-referenced with the documents and procedures.

11 Revision History (Internal Use Only)

NOTE: Asterisk (*) denotes a new entry for this revision of the Specification

11.1 Deleted

11.2 Design Changes Incorporated by Design

24590-WTP-SDDR-PROC-02-0145
24590-WTP-SDDR-PROC-02-0155
24590-WTP-SDDR-PROC-02-0183
24590-WTP-SDDR-PROC-03-0023
24590-WTP-SDDR-PROC-03-0053
24590-WTP-SDDR-PROC-03-0075
24590-WTP-SDDR-PROC-03-0082
24590-WTP-SDDR-PROC-03-0083
24590-WTP-SDDR-PROC-03-0086
24590-WTP-SDDR-PROC-03-0100
24590-WTP-3PN-MV00-00001
24590-WTP-3PN-MV00-00002
24590-WTP-3PN-MV00-00009
24590-WTP-3PN-MV00-00011
24590-WTP-3PN-MV00-00012
24590-WTP-3PN-MV00-00014
24590-WTP-3PN-MV00-00015
24590-WTP-3PN-MV00-00016 with modifications:
24590-WTP-SDDR-PROC-05-00100 is incorporated by reference in lieu of 24590-WTP-SDDR-PROC-04-00100
24590-WTP-SDDR-PROC-05-00197 is incorporated by reference in lieu of 24590-WTP-SDDR-PROC-04-00197
24590-WTP-3PN-MV00-00017
24590-WTP-3PN-MV00-00019
24590-WTP-3PN-MV00-00020
24590-WTP-3PN-MV00-00022
24590-WTP-3PN-MV00-00033
24590-WTP-3PN-MV00-00027
24590-WTP-3PN-MV00-00028
24590-WTP-3PN-MV00-00030
24590-WTP-3PN-MV00-00032
24590-WTP-3PN-MV00-00033
* 24590-WTP-3PN-MV00-00034
* 24590-WTP-3PN-MV00-00035
* 24590-WTP-3PN-MV00-00038

11.3 Design Changes Incorporated by Reference

24590-WTP-SDDR-PROC-02-0128
24590-WTP-SDDR-PROC-02-0136
24590-WTP-SDDR-PROC-02-0182

24590-WTP-SDDR-PROC-03-0020
24590-WTP-SDDR-PROC-03-0066
24590-WTP-SDDR-PROC-03-0076
24590-WTP-SDDR-PROC-03-0157
24590-WTP-SDDR-PROC-03-0168
24590-WTP-SDDR-PROC-03-0169
24590-WTP-SDDR-PROC-03-0226
24590-WTP-SDDR-PROC-03-0240
24590-WTP-SDDR-PROC-03-0242
24590-WTP-SDDR-PROC-03-0255
24590-WTP-SDDR-PROC-03-0263
24590-WTP-SDDR-PROC-03-0285
24590-WTP-SDDR-PROC-04-00130
24590-WTP-SDDR-PROC-04-00184
24590-WTP-SDDR-PROC-04-00201
24590-WTP-SDDR-PROC-04-00216
24590-WTP-SDDR-PROC-04-00269
24590-WTP-SDDR-PROC-04-00411
24590-WTP-SDDR-PROC-04-00551
24590-WTP-SDDR-PROC-04-00613
24590-WTP-SDDR-PROC-04-00645
24590-WTP-SDDR-PROC-04-00744
24590-WTP-SDDR-PROC-04-00788
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24590-WTP-SDDR-PROC-04-01275
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24590-WTP-NCR-CON-03-202
24590-WTP-NCR-CON-04-0080
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24590-WTP-SDDR-PROC-05-00197
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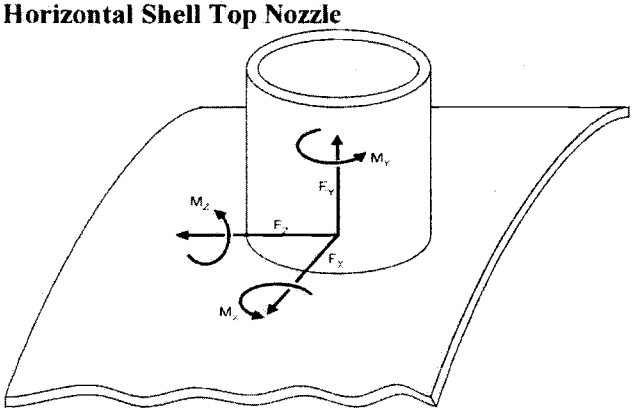
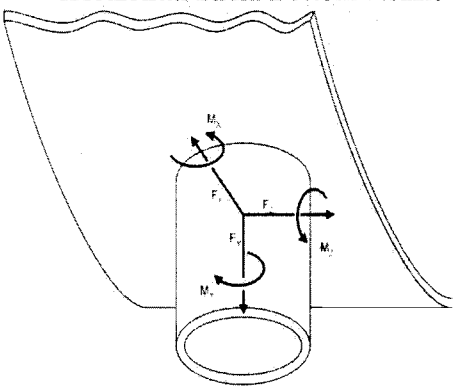
Appendix A: Minimum Nozzle Design Loads

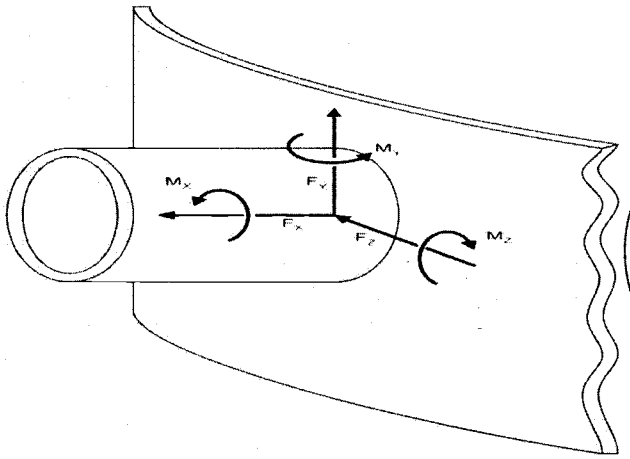
Horizontal Shell Top Nozzle



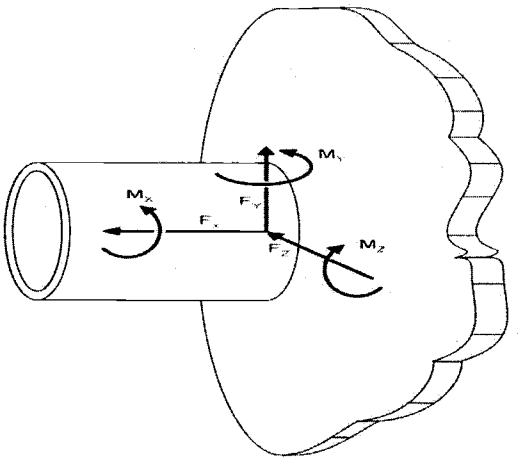
Horizontal Shell. Bottom Nozzle



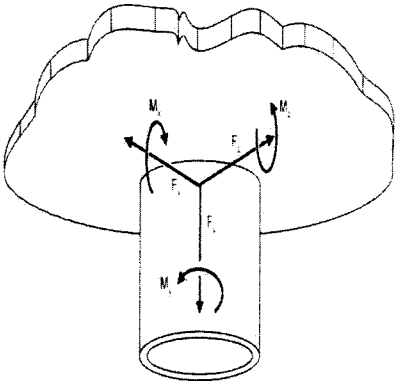
Vertical Shell Horizontal Nozzle



Horizontal Head Nozzle



Vertical Bottom Head Nozzle



Vertical Top Head Nozzle

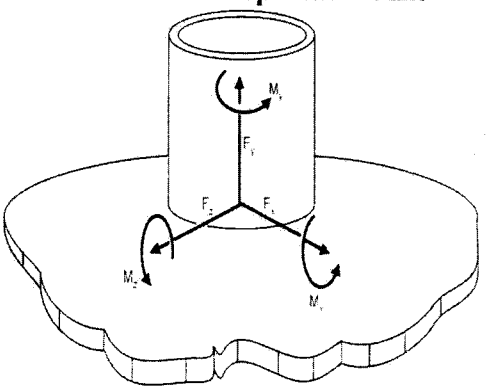


Table A1- Minimum Nozzle Loads Due to Stainless Steel Piping on Vessels Designated as SC-I

Pipe Size	Load Type	Forces			Moments		
		Fx (lb)	Fy (lb)	Fz (lb)	Mx (ft-lb)	My (ft-lb)	Mz (ft-lb)
1 in	Weight	10	16	10	10	6	6
	Seismic	30	20	30	37	55	55
	Thermal	30	26	40	38	77	77
1-1/2 in	Weight	20	32	20	24	15	15
	Seismic	60	40	60	91	137	137
	Thermal	64	56	86	96	192	192
2 in	Weight	36	56	36	42	26	26
	Seismic	106	70	106	158	237	237
	Thermal	114	100	152	169	337	337
3 in	Weight	69	111	69	158	99	99
	Seismic	215	143	215	623	934	934
	Thermal	228	203	305	664	1330	1330
4 in	Weight	116	186	116	288	180	180
	Seismic	365	243	365	1170	1760	1760
	Thermal	393	350	524	1260	2520	2520
6 in	Weight	279	446	279	797	498	498
	Seismic	884	590	884	3230	4850	4850
	Thermal	980	872	1310	3580	7160	7160
8 in	Weight	311	497	311	988	618	618
	Seismic	978	653	978	3930	5890	5890
	Thermal	1190	1060	1590	4800	9590	9590
10 in	Weight	351	561	351	1880	1180	1180
	Seismic	1090	728	1090	7340	11000	11000
	Thermal	1270	1130	1690	8500	17000	17000
12 in	Weight	485	776	485	2710	1700	1700
	Seismic	1510	1010	1510	10500	15800	15800
	Thermal	1780	1580	2370	12400	24800	24800
14 in	Weight	581	930	581	3320	2080	2080
	Seismic	1800	1200	1800	12600	18900	18900
	Thermal	2140	1900	2860	15000	30100	30100
16 in	Weight	729	1170	729	4170	2610	2610
	Seismic	2280	1520	2280	16100	24200	24200
	Thermal	2800	2490	3730	19800	39500	39500
18 in	Weight	911	1460	911	5070	3170	3170
	Seismic	2820	1880	2820	20000	29900	29900
	Thermal	3550	3160	4730	25200	50300	50300
20 in	Weight	1120	1790	1120	6310	3950	3950
	Seismic	3400	2270	3400	23900	35800	35800
	Thermal	4440	3950	5920	31200	62400	62400
22 in	Weight	1340	2150	1340	7300	4560	4560
	Seismic	4030	2690	4030	28100	42200	42200
	Thermal	5430	4830	7240	37900	75800	75800
24 in	Weight	1570	2510	1570	8510	5320	5320
	Seismic	4710	3140	4710	32400	48700	48700
	Thermal	6560	5840	8750	45200	90400	90400

Note: Unless otherwise specified on the MDS utilize the minimum nozzle loads specified

Table A2- Minimum Nozzle Loads Due to Stainless Steel Piping on Vessels Designated as SC-II, III, and IV

Pipe Size	Load Type	Forces			Moments		
		Fx (lb)	Fy (lb)	Fz (lb)	Mx (ft-lb)	My (ft-lb)	Mz (ft-lb)
1 in	Weight	10	16	10	11	7	7
	Seismic	66	44	66	92	137	137
	Thermal	28	24	38	38	77	77
1-1/2 in	Weight	20	32	20	26	16	16
	Seismic	138	92	138	228	342	342
	Thermal	58	52	78	96	192	192
2 in	Weight	34	56	34	46	29	29
	Seismic	244	162	244	398	597	597
	Thermal	104	92	138	169	337	337
3 in	Weight	71	113	71	180	112	112
	Seismic	491	327	491	1570	2350	2350
	Thermal	209	185	278	664	1330	1330
4 in	Weight	120	192	120	342	214	214
	Seismic	834	557	834	2960	4440	4440
	Thermal	356	317	474	1260	2520	2520
6 in	Weight	290	462	290	951	595	595
	Seismic	2025	1350	2025	8290	12400	12400
	Thermal	875	777	1170	3580	7160	7160
8 in	Weight	333	534	333	1210	758	758
	Seismic	2360	1580	2360	10700	16000	16000
	Thermal	1050	938	1410	4800	9590	9590
10 in	Weight	361	578	361	2210	1380	1380
	Seismic	2540	1690	2540	19400	29100	29100
	Thermal	1110	991	1490	8500	17000	17000
12 in	Weight	502	803	502	3240	2020	2020
	Seismic	3510	2340	3510	28100	42100	42100
	Thermal	1550	1380	2070	12400	24800	24800
14 in	Weight	591	946	591	3870	2420	2420
	Seismic	4160	2780	4160	33900	50900	50900
	Thermal	1850	1640	2460	15000	30100	30100
16 in	Weight	757	1210	757	5080	3180	3180
	Seismic	5310	3540	5310	44100	66100	66100
	Thermal	2380	2120	3180	19800	39500	39500
18 in	Weight	1200	1930	1200	8190	5120	5120
	Seismic	8490	5660	8490	71500	107000	107000
	Thermal	2990	2660	3980	25200	50300	50300
20 in	Weight	1280	2050	1280	8630	5400	5400
	Seismic	8910	5940	8910	75900	114000	114000
	Thermal	3660	3260	4880	31200	62400	62400
22 in	Weight	1380	2200	1380	9380	5860	5860
	Seismic	9510	6340	9510	81500	122000	122000
	Thermal	4420	3930	5900	37900	75800	75800
24 in	Weight	1600	2570	1600	11000	6870	6870
	Seismic	11100	7430	11100	96100	144000	144000
	Thermal	5240	4660	6990	45200	90400	90400

Note: Unless otherwise specified on the MDS utilize the minimum nozzle loads specified

Table A3- Minimum Nozzle Loads Due to Carbon Steel Piping on Vessels Designated as SC-1

Pipe Size	Load Type	Forces			Moments		
		Fx (lb)	Fy (lb)	Fz (lb)	Mx (ft-lb)	My (ft-lb)	Mz (ft-lb)
1 in	Weight	10	16	10	11	7	7
	Seismic	30	20	30	45	67	67
	Thermal	36	32	46	53	106	106
1-1/2 in	Weight	20	32	20	28	18	18
	Seismic	60	40	60	111	166	166
	Thermal	72	64	96	132	265	265
2 in	Weight	34	54	34	50	31	31
	Seismic	100	68	100	192	288	288
	Thermal	122	108	162	232	465	465
3 in	Weight	68	108	68	192	120	120
	Seismic	207	138	207	755	1130	1130
	Thermal	251	222	335	915	1830	1830
4 in	Weight	113	180	113	357	223	223
	Seismic	344	230	344	1420	2130	2130
	Thermal	420	374	561	1740	3480	3480
6 in	Weight	260	416	260	1000	626	626
	Seismic	792	528	792	3950	5930	5930
	Thermal	989	879	1320	4930	9870	9870
8 in	Weight	302	482	302	1290	806	806
	Seismic	932	621	932	5250	7870	7870
	Thermal	1170	1040	1560	6610	13200	13200
10 in	Weight	411	658	411	2390	1500	1500
	Seismic	1270	848	1270	9130	13700	13700
	Thermal	1630	1450	2180	11700	23400	23400
12 in	Weight	608	973	608	3760	2350	2350
	Seismic	1880	1250	1880	14200	21300	21300
	Thermal	2430	2160	3240	18400	36800	36800
14 in	Weight	744	1190	744	4710	2940	2940
	Seismic	2350	1560	2350	18500	27800	27800
	Thermal	3030	2700	4040	23900	47900	47900
16 in	Weight	1030	1650	1030	7040	4400	4400
	Seismic	3250	2170	3250	27700	41500	41500
	Thermal	4200	3730	5600	35800	71500	71500
18 in	Weight	1410	2250	1410	9840	6150	6150
	Seismic	4240	2830	4240	38700	58000	58000
	Thermal	5580	4960	7440	50900	102000	102000
20 in	Weight	1730	2770	1730	12700	7970	7970
	Seismic	5340	3560	5340	49600	74400	74400
	Thermal	7160	6360	9540	66500	133000	133000
22 in	Weight	2080	3340	2080	13100	8200	8200
	Seismic	6290	4190	6290	50300	75500	75500
	Thermal	8590	7640	11500	68800	138000	138000
24 in	Weight	2650	4240	2650	20700	12900	12900
	Seismic	7980	5320	7980	79900	120000	120000
	Thermal	11100	9870	14800	111000	222000	222000

Note: Unless otherwise specified on the MDS utilize the minimum nozzle loads specified

Table A4- Minimum Nozzle Loads Due to Carbon Steel Piping on Vessels Designated as SC-II, III or IV

Pipe Size	Load Type	Forces			Moments		
		Fx (lb)	Fy (lb)	Fz (lb)	Mx (ft-lb)	My (ft-lb)	Mz (ft-lb)
1 in	Weight	10	16	10	13	8	8
	Seismic	68	46	68	110	166	166
	Thermal	32	30	44	53	106	106
1-1/2 in	Weight	20	32	20	31	20	20
	Seismic	140	92	140	275	412	412
	Thermal	68	60	90	132	265	265
2 in	Weight	34	54	34	55	34	34
	Seismic	234	156	234	480	721	721
	Thermal	114	100	150	232	465	465
3 in	Weight	62	99	62	176	110	110
	Seismic	482	321	482	1910	2870	2870
	Thermal	231	206	308	915	1830	1830
4 in	Weight	104	167	104	335	209	209
	Seismic	804	536	804	3610	5420	5420
	Thermal	387	344	516	1740	3480	3480
6 in	Weight	243	389	243	949	593	593
	Seismic	1860	1250	1860	10200	15200	15200
	Thermal	906	806	1210	4930	9870	9870
8 in	Weight	353	564	353	1450	903	903
	Seismic	2690	1800	2690	13400	20200	20200
	Thermal	1320	1180	1770	6610	13200	13200
10 in	Weight	384	615	384	2600	1630	1630
	Seismic	2920	1950	2920	23700	35600	35600
	Thermal	1450	1290	1930	11700	23400	23400
12 in	Weight	567	908	567	4150	2590	2590
	Seismic	4310	2880	4310	37100	55600	55600
	Thermal	2140	1910	2860	18400	36800	36800
14 in	Weight	707	1130	707	5400	3380	3380
	Seismic	5380	3590	5380	48100	72200	72200
	Thermal	2670	2380	3570	23900	47900	47900
16 in	Weight	980	1570	980	8040	5020	5020
	Seismic	7450	4970	7450	71900	108000	108000
	Thermal	3700	3290	4940	35800	71500	71500
18 in	Weight	1300	2080	1300	11300	7090	7090
	Seismic	9890	6590	9890	102000	152000	152000
	Thermal	4950	4400	6600	50900	102000	102000
20 in	Weight	1640	2630	1640	14900	9330	9330
	Seismic	12500	8320	12500	132000	198000	198000
	Thermal	6300	5600	8400	66500	133000	133000
22 in	Weight	1900	3040	1900	15400	9620	9620
	Seismic	14400	9610	14400	135000	203000	203000
	Thermal	7330	6520	9770	68800	138000	138000
24 in	Weight	2510	4020	2510	24800	15500	15500
	Seismic	19000	12700	19000	217000	326000	326000
	Thermal	9760	8680	13000	111000	222000	222000

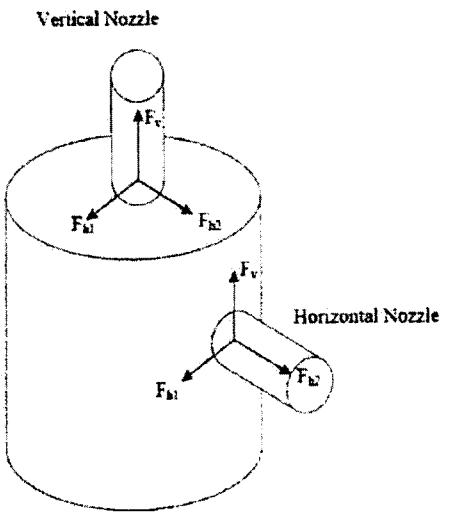
Note: Unless otherwise specified on the MDS utilize the minimum nozzle loads specified

Appendix B: Minimum Nozzle Loads Due to Jumpers

[redacted]

Minimum Nozzle Forces Due to HLW Jumpers on Vessels/Equipment

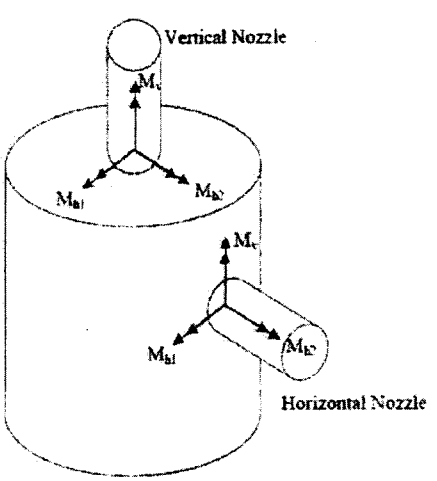
Jumper Pipe Size	Load Type	Forces		
		F_v (lb)	F_{h1} (lb)	F_{h2} (lb)
2 in	Weight	150	30	30
	Seismic	140	100	100
	Thermal	80	200	200
3 in	Weight	490	170	170
	Seismic	290	430	430
	Thermal	360	610	610
4 in	Weight	800	500	500
	Seismic	500	550	550
	Thermal	600	1300	1300
6 in	Weight	2000	600	600
	Seismic	1500	1500	1500
	Thermal	2000	2000	2000
8 in	Weight	3600	1800	1800
	Seismic	3100	3100	3100
	Thermal	3100	3100	3100



Orientation of Forces With Respect to the Jumper Nozzle

Minimum Nozzle Moments Due to HLW Jumpers on Vessels/Equipment

Jumper Pipe Size	Load Type	Moments		
		M_v (ft-lb)	M_{h1} (ft-lb)	M_{h2} (ft-lb)
2 in	Weight	20	100	100
	Seismic	200	225	225
	Thermal	200	250	250
3 in	Weight	280	300	300
	Seismic	400	600	600
	Thermal	500	1010	1010
4 in	Weight	500	950	950
	Seismic	650	650	650
	Thermal	1000	1050	1050
6 in	Weight	700	2000	2000
	Seismic	1500	1500	1500
	Thermal	2000	2000	2000
8 in	Weight	1800	3100	3100
	Seismic	3100	3600	3600
	Thermal	3100	3100	3100



Orientation of Moments With Respect to the Jumper Nozzle

NOTE: Loads are applied at the nozzle to shell/head juncture. Loads provided do not have a sign convention: supplier ensures that the direction of load application provides the most conservative stresses at the nozzle to shell or head junction. The V-axis is vertical and in the direction of gravity regardless of the orientation of the nozzle. Thermal reductions per section 3.7.5 are not applied to jumper nozzle loads.

Appendix C: AISC M016 Tailoring

Implementing Standards for AISC M016, Manual of Steel Construction, Allowable Stress Design (ASD)

Revision: 9th Edition
Sponsoring Origination: American Institute of Steel Construction

WTP Specific Tailoring

The following tailoring of M016 is required for use by the WTP contractor as an implementing standard for design of structural steel for Seismic Category III SSCs.

No specific section

Load combination for design of structural steel members utilize those identified in UBC 97, section 1612.3

Justification: These load combination represent the commercial requirements for allowable stress design of structural steel. Use of these load combinations will ensure compliance with commercial design in accordance with the UBC.

No specific section

Seismic detailing requirements shall be in accordance with UBC 97, Chapter 22, Division V, section 2214, for moderate seismic risk structures.

Justification: The requirements contained in this section contain accepted industry practice for design of important commercial steel structures. Use of this section will ensure compliance with commercial design in accordance with the UBC.

Appendix D: 3.0 ANSI/AISC N690 WTP Specific Tailoring

3.0 ANSI/AISC N690, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities"

Revision: 1994
Sponsoring Origination: American National Standards Institute/American Institute of Steel Construction.

The following tailoring of ANSI/AISC N690 is required for use by the WTP contractor as an Implementing Standard for structural design.

Ref ANSI/AISC N690 Page 22, Section Q1.5.7.1 Primary Stresses with revised Stress Limit Coefficient for WTP project.

Revised stress limit coefficients for compression in Table Q1.5.7.1 as follows:

- 1.3 instead of 1.5 [stated in footnote (c)] in load combinations 2, 5, and 6
- 1.4 instead of 1.6 in load combinations 7, 8, and 9
- 1.6 instead of 1.7 in load combination 11

Page 22, Section Q1.5.7.1 Primary Stresses

Do not Consider the following load combinations:

- 4. D + L + Eo
- 6. D + L + Ro + To + Eo

  For carbon steel structures see section 3.9.1.3

Appendix E: Vessel Item Temperature

There are four temperatures to be considered when developing the vessel and support (e.g. skirt) model and analysis.

From Vessel MDS

T_D Vessel Design temperature
Tov Vessel Operating temperature

From Vessel EQD

To 'Abnormal' temperature
Ta 'DBE' temperature

Temp.	ASME Sect VIII (vessel stress checks)	ASME B31.3 (vessel piping stress checks)	AISC N690 (internal vessel support members)	AISC N690 (outer vessel support members, e.g. skirt, and embed/anchorage)
T_D	Used for vessel component design, in design load case summations.	Used for piping design, in design load case summations.	Used for supports design, in design load case summations.	Used for support design (skirt), in design load case summations, when doing so gives a greater thermal differential than T_O or T_a.
	Not used in occasional (seismic) load case summations.			
T_{OV}	Used for vessel component design, in occasional load case summations.	Used for piping design, in occasional load case summations.	Used for supports in occasional load case summations.	Used for support design (skirt), in occasional load case summations, when doing so gives a greater thermal differential than T_O.
	Not used with design load case summations.			
T_O	Used for support interface design (skirt), in design and occasional load case summations, when doing so gives a greater thermal differential than T_D or T_{OV}.	Not applicable to vessel piping.	Not applicable to vessel internal supports.	Used for support design (skirt), in design and occasional load case summations, when doing so gives a greater thermal differential than T_D or T_{OV}.

T_a	Used for support interface design (skirt). in design load case summations when doing so gives a greater thermal differential than T_D.	Not applicable to vessel piping.	Not applicable to vessel internal supports	Used for support design (skirt). in design load case summations when doing so gives a greater thermal differential than T_D.
	Not used with occasional (seismic) load case summations.			

River Protection Project
Waste Treatment Plant

MECHANICAL DATA SHEET

LAW Catalytic Oxidizer / Reducer

PLANT ITEM No.
24590-LAW-MX-LVP-SKID-00002
24590-LAW-MX-LVP-SKID-00003
(General Note 2)

Data Sheet No.	Rev.
24590-LAW-MKD-LVP-00012	**14**

Project:	**RPP-WTP**	System Description	**Selective Catalytic Oxidizer/Selective Catalytic Reducer**
Project No.:	**24590**		
System No.:	**LVP**	Reference Docs.	**Specification: 24590-LAW-3PS-MBTV-T0001** **References attached below**
Building:	**LAW**		
Quality Level	**Q**	Associated Dwgs.	**24590-LAW-M5-V17T-00011** **24590-LAW-M6-LVP-00005001, 24590-LAW-M6-LVP-00005002** **24590-LAW-P1-P23T-00051, -00052**
Safety Classification	**SS**		
Seismic Category	**SC-III**		

Process Data

Offgas Inlet Conditions:

		2 Melter Nominal	2 Melter Maximum	Design
Vol. Flow *(Process Notes 3, 5)*	(acfm) (scfm)	4,702 2,900	5,395 2,986	6,000 N/A
Mass Flow	lb/hour	12,600	13,000	N/A
Temperature	(°F)	169	189	300 *(Process Note 7)*
Pressure	(in. WG)	-100	-122	-200 *(Process Note 8)*
Density	(lb/ft^3)	0.0447	0.0402	N/A
Allowable Diff. Pressure (in. WG)		8.2 *(Process Note 10)*	9.1 *(Process Note 10)*	12 *(Process Note 10)*

Offgas Inlet Composition:

		2 Melter Nominal	2 Melter Maximum
N_2	(% Volume)	68.2%	67.5%
O_2	(% Volume)	18.3%	18.1%
H_2O	(% Volume)	11.1%	11.5%
CO_2	(% Volume)	1.10%	1.18%
Ar	(% Volume)	0.82%	0.81%

Offgas Outlet Conditions:

	2 Melter Nominal	2 Melter Maximum	Design
Temperature (°F)	* 370*(General Note 3 [TYP])*	412 *(Process Note 2 & 6)*	490 *(Process Note 2)*
Maximum Ammonia Slip, ppm	* 63	200	300

Minor Offgas Components *(Process Note 5)*	2 Melter Nominal, kg/hour	2 Melter Maximum, kg/hour *(Process Note 9)*
NH_3	3.09E-02	6.55E-02
NO *(Process Note 4)*	1.49E+01	2.13E+01
N_2O *(Process Note 4)*	3.97E+00	6.38E+00
NO_2 *(Process Note 4)*	1.98E+01	3.92E+01
CO *(Process Note 4)*	1.07E+00	2.08E-00
SO_2 *(Process Note 1)*	3.16E-02	6.13E-02
Hg	1.97E-04	2.01E-04
HCl	1.53E-03	4.10E-03
HF	8.30E-05	1.22E-04
H_2	3.83E-02	5.01E-02
I_2	5.56E-05	5.56E-05
Particulate	1.24E-05	3.65E-05
VOC/SVOC	5.63E-01	1.17E-00

Process Notes:

1. Maximum SO_2 listed does not include transient spikes.
2. Seller's * process design limit temperature based on the Selective Catalytic Oxidizer/Selective Catalytic Reducer vessel and internal component temperatures using thermodynamic activities in the equipment. * Each of the following locations must be monitored to prevent equipment design temperature (850°F) from being reached.
   a. Seller's process design limit temperature at outlet = 486°F
   b. Seller's process design limit temperature for z-instruments TE-0509 and TE-0516 per Seller = 805°F.
3. Offgas flowrate turn-down ratio of 3:1 required, during planned melter/primary offgas maintenance.
4. Maximum step changes in NO and NO_2 concentrations over a ten-minute period may be as high as 2000 ppmv NO and 1000 ppmv NO_2. Maximum step changes for CO over a 10 minute period may be as high as 500 ppmv. There is no NOx generation during melter idling.

Process Notes (cont'd)

5. Heater sizing for initial heat-up to system operating temperature shall not include contribution from minor offgas components and specified design flow and temperature (inlet conditions).
6. Assumption-70% Heat Exchanger Efficiency.
7. A 111 °F contingency is added to reach a design inlet temperature of 300 °F (see 24590-LAW-MVD-LVP-00003, Process Note 8).
8. Design to 2 psig internal pressure and 7.2 psig external pressure.
9. The constituent concentrations and flowrates are based on the 2-Melter Maximum flowsheet (24590-LAW-M4C-LOP-00001) per 24590-WTP-BODCN-ENG-09-0018.
10. Values supported by BUYER calculations. Margin exists in TCO inlet/outlet piping. See 24590-LAW-MAJ-MS-12-0009, rev 1 for technical justification. Seller to provide nominal, maximum and design differential pressures for BUYER approval.

2 Melter Nominal Differential Pressure per Seller = *14 = (11.89in WG calculated + 2.11in WG margin) in. WG. (Not to Exceed 14 in. WG.)

2 Melter Maximum Differential Pressure per Seller = *15 = (14.35inWG calculated +0.65in WG margin) in. WG. (Not to Exceed 15 in. WG.)

Design Differential Pressure per Seller = * N/A, can't be calculated with values provided in. WG. (Not to Exceed 16 in. WG.)

Ammonia Supply:

		Nominal	Maximum	Design
Temperature	(°F)	77	125	150
Pressure	(psig)	21	45	300
Solids Content	(wt. %)	0 %	0 %	0%

Ammonia Note: Buyer will supply anhydrous ammonia at Seller's specified flowrate to meet design conditions. Seller is responsible for flow control of anhydrous ammonia to meet performance requirements. Ammonia vaporizer assures nominal conditions *(General Note 6)*.

Ammonia Dilution Air Supply:

- Air used for anhydrous ammonia dilution shall be HEPA filtered to an efficiency of 99.97% meeting the requirements in engineering specification 24590-LAW-3PS-MBTV-T0001. For operational testing ammonia dilution shall be HEPA filtered to an efficiency of 99.95%.
- Dilution air shall be pulled from C3V exhaust ducts routed through the secondary offgas room (L-0304F).
- C3V exhaust air temperature shall be maximum 95 °F db / minimum 62 °F wb with an average low pressure of -4 in-WG.

The following are the WTP Dangerous Waste Permit Performance Standards:

1. The Selective Catalytic Oxidizer / Reducer destruction removal efficiency (DRE) for volatile organic compounds (VOCs) and semi-volatile compounds (SVOCs) shall be greater than or equal to 95%. The WTP DRE for VOCs and SVOCs is 99.99%. The principal organic dangerous constituents (PODCs) to be used in LAW performance testing are naphthalene (CAS 00091-20-3) and allyl alcohol (CAS 00107-18-6).
2. The NOx (defined as NO and NO_2) Selective Catalytic Reduction (SCR) unit shall perform with a reduction efficiency of 98%.
3. Dioxin and furan emissions at the stack shall meet the WTP Dangerous Waste Permit Performance Standard criteria of 0.2 ng/m^3 TEQ (Toxic Equivalent).
4. Maximum inlet loading 0.7 grams per minute naphthalene and 1.4 grams per minute allyl alcohol, and a minimum oxidation catalyst outlet temperature of 700°F shall be used for DRE determination *(General Note 9)*.
5. Carbon monoxide (CO) emission shall meet the WTP Dangerous Waste Permit Performance Standard criteria of 100 parts per million (ppm) by volume, over an hourly rolling average, dry basis.
6. Hydrocarbon emission shall meet the WTP Dangerous Permit Performance Standard criteria of 10 parts per million (ppm) by volume, over an hourly rolling average dry basis and reported as propane.

Please note that source, special nuclear and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the US Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only

Approvals

14	Updated the revision numbers for the corrosion evaluations. Margin is not reduced. Updating revision numbers for the corrosion evaluations does not reduce margin.	Reviewed M O'Neill	Originator D Rickettson	Checked L Lewis	N/A	N/A	P Rajagopalan	7/1/15
13	Deleted "Piping" from the Piping /Ducting header. Under Electric Heater section, added "Materials in contact with offgas", deleted enclosure material type & 347SS. Deleted "high temp surface & Instr housing matl", added matl in contact with offgas, added Inconel 800. Revised submittal number 24590-CD-POC-MBT0-00007-01-00386 to 24590-CD-POC-MBT0-00007-01-00353. Revised General Note 11. Margin is not affected. This datasheet summarizes technical data developed in calculations and reports or documented in design basis documents. These documents contain the margin.	M O'Neill	D Rickettson	L Lewis	N/A	N/A	P Rajagopalan	06/18 /15
12	Deleted reference to MACT and replaced with Performance Standards consistant with the DWP. Deleted E&NS Safety Screening Required statement. Updated maximum Heat loss to 17.6 kW. Deleted reference to "General Note 10". Deleted General note 5. Deleted redundant requirement for shipping weights. Added note 1 to EQ section 1.11. Updated references as required.	M O'Neill	D Rickettson	J Marsh	N/A	P Leatherbarrow	S Kretzschmar	03/20 /15
11	Revised the skid height, removed the conceptual design information, deleted component tag numbers, revised the quality level in General Note 5, updated the EQ data sheet to the latest version, added reference list, removed the nozzle loads from the technical notes and added them to the data sheet, added 20% to the nozzle loads per email from Grant Goolsby dated 6/19/14 – CCN: 270007. Major revision, triangles not used for clarity. Margin is not affected. This datasheet summarizes technical data developed in calculations and reports or documented in design basis documents. These documents contain the margin.	Mike O'Neill	D Rickettson	G Goolsby	N/A	Dick Hills	Stuart Kretzschmar	10/21 /14

10	No margin analysis justification is required because these changes do not reduce or eliminate margin (ref. CCN 222685). Revision triangles used. Added technical justification to process note 10. Increased overall length and width due to analyzer probe nozzle addition. Clarified reference points for TCO inlet/outlet height measurement. Revised North arrow for ammonia skid layout. Deleted FILT-00001 from general note 2. Revised section 4.4.3.1. Revised EQD, Section 20. Mounting Method. No margin justification is required because these changes do not reduce or eliminate margin. (Ref. CCN 222685). Revised the Offgas Outlet Minimum Temperature.	M. O'Neill No Comments per email dated 2/24/13	J. Marsh	S. Edwards	D. Krahn Comments resolved per email dated 6/14/13	D. Hills No Comments per email dated 2/12/13	Peter Omel	6/19/13
9	Revision triangles used. Complete re-write of the EQD into the new form. Allowable differential pressure has decreased. However, the SELLER indicates the allowable differential pressures are unattainable. Specified inlet/outlet nozzle height. Increased the allowable envelope and shipping height of the Ammonia/Air Dilution Skid per Seller request. Increased the allowable length of the TCO Skid. Decreased Offgas Outlet Design Temperature. Incorporated TCO nozzle design loads to reflect TCN 24590-QL-MRA-MBT0-00007-T0006. Decreased Abnormal High Temp and DBE High Temp per 24590-LAW-M0E-M40T-00007.	M. O'Neill	D. Nelson	J. Wood	D. Krahn	R. Mills	D. Mildon	07-24-12
8	Revision triangles used. Removed cancelled process calculation 24590-LAW-MEC-LVP-00001. Revised component flowrates to align with 2-Melter Maximum flow sheet guidance per 24590-WTP-BODCN-ENG-09-0018 and ECCN # 24590-LAW-M4E-LOP-00009. Increased the allowable ammonia/air dilution skid height to 11'-0". Specified dilution air flowrate, heat transfer coefficient and heat exchanger area.	M. O'Neill	D. Nelson	M. Parker	D. Krahn	K. Simon	D. Mildon	12-15-11
7	Revision triangles used. Revised Allowable Differential Pressure. Revised Construction Data (Section height, Overall height). Revised catalyst data per manufacturer's and Seller's recommendations. For the EQD portion of the MDS, revised the requisition number, LAW Room datasheet revision number, the area classification "R" value and the chemical exposure details.	M. O'Neill	D. Nelson	D. Rickettson	D. Krahn	K. Simon	J. Schneider	04-18-11
6	Major Revision. Revision triangles not used.	M. O'Neill	T. Valenti	D. Rickettson	D. Krahn	K. Simon	J. Roth	01-12-10

Rev	Reason for revision	Mech Sys/ Proc. Eng.	Project Equipment	Checked	E&NS	EQ	Approved	Date
5	Revised General Notes 7 & 8. Revised Process Data. Revised Material Selection for subcomponents based on MET Corrosion Analyses Added reference to LAW C3 Cost Benefit Analysis. Clarified dimensions of skid. Misc. editorial changes.	Mike O'Neill	Josh Wood	Ray Peters	Dwight Krahn	Jeff White	John Julyk	04-Sep-08
4	Added plant item number for ammonia supply skid. Updated quality level designator. Added safety classification. Updated process data. Revised general note 4, added general note 7, 8, & 9. Revised note 5 & 6, and added note 7 for ammonia skid requirements. Revised reference process calculation. Added approval signature block for E&NS. Increased size of ammonia skid sketch for clarity. Added Attachment 1. Added EQ datasheets and Sketch. Added new process data from 24590-LAW-M4C-LOP-00001, Rev. 0. Updated reference P&IDs.	Mike O'Neill	Grant Goolsby	Utpal Sen	Dwight Krahn	Dick Hills	John Julyk	14-Feb-08
3	Revised housing material, system performance and added NOx concentration step change requirement.	R. Hanson	D. Pease	C. Morley	N/A	N/A	M Hoffmann	31-Jul-05
2	Revised pressures and catalyst model number per SDDR 24590-WTP-SDDR-PROC-04-00879. Added dilution air, outlet piping, and ammonia skid requirements.	R. Hanson	D. Pease	C. Morley	N/A	N/A	M. Hoffmann	31-Oct-04
1	Revised Seller Information	J. Rewari / S. Colby	D. Pease	C. Morley	N/A	N/A	M. Hoffmann	6-May-04
0	Issued for Purchase	J. Rewari / S. Colby	D. Pease	E. Isern	N/A	N/A	M. Hoffmann	18-Apr-04

River Protection Project Waste Treatment Plant	**MECHANICAL DATA SHEET** **LAW Catalytic Oxidizer / Reducer**	**PLANT ITEM No.** **24590-LAW-MX-LVP-SKID-00002** **24590-LAW-MX-LVP-SKID-00003** ***(General Note 2)***

Data Sheet No.	Rev.
24590-LAW-MKD-LVP-00012	**14**

Mechanical Data (Buyer)

Construction Data:

Process Equipment Dimensions (L x W x H):

Sections (Applicable Only to SCO/SCR skid components/sections that will require replacement prior to 40 years)	15'-6" x 9'-0" x 13'-0"	ft
Overall-Less Maximum TCO Inlet/Outlet Expansion Joint Height (See Below)	44'-6" x 10'-0" x 13'-0"	ft
TCO Inlet/Outlet Expansion Joint Height (Maximum-From Frame Base to Top of Inlet/Outlet Bellows Flanges)	12'-6"	ft
Operating Weight	*103,000 (est.)	lb
Shipping Dimensions	*Length: 13.5 (Heater) Width: 6.5 (Heat Ex.) Height: 8.5 (Heat Ex.) (est.)	ft
Shipping Weight	*20,000 (est)	lb

Ammonia/ Air Dilution Equipment (L x W x H):

Skid dimensions with dilution air fans	13'-0" x 9'-0" x 12'-0"	ft
Skid dimensions without dilution air fans	N/A	ft
Operating Weight	*18,000 (est.)	lb
Shipping Dimensions	13'-0" x 9'-0" x 12'-0"	ft
Shipping Weight	*18,000 (est.)	lb

Thermal Analysis Data:

Room Temperature	59-95	°F
Room Temperature Under Floor	59-95	°F
Maximum Heat Loss	17.6	kW

Concrete Slab Base Thickness	10	in
Thermal Conductivity of Concrete Slab	1.8	W / m-K
Room Pressure Atm. Less	0.2	in-WG

Thermal Cycling Frequency:
Per 24590-WTP-MVC-50-00009, Rev 00B, use a thermal cycle total of 100 for the life of the plant (40 years).

Volatile Organic DRE	*95	%
NOx Reduction	*98	%
NOx emissions, max	*160	ppmvw
Ammonia slip, max	*200	ppmvw
Ammonia/NOx molar injection ratio	*4:3	
Overall Pressure drop through Oxidizer	*10.9 (dP=SCO+SCR)	in-WG
Minimum service life catalyst:		
Oxidation Catalyst	*3	yrs (EST.)
NOx Catalyst	*3	yrs (EST.)

Semi-Volatile Organic DRE		*95	%
Ammonia consumption, max		*89	lb/hr
Ammonia entering injection chamber:	Pressure	*15.8	in-WG
	Flow	*92	lb/hr
	Temp.	*96	°F
Dilution Air entering injection chamber:	Pressure	*15.8	in-WG
	Flow	800	scfm

System Performance (Seller, *General Note 1*)

Nozzle Loading (Buyer)

LAW TCO INLET/OUTLET NOZZLE DESIGN LOADS (LVP-SKID-00002)

NOZZLE	SIZE	LOAD TYPE	FORCES - lbs			MOMENTS - ft-lbs		
			Fx	Fy	Fz	Mx	My	Mz
N01	18	Weight	750	250	150	150	150	150
		Seismic	1500	600	1200	1500	500	1000
		Thermal	750	600	1100	2000	500	500
N02	18	Weight	750	250	150	150	150	150
		Seismic	1500	600	1200	1500	500	1000
		Thermal	750	600	1100	2000	500	500

X = North/South Y = Vertical Z = East/West

LAW TCO Ammonia / Air Manifold Nozzle Design Loads (LVP-SKID-00002).

NOZZLE	SIZE	LOAD TYPE	FORCES - lbs			Moments - ft lbs		
			Fx	Fy	Fz	Fx	Fy	Fz
N03	8	Weight	50	240	50	50	50	50
		Seismic	240	220	720	4500	700	800
		Thermal	50	120	250	1400	80	200

X = North / South
Y = Vertical
Z = East / West

LAW Ammonia / Air Dilution Skid Nozzle Design Loads (LVP-SKID-00003).

NOZZLE	SIZE	LOAD TYPE	FORCES - lbs			Moments - ft lbs		
			Fx	Fy	Fz	Mx	My	Mz
N01	8	Weight	60	158	60	60	60	60
		Seismic	326	583	445	935	60	624
		Thermal	60	526	755	1972	60	379
N02	8	Weight	60	389	60	60	66	124
		Seismic	251	552	276	461	110	966
		Thermal	229	188	412	532	440	1769
N04	8	Weight	60	395	60	60	60	266
		Seismic	422	391	406	1187	396	798
		Thermal	114	217	60	71	211	192
N05	2	Weight	24	96	24	31	41	158
		Seismic	107	80	275	314	521	182
		Thermal	24	24	50	44	74	24

X = North / South
Y = Vertical
Z = East / West

Components (Seller, *General Note 1*)

Catalyst:	Organic (LVP-SCO-00001)	NO_x (LVP-SCR-00001)
Manufacturer	BASF (VOCat 300S) "Source Controlled"	*BASF NOxCat VNX-300
Number of reactors	1	1
Number of catalyst modules per layer	*12	*12
Residence time (at standard conditions), seconds, minimum.	0.77 *(General Note 8)*	*0.91
Arrangement	*4 wide x 3 high	*4 wide x 3 high
Total reactor catalyst volume, cubic feet, minimum.	39/ * 39.6 (actual)	*59
Type	Precious metal - platinum	*Vanadium/Titanium
Material: base/substrate	Ceramic - cordierite	*Ceramic - cordierite
Total Number of layers per reactor	3	4/ *5 (actual)
Thickness of layer, in	*10	*9
Space provided between layers for remixing	Yes	*Yes
Space for additional layer, in	No	*No
Is dummy layer provided	No	*No
Number of flow passages	230 cpsi	*64 cpsi
Flow passage, in. x in.	0.060" x 0.060"	*0.11" x 0.11"
Face velocity thru reactor, fpm	*639	*750
Catalyst Section Pressure Drop, in WG	*6.72	*4.18
Inlet Offgas Temperature for MACT Performance Testing, °F	720 (Min) - 750 (Maximum)	*607-631
Design temp, °F	* 850	* 850
Catalyst Module Dimensions, (L x W x D)	*18" x 12" x 10"	*18" x 12" x 9"
Catalyst Module weight, lb	*	*
Total weight of catalyst reactor, lb	*	*

Components (Seller, *General Note 1*)

Housing:	LVP-SCO-00001	LVP-SCR-00001
Material Type	347 SS	347 SS
Material/Thickness, in	*3/8	*3/8
Number of Sections	*1	*1
Weight of Heaviest Section, lb	*10,100 (est.)	*16,300 (est.)
Insulation	*	*
Material/Thickness, in	*	*
Corrosion Allowance, in *(General Note 11)*	0.010	0.010
Thermal Cond, Btu-in/hr ft^2 °F	*	*
Method of Attachment	*Studs with clips	*Studs with clips
Design pressure, psig (internal/external)	* See Offgas Inlet Conditions on Page 1	
Operating pressure, psig	*See Offgas Inlet Conditions on Page 1	
Design temperature, °F	* 850	

Components (Seller, *General Note 1*)

Ducting:	**Inlet**	**Outlet**
Material/Thickness, in	*3/8	*3/8
Cross Section, ft x ft	*47 – 1/8" x 26"	*47-1/8" x 26"
Duct Velocity, fpm	*1143	*1203
Design Temperature, °F	*850	*850
Electric Heater (LVP-HTR-00002)		
Manufacturer	*	
Type	*Tubular elements	
Number of Heat Zones	*5	
Watt Density, W/in^2	*8.5	
Power, kW	*310	
Voltage/Current rating	*480V / TBD	
Housing Material Type	*347 SS	
Materials in contact with offgas, Corrosion Allowance, in *(General Note 11)*	0.010	
Heating Elements	Incoloy 800	
Materials in contact with offgas	347 SS, Incoloy 800	
Design Temperature °F	*850	
Recuperative Heat Exchanger (LVP-HX-00001)		
Manufacturer	*Munters Corporation – DES Champs Products	
Type	*Plate/Frame	
Structural Support Material Type	*347 SS	
Cold Side Components & Enclosure Material Type	347 SS	
Hot Side Plate/Membrane Material Type	347 SS	
Heat transfer coefficient, Btu/hr ft^2 °F-Minimum	3.4	
Heat exchange area, ft^2-Minimum	3105	
ΔT (LMTD) °F	*152 (est.)	
Heat Exchanger duty, Btu/hr	*1,844,030 (est.)	
Corrosion Allowance, in *(General Note 11)*	0.010	
Design Temperature °F	* 850	
Ammonia Injection Manifold:		
Type/Arrangement	*3" injection pipes, horizontal	
Feed Inlet Dia. in	*8	
Supply Pressure/Temp (psi/°F)	*0.57 psig / 96°F (at manifold)	
Material Type (SCR Piping)	347 SS (Vessel Internals) 316L SS (External to Vessel)	
No. of nozzle bars per manifold	*6	
No. of nozzles per bar	*1,138	
Spacing between nozzles, in	*Vertical: 15° / Horizontal: ½" staggered	
Nozzle opening diameter, in	*0.1	

LVP-SKID-00002, Catalytic Oxidizer/Reducer Skid Layout

This sketch has been replaced by 24590-CD-POC-MBT0-00007-01-00353.

LVP-SKID-00003, Ammonia/Air Dilution Skid Layout

This sketch has been replaced by 24590-CD-POC-MBT0-00007-01-00175.

General Notes

1. Seller to confirm values and specify specific model numbers for components listed.
2. LVP-SKID-00002 is the catalytic oxidizer/ reducer unit, and is made up of sub component tag numbers:

   24590-LAW-LVP-HX-00001
   24590-LAW-LVP-HTR-00002
   24590-LAW-LVP-SCO-00001
   24590-LAW-LVP-SCR-00001

   LVP-SKID-00003 is the ammonia supply and air dilution equipment and piping, and includes sub component tag numbers:

   24590-LAW-LVP-FAN-00001 & 00002
   Deleted
   Deleted
   24590-LAW-LVP-HEPA-00004A/B
   Deleted

3. Data marked with an asterisk * is, or will be, provided by Seller.
4. Equipment on LVP-SKID-00002 is Dangerous Waste Permit Affecting.
5. Deleted
6. Ammonia supply design pressure shall be applied to the design of the dilution air piping, up to and including valve YV-0538, and to the combined ammonia/air piping up to nozzle N04.
7. Equipment location is shown on Drawings 24590-LAW-P1-P23T-00051 and 24590-LAW-P1-P23T-00052.
8. Oxidation catalyst residence time is based on pilot plant performance at the Catholic University's Vitreous State Laboratory (VSL). Reference: Regulatory Off-Gas Emissions Testing on the DM1200 Melter System Using HLW and LAW Simulants, 24590-101-TSA-W000-0009-166-00001.
9. Organic loading is based on pilot plant performance at the Catholic University's Vitreous State Laboratory (VSL). Reference *Regulatory Off-Gas Emissions Testing on the DM1200 Melter System Using HLW and LAW Simulants*, 24590-101-TSA-W000-0009-166-00001 and *Small Scale Melter Testing for Allyl Alcohol Method Verification*, 24590-101-TSA-W000-0009-195-00002.
10. Deleted
11. Reference Corrosion Evaluations, 24590-LAW-N1D-LVP-00005, -00006, -00007 and -00008. No corrosion allowance for heating elements. Heaters are designed for replacement. Expected life of the heaters is nominally 5 years.

PART A - For Supplier/Subcontractor Information

Section 1 - Completed by Design Engineering

1.1 Equipment Description:
Secondary Melter Offgas Skids

1.2 Requisition Number: 24590-QL-MRA-MBT0-00007

For Supplier/ Subcontractor Use				WTP Internal Use Only	
1.3 Component Tag Number	Stock Code	Bounding Operating Conditions Reference	Equipment Mounting Elevation	Location (i.e., room number)	Location (thru wall)
24590-LAW-MX-LVP-SKID-00002	N/A	24590-LAW-MKD-LVP-00012	EL. 48'2"	L-0304F	N/A
24590-LAW-LVP-HX-00001	N/A	24590-LAW-MKD-LVP-00012	EL. 48'2"	L-0304F	N/A
24590-LAW-LVP-HTR-00002	N/A	24590-LAW-MKD-LVP-00012	EL. 48'2"	L-0304F	N/A
24590-LAW-LVP-SCO-00001	N/A	24590-LAW-MKD-LVP-00012	EL. 48'2"	L-0304F	N/A
24590-LAW-LVP-SCR-00001	N/A	24590-LAW-MKD-LVP-00012	EL. 48'2"	L-0304F	N/A
24590-LAW-MX-LVP-SKID-00003	N/A	24590-LAW-MKD-LVP-00012	EL. 48'1"	L-0304F	N/A
24590-LAW-LVP-FAN-00001	N/A	24590-LAW-MKD-LVP-00012	EL. 48'1"	L-0304F	N/A
24590-LAW-LVP-FAN- 00002	N/A	24590-LAW-MKD-LVP-00012	EL. 48'1"	L-0304F	N/A
24590-LAW-LVP-HOSE-00001	N/A	24590-LAW-MKD-LVP-00012	EL. 48'1"	L-0304F	N/A
24590-LAW-LVP-HOSE- 00002	N/A	24590-LAW-MKD-LVP-00012	EL. 48'1"	L-0304F	N/A
Deleted					
Deleted					
24590-LAW-LVP-HEPA-00004A	N/A	24590-LAW-MKD-LVP-00012	EL. 48'1"	L-0304F	N/A
24590-LAW-LVP-HEPA-00004B	N/A	24590-LAW-MKD-LVP-00012	EL. 48'1"	L-0304F	N/A
Deleted					

1.4 Safety Function:
Excerpts from 24590-WTP-PSAR-ESH-01-002-03, Rev 05i:
Section 4.4.3.1:
The LAW melter offgas system (the LAW primary offgas process system and the LAW secondary offgas/vessel vent process system) is considered SS to support the following credited safety functions.

- The melter offgas system is credited with maintaining an unobstructed flowpath from the melter to the ventilation exhaust stack (Melter Offgas Release, Section 3.4.1.1, and Offgas Exhauster Fire Analysis, Section 3.4.1.2) whenever a melter has a cold cap. The analysis relies upon an unobstructed flowpath to the exhaust stack to allow an elevated release. The enhanced dispersion provided by elevated release decreases the chemical exposure to the co-located worker to acceptable levels.

Section 4.4.14.1
The catalytic oxidizer/reducer skid heater interlock is considered SS to support the following credited
Safety function:

- The melter offgas system must maintain a continuous flow from the melter to the exhaust stack, which ensures that melter offgases are not released to normally occupied areas of the LAW facility (Section 3.4.1.1) whenever a melter has a cold cap. The analysis relies on this flow to prevent exposure of the facility worker to nitrogen oxide (NOx) gases, and to direct releases to the exhaust stack to achieve an elevated release and decrease the exposure to the co-located worker to acceptable levels. The catalytic oxidizer/reducer skid heater interlock prevents excessive temperatures that could result in a breach of the melter offgas confinement boundary and a subsequent melter offgas release event. This interlock as associated detection instrumentation detects high heater temperatures and cuts off the heater before excessive temperatures are reached.

Safety Function *(continued)*

Section 4.4.15.1
The credited safety function of the ammonia transfer piping and valves is to provide primary confinement for the anhydrous ammonia.

Section 4.4.16.1
The ammonia/dilution-air supply flow isolation interlock, its related detection instrumentation, and its related isolation valves are considered SS to prevent releases of NOx or ammonia in excess of the chemical exposure standards. The ammonia/dilution-air supply flow isolation interlock supports the following credited safety function:

☐The ammonia/dilution-air supply flow isolation interlock stops the flow of ammonia to the SCR upon reaching setpoints established to prevent releases of ammonia and/or NOx harmful to workers, colocated workers, and/or the public under the following conditions:

-detection of reduced dilution-air flow to the SCR mixing chamber below a predetermined setpoint,
-detection of increased ammonia flow above a predetermined setpoint.

The safety functions identified above are credited in the accident analysis to 1) prevent a release of undiluted ammonia from the exhaust stack, 2) prevent a backflow of ammonia through the dilution air supply system and subsequent release into the facility, and 3) prevent ammonia concentrations in the melter offgas system that could result in an ammonia fire or deflagration in, or downstream of, the SCR unit (which in turn could result in damage to the melter offgas system and a release of ammonia/NOx inside the facility). (Sections 3.4.1.1 and 3.4.1.4)

The ammonia supply is also isolated on detection of a low or excessive LVP header vacuum as part of a system-wide reconfiguration (Sections 4.4.33 and 4.4.34), on detection of high or low offgas temperatures at the outlet of the SCO/SCR (Sections 4.4.23 and 4.4.35), on detection of high offgas temperatures at the caustic scrubber outlet (Section 4.4.36), and on detection of the caustic scrubber bypass isolation valve not being closed (Section 4.4.37).

The following are the safety significant functions of the TCO credited for DBE (P&ID, 24590-LAW-M6-LVP-00005001 & -00005002 show instruments that are outside of seller's scope):

- The catalyst skid shall provide a confinement boundary for melter offgas. (Passive Mechanical)
- The high temperature interlock (Signal from TE 0509 or TE 0516) shall shut down catalyst skid electric heater (LVP-HTR-00002) at a high temperature set point to prevent over temperature condition. (Electrical)
- Ammonia air addition (dilution) shall dilute and maintain the SCO/ SCR ammonia concentration below the Lower Flammable Limits (LFL). (Active Mechanical)
  - Transmit flow information from flow transmitters FT 0530, FT 0531, FT 0540, and FT 0541 to indicators (by others) and for use by the BUYER'S PPJ system
  - Close YV 0538 when signaled to do so by the BUYER'S PPJ system, or upon loss of power or control signal.
- Ammonia piping shall provide confinement boundary for ammonia (all Q components). (Passive Mechanical)
- Ammonia Supply Isolation Valve functions: (Active Mechanical)

Close YV 0528 when signaled to do so by the BUYER'S PPJ system, or upon loss of power or control signal.

1.5	**Safety Classification**	☐ SC	☒ SS	☐ Non-Safety		
1.6	**Post Accident Monitoring (PAM)**	☒ No	☐ Yes			
1.7	**Seismic Category**	☐ SC-I	☐ SC-II	☒ SC-III	☐ SC-IIIE	☐ SC-IV
1.8	**Seismic Safety Function**	☐ No	☒ Yes			
1.9	**Seismic Operability Requirements** Note 5	☒ During Seismic Event		☒ After Seismic Event	☐ None	
1.10	**Qualified Life** Note i ☒ 40 years	☐ Other:		☐ To be determined by Qualifier		
1.11	**Normal Plant/Process Induced Vibration** Note 1	☒ No	☐ Yes			
1.12	**Design Basis Accident (DBA) Submergence** Note 3	☒ No	☐ Yes			

Electrical Interfaces Supporting the Safety Function
1.13 Power Supply Voltage (VAC, VDC): 120 and 480 VAC
1.14 Power Supply Frequency (Hz): 60
1.15 Power Connection Method: 3 wire grounded
1.16 I/O Signals to/from Equipment: 24590-LAW-3PS-MBTV-T0001
1.17 I/O Connection Method: 4-20 mA

Mechanical Interfaces Supporting the Safety Function
1.18 Mounting Configuration (orientation): Floor Mounted, Horizontal
1.19 Mounting Method (bolts, welds, etc.): Frame welded to surface mounted interface plates
1.20 Auxiliary Devices: Lifting Lugs

Section 2 - Initial Input by EEQ

2.1	**Equipment Safety Function Type** Note m Note 6	☒ Electrical	☒ Active Mechanical	☒ Passive Mechanical		
2.2	**Classification of Environment**	☐ Harsh	☒ Mild	☐ To be determined by Vendor		
2.3	**Abnormal Wet Sprinkler** Note g	☐ No	☒ Yes	Duration: 2 hr		
2.4	**Design Basis Accident (DBA) Steam Break**	☒ No	☐ Yes	Duration: N/A	Temp: N/A	
2.5	**Design Basis Accident (DBA) Flooding** Note 3			Duration: N/A hr	Flood height: 0.92 ft	

2.6 Indoor Environmental Ambients

		Normal		Abnormal		Design Basis Accident (DBA)	
		High	Low	High	Low	High	Low
Temperature		95 °F	59 °F	134 °F	40 °F	135 °F	40 °F
	Note	*Ref. 1*	*Note b, Ref.1*	*Ref. 6*	*Note b, Ref. 1*	*Ref. 6*	*Note b, Ref. 1*
	Duration	40 yr	N/A	8 hr/yr	N/A	2 hr	N/A
	Note	*Note a*	*Note b*	*Note a, Ref. 1*	*Note b*	*Ref. 1*	*Note b*
Relative Humidity		90 %	10 %	100 % Cond	6 %	100 % Cond	6 %
	Note	*Note c, Ref. 1*	*Note c, Ref. 1*	Note c, Ref. 1	Note c, Ref. 1& 6	*Note c, Ref. 1*	*Note c, Ref. 1 & 6*
	Duration	N/A	N/A	N/A	N/A	2 hr	2 hr
	Note	*Note c*	*Note c*	*Note c*	*Note c*	*Ref. 1*	*Ref. 1*
Pressure		0 in-w.g.	-0.4 in-w.g.	4 in-w.g.	-2.4 in-w.g.	4 in-w.g	-2.4 in-w.g
	Note	*Note d, Ref. 1*	*Note d, Ref. 1*	*Note d, Ref. 1*	*Note d, Ref. 1*	*Note d, Ref. 1*	*Note d, Ref. 1*
	Duration	N/A	N/A	N/A	N/A	2 hr	2 hr
	Note	*Note d*	*Note d*	*Note d*	*Note d*	*Ref. 1*	*Ref. 1*
Radiation Dose Rate		0.5 mRad/hr		0.5 mRad/hr		0.5 mRad/hr	
	Note	*Ref. 1 & 16*		*Ref. 1 & 16*		*Ref. 1 & 16*	
	Duration	40 yrs		0 hr		0 hr	
	Note	*Note e, Ref. 1*		*Note e, Ref. 1*		*Ref. 1*	

2.6 Indoor Environmental Ambients						
	Normal		Abnormal		Design Basis Accident (DBA)	
	High	Low	High	Low	High	Low
Additional Information	Note h, i		Note h		Note f, h	

2.7 Outdoor Environmental Ambients - N/A

2.8 Normal Spray Exposure

Chemical/Fluid	Concentration (M)	Duration (yr)	Note
None		40	Other spray sources exist in room L-0304F; however, they are not in the immediate vicinity of the TCO equipment and have been determined to not impact this equipment.

2.9 Design Basis Accident (DBA) Spray Exposure & Flood Composition

Chemical/Fluid	Concentration (M)	Duration (hr)	Note
Fire Water	None	2.0	

Chemical/Fluid	Flowstream	pH	Temp (° F)	Duration (hr)	Note
None				12.5	

2.10 General EQD Notes *(check all that apply)*:

☒ a) For thermal aging, the high normal temperature shall be assumed to subsist for 40 years less the duration of the high abnormal temperature. For any lesser qualified life, the normal and abnormal condition durations shall be assigned proportionally. The abnormal temperature is stated to subsist for a certain number of hours per year. It shall be taken to subsist for this number of hours for each year of the qualified life.

☒ b) The ability to provide the safety function at the low normal temperature, the low abnormal temperature or the low DBA temperature (whichever be the lowest) shall be established by test, analysis, or operating experience. The thermal aging at these respective low temperatures will be conservatively covered by the thermal aging per item a) above. Therefore, no duration is assigned for the low temperatures.

☒ c) The ability to provide the safety function at the extremes of the normal and abnormal humidity conditions, taking into consideration the high and the low normal and high and low abnormal, shall be established by test, analysis, or operating experience. No duration is assigned for the normal and abnormal humidity conditions.

☒ d) If the performance of the safety function of the equipment is affected by ambient pressure, the ability to provide the safety function at the extremes of the normal and abnormal pressure conditions, taking into consideration the high and the low normal and the high and low abnormal pressures, shall be established by test, analysis, or operating experience. No duration is assigned to the normal and abnormal pressure conditions.

☒ e) (1) If the abnormal radiation dose rate is the same as the normal radiation dose rate, the normal radiation dose rate shall be assumed to subsist for 40 years, or any lesser qualified life, and the duration of the abnormal radiation dose rate is "0."

☐ (2) If the abnormal radiation dose rate is higher than the normal radiation dose rate, the abnormal radiation dose rate shall be assumed to subsist for 40 years, or any lesser qualified life, and the duration of the normal radiation dose rate is "0."

☒ f) The DBA conditions shall be taken to subsist for the stated number of hours following the qualified life of the equipment.

☒ g) Spray due to fire sprinkler actuation shall be taken to occur once over the entire qualified life duration for a period of 2 hours, even if the qualified life is a period less than 40 years. If spray qualification is provided for DBA conditions (whether for water or chemical spray), then separate qualification for the fire sprinkler spray need not be provided.

☒ h) The values stated in this EQD are the ambients and do not include the thermodynamic and radiation conditions imposed by the process fluids. The data pertaining to process fluid and service induced parameters are to be taken into account where significant, such as in thermal aging analyses. This data can be obtained from the equipment data sheets or the Equipment Specification.

☒ i) Equipment that is to be installed in inaccessible locations must be qualified to a 40-year life without the need for maintenance or replacement.

☐ j) For suspended ash, 24590-WTP-U0D-W16T-00001, Rev 0, states:

Suspended Ash Concentrations (mg/m^3):	174 (ave), 220 (max.)
Ash fall Rate (in/hr):	0.35 (ave), 0.44 (max)

2.10 General EQD Notes *(check all that apply)*:

Grain Size (µm):	75
Max. Ash fall (in)	7.4 (uncompacted), 3.0 (compacted)
Compacted Density:	96 lb/ft^3

☒ k) The equipment qualifier shall perform qualification to the most conservative capability of the equipment. The qualification shall not be less conservative than the bounding environmental conditions detailed in this document.

☒ m) For environmental qualification purposes, an active mechanical safety function bounds passive mechanical, and an electrical safety function bounds both, with respect to the environmental qualification requirements.

2.11 Specific Notes:

1. Equipment is mounted to the structural floor of the LAW facility and is Q, SC-III analyzed. The only rotating loads associated with this equipment are two small, single-stage centrifugal fans that are small in mass relative to the mass of the SCO/SCR and the ammonia dilution skid. There are no other rotating or oscillating loads located in the vicinity of the LAW TCO or the ammonia dilution skid which would produce significant plant / process induced vibration. As a result, no normal plant / process vibrations are expected in the area of this equipment. This equipment is not considered sensitive to vibration and as such, normal plant vibrations are not expected to have an impact on this equipment.
2. Deleted
3. SELLER design to preclude submergence of sensitive components of the skids.
4. Deleted
5. Seismic Operability Requirements: close ammonia supply and ammonia/air dilution isolation valves, open SCO/SCR bypass valve, shut off power to electric heaters.
6. Equipment Safety Function Type: Passive - maintain confinement boundaries; Active - close ammonia supply and ammonia/air dilution isolation valves, open SCO/SCR bypass valve; Electrical - shut off power to electric heaters.

Section 3 - Completed by ESQ

3.1 WTP Seismic Design Specification and/or Criteria:

Document No.	Remarks / Notes
N/A	Seismic Qualification By BNI

3.2 Specified Seismic Load Parameters:

Document No.	Remarks / Notes
N/A	

PART B - Internal WTP Use Only

Section 4 - Completed by EEQ, ESQ, and Design Engineering as necessary

4.1 Reference List

(Source and developmental documents. See Material Requisition for documents transmitted to the vendor.)

No.	Document No.	Rev	Title
1.	24590-LAW-U0D-W16T-00001	2	LAW Room Environment Data Sheet

No.	Document No.	Rev	Title
2.	N/A		
3.	N/A		
4.	N/A		
5.	24590-WTP-PSAR-ESH-01-002-03	05i	Preliminary Documented Safety Analysis To Support Construction Authorization; LAW Facility Specific Information
6.	24590-LAW-M0E-M40T-00007	NA	ECCN for Calculation LAW-M0C-M40T-00001
7.	24590-LAW-3PS-MBTV-T0001	4	Engineering Specification for LAW Thermal Catalytic Oxidizer/Reducer
8.	24590-LAW-M6-LVP-00005001	2	P&ID - LAW Secondary OffGas / Vessel Vent Process System Ammonia Dilution Skid
9.	24590-LAW-M6-LVP-00005002	2	P&ID - LAW Secondary OffGas / Vessel Vent Process System SCO/SCR Skid
10.	24590-LAW-P1-P23T-00051	4	LAW-Vitrification Building Equipment Location Pan El. 48'-0" / Area 4
11.	24590-LAW-P1-P23T-00052	5	LAW-Vitrification Building Equipment Location Pan El. 48'-0" / Area 5
12.	24590-LAW-N1D-LVP-00005	3	Corrosion Evaluation - LVP-HX-00001
13.	24590-LAW-N1D-LVP-00006	3	Corrosion Evaluation - LVP-HTR-00001
14.	24590-LAW-N1D-LVP-00007	4	Corrosion Evaluation - LVP-SCO-00001
15.	24590-LAW-N1D-LVP-00008	3	Corrosion Evaluation - LVP-SCR-00001
16.	24590-LAW-P1-P01T-00005	5	LAW Vitrification Building General Arrangement Plan at El. 48 Feet - 0 Inches

REFERENCES for Data Sheet: 24590-LAW-MKD-LVP-00012, Rev 14 (For BNI Use only)

Data	Document #	Rev	Document Title
Quality Level	24590-LAW-M6-LVP-00005001 24590-LAW-M6-LVP-00005002	2 2	*P&ID – LAW Secondary Offgas/Vessel Vent Process System Ammonia Dilution Skid* *P&ID-LAW-Secondary Offgas/Vessel Vent Process System SCO/SCR Skid*
Seismic Category	24590-LAW-M6-LVP-00005001 24590-LAW-M6-LVP-00005002	2 2	*P&ID – LAW Secondary Offgas/Vessel Vent Process System Ammonia Dilution Skid* *P&ID-LAW-Secondary Offgas/Vessel Vent Process System SCO/SCR Skid*
2 Melter Maximum Flow Rate	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 7*
Design Volumetric Flow Rate	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 9*
2 Melter Nominal Inlet Temperature	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 7*
2 Melter Maximum Inlet Temperature	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 7*
Design Inlet Temperature	24590-LAW-MVD-LVP-00003	6	*24590-LAW-MV-LVP-ADBR-00001A 24590-LAW-MV-LVP-ADBR-00001B - Activated Carbon Adsorber For Mercury Abatement (LVP-SKID-00001), page 2*
Maximum Outlet Temperature	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 3*
Design Outlet Temperature	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 7*
2 Melter Nominal Pressure	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 7*
2 Melter Maximum Pressure	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 7*
Design Inlet Pressure (Vacuum)	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 8*
Allowable Differential Pressure (Nominal)	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page 11*
Allowable Differential Pressure (Maximum)	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page15*
Allowable Differential Pressure (Design)	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 9*
2 Melter Maximum Mass Flow	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page15*
2 Melter Maximum Density	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page 15*
2 Melter Nominal Mass Flow	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page 11*
2 Melter Nominal Density	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page 11*
2 Melter Nominal Volumetric Flow	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page 11*
2 Melter Nominal Offgas Composition	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Pages 12-14*

2 Melter Maximum Offgas Composition	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Pages 16-18*
Ammonia Supply Conditions	24590-LAW-M6WX-LVP-00005001	1	*MS Line List for P&ID 24590-LAW-M6-LVP-00005001, Page 1*
Maximum Ammonia Slip	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, Page 17*
Design Ammonia Slip	24590-LAW-MKC-LVP-00003	1	*LAW Catalytic Oxidizer/Reducer Skid Inlet Operating Conditions and Design Requirements, page 6*
VOC Removal Efficiency	24590-WTP-DB-ENG-01-001	2	*Basis of Design, Section 14.4.3.3*
Maximum Offgas Inlet Composition	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, page 16*
Minor Offgas Components	24590-LAW-M4E-LOP-00009	N/A	*LAW Melter Offgas System Design Basis Flow Sheets, pages 17 and 18*
Mechanical Data – Ammonia / Air Dilution Skid	24590-CD-POC-MBT0-00007-01-00042	00B	*LAW Ammonia / Air Dilution Skid General Arrangement*
Nozzle Loads	24590-LAW-P6C-LVP-30000	TBD	*Interim – Pipe Stress Analysis for LAW LVP System*
Nozzle Loads	24590-LAW-P6C-LVP-30010	TBD	*Interim – Pipe Stress Analysis LAW LVP System*
Nozzle Loads	24590-LAW-P6C-AMR-30001	TBD	*Interim - Pipe Stress Analysis - LAW AMR/LVP System*
Catalyst Data (Organic)	24590-CD-POC-MBT0-00007-03-00003	00C	*Data Sheet – Selective Catalytic Oxidation(SCO) Catalyst*
Catalyst Data (NOx)	24590-CD-POC-MBT0-00007-03-00004	00C	*Data Sheet – Selective Catalytic Reduction (SCR) Catalyst*
Nominal and Maximum Pressure Differential	24590-CD-POC-MBT0-00007-02-00001	00C	*Calculation – Mass & Energy Balance for LAW Catalytic Oxidizer / Reducer*
LVP-SCR-00001 Material Type and Corrosion Allowance	24590-LAW-N1D-LVP-00008	3	*LVP-SCR-00001 (LAW) – NOx Selective Catalytic Reducer*
LVP-SCO-00001 Material Type and Corrosion Allowance	24590-LAW-N1D-LVP-00007	4	*LVP-SCO-00001 (LAW) – Thermal Catalytic Oxidizer*
LVP-HTR-00002 Material Type and Corrosion Allowance	24590-LAW-N1D-LVP-00006	3	*LVP-HTR-00002 (LAW) – Catalytic Oxidizer Electric Heater*
LVP-HX-00001 Material Type and Corrosion Allowance	24590-LAW-N1D-LVP-00005	3	*LVP-HX-00001 (LAW) – Catalytic Oxidizer Heat Recovery Exchanger*
Construction Data	24590-CD-POC-MBT0-00007-03-00001	00B	*Data Sheet – Mechanical Data Sheet, LAW Catalytic Oxidizer/Reducer*
Electric Heater	24590-CD-POC-MBT0-00007-03-00009	00F	*Data Sheet – Electric Heater, LAW TCO*
Recuperative Heat Exchanger	24590-CD-POC-MBT0-00007-03-00008	00C	*Data Sheet – Heat Exchanger Core, LAW TCO*

REFERENCES for Data Sheet: 24590-LAW-MKD-LVP-00012, Rev 14 (For BNI Use only)

Vendor Provided Data	24590-CD-POC-MBT0-00007-03-00001	00B	*Data Sheet - Mechanical Data Sheet, LAW Catalytic Oxidizer / Reducer*
Maximum Heat Loss	24590-LAW-MVC-LVP-00004	00A	*LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS*

ISSUED BY
RPP-WTP PDC

R11727036

CORROSION EVALUATION

LVP-HX-00001
Catalytic Oxidizer Heat Recovery Exchanger

Contents of this document are Dangerous Waste Permit affecting

Results

Materials Considered:

Materials Considered (UNS No.)	Acceptable Materials
Type 304L (S30403)	
Type 316L (S31603)	
Type 347 (S34700)	X
AL-6XN® 6% Mo alloy (N08367)	
Hastelloy® C-22® (N06022)	

Recommended Material Types:

Structural support:	Type 347 stainless steel
Hot side plates:	Type 347 stainless steel
Cold-side components and enclosure:	Type 347 stainless steel

Minimum Corrosion Allowance: 0.010 inch (structural steel in contact with offgas)
No corrosion allowance required for heat transfer surface

Inputs and References

- Operating temperature, cold-side (°F) (norm/max): 169/189 (in); 370/412 (out) (24590-LAW-M4E-LOP-00009)
- Operating temperature, hot-side (°F) (norm/max): 624/680 (out); 724/792 (in) (24590-LAW-M4E-LOP-00009)
- Corrosion allowance (in contact with offgas, excluding heat transfer surfaces): 0.010 inch (24590-WTP-SRD-ESH-01-001-02)
- Corrosion allowance (heat transfer surfaces): 0.00 inch (24590-WTP-GPG-M-047)
- Location: room L-0304F; out cell (24590-LAW-P1-P01T-00005)
- Operating conditions are as stated in the applicable section of *WTP Process Corrosion Data - Volume 4* (24590-WTP-RPT-PR-04-0001-04)

Assumptions and Supporting Justification (refer to Section 19—References)

- Operating conditions presented on the Process Corrosion Datasheet (PCDS) are conservative with respect to corrosion.

Operating Restrictions

- Develop a procedure for decontamination.
- Develop procedure to control lay-up and storage (mitigation of condensation in accordance with *Manual - Operation, Maintenance And Installation Instructions For LAW Thermal Catalytic Oxidizer / Reducer (TCO) And Ammonia Dilution Skid*, 24590-CD-POC-MBT0-00007-05-00004); including both before plant is operational and during inactive periods during plant operation.
- Procedures are to be reviewed and accepted by MET prior to use.

Concurrence _____
Operations

REV	DATE	REASON FOR REVISION	ORIGINATE	CHECK	REVIEW	APPROVE
3	6/23/15	To expand material selection information and references to address ORP and Ecology comments.	DLAdler	~~APRangus~~ Tom Ervin 6/25/15	RBDavis	~~TErwin~~ J. Leann 6/25/15
2	12/16/14	Complete re-write: no rev bars shown New format Incorporate revised PCDS Revise Ops Restrictions Update references Add AEA notice	DLAdler	JRDivine	RBDavis	TErwin
1	7/18/12	Incorporate revised PCDS Update design temp/pressure Include AEA notice Minor format and editorial changes	DLAdler	RBDavis	NA	DJWilsey
0	3/19/08	Initial Issue	DLAdler	JRDivine	RBDavis	SWVail

CORROSION EVALUATION

Please note that source, special nuclear and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the U.S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

This bound document contains a total of 15 sheets.

CORROSION EVALUATION

Corrosion/Erosion Detailed Discussion

The heat recovery exchanger raises the offgas temperature from LVP-ADBR-00001A/B, using the hot offgas from the catalyst beds (LVP-SCR-00001).

1 General/Uniform Corrosion Analysis

a Background

General corrosion or uniform corrosion is corrosion that is distributed more-or-less uniformly over the surface of a material without appreciable localization. This leads to relatively uniform thinning on sheet and plate materials and general thinning on one side or the other (or both) for pipe and tubing. It is recognized by a roughening of the surface and usually by the presence of corrosion products. The mechanism of the attack typically is an electrochemical process that takes place at the surface of the material. Differences in composition or orientation between small areas on the metal surface create micro-anodes and cathodes that facilitate the corrosion process.

b Component-Specific Discussion

Offgas corrosion, like atmospheric corrosion, depends on the development of corrosion cells or electrochemical cells consisting of the base metal, corrosion products, deposition products, anode, cathode, electrolyte, and current path. Stainless steels also have the added influence of the protective passive film. Because the corrosion process is electrochemical, an electrolyte must be present on the surface for corrosion to occur. In the absence of moisture, corrosion will not take place. As an example, where temperatures are less than freezing, corrosion is minor because the ice is not a good conductor; or when the relative humidity is low, the water condensation is negligible and corrosion is negligible. Offgas corrosion is also influenced by the deposition of particulates, dust, and thin monolayers of gas constituents. The physically adsorbed molecules on the surface (HCl, HNO_3, and H_2SO_4) will form an acid droplet from the deliquescence of water molecules. Moisture is needed to activate the corrosion process; typically a relative humidity of 60% to 80% is necessary to support corrosion; below this range corrosion does not occur. The relative humidity range for corrosion is discussed in Coburn (1978), Dean and Lee (1986), Dean and Rhea (1980), Schweitzer (1988), and in the *ASM Metals Handbook, Volume 13*. Normal operating conditions for the components of the thermal catalytic oxidizer (TCO) skid are dry, and relative humidity is very low (0.04% relative humidity, as shown in the PCDS). The anticipated dry-air conditions are not conducive to general corrosion and none is expected. Further, operating restrictions are in place to ensure that dry-air conditions are maintained.

The stabilized austenitic Type 347 stainless steel is considered suitable for the offgas conditions. The Type 347 austenitic stainless steel is an enhancement over that of a Type 300 stainless steel. The corrosion rates are a product of the alloy chemistry, and the only difference between Type 347 and Type 304L is the increase in carbon content that improves the high temperature properties. The carbon increase is offset with niobium and tantalum alloyed to decrease the tendency for carbide precipitation during fabrication and welding. Type 347 alloy has improved oxidation resistance and high temperature properties and is a good choice for the TCO components. Type 347 was selected for the following reasons: improved thermal properties, readily available in most product forms, standard stainless steel fabrication practice (tools and processes), and lower cost per pound than the higher nickel or duplex alloys (*High-Temperature Characteristics of Stainless Steels*, NIDI Publication No. 9004).

The recuperative heat exchanger is operated at elevated temperatures; oxidation is considered as part of this corrosion evaluation. The recommended alloy for the elevated temperature sections is Type 347 stainless steel. The higher carbon content and the addition of niobium to prevent sensitization act to improve the oxidation resistance.

The skid base frame is not considered as a material in contact with the offgas. If structural materials are not welded to the pressure boundary of the heat exchanger, they are outside the scope of this corrosion evaluation.

2 Pitting Corrosion Analysis

Pitting is localized corrosion of a metal surface that is confined to a point or small area and that takes the form of cavities. Pitting corrosion will only be a concern if sufficient moisture is present. The heat exchanger normally operates at temperatures above the dew point of the dry offgas, and therefore sufficient moisture is not present to act as an electrolyte for corrosion processes to proceed. It is assumed that there will be no condensation in the unit.

Justification for this position is that corrosion will not proceed without an electrolyte present.

3 Crevice Corrosion Analysis

Crevice corrosion is a form of localized corrosion of a metal or alloy surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity of the metal or alloy to the surface of another material or an adjacent surface of the same metal or alloy. Crevice corrosion is similar to pitting in mechanism. Crevice corrosion will only be a concern if sufficient moisture is present. The offgas humidity is controlled so that there will be no condensation.

Justification for this position begins with the understanding that this is an air handling unit operating at elevated temperatures, above the dew point. Corrosion will not take place or initiate when no electrolyte is present.

4 Stress Corrosion Cracking Analysis

Stress corrosion cracking (SCC) is the cracking of a material produced by the combined action of corrosion and sustained tensile stress (residual or applied). In addition, sensitization of the grain boundaries is prevented with the materials recommended. Either an "L" grade, low carbon, stainless steel or a niobium-stabilized stainless steel is specified to negate sensitization from becoming a

CORROSION EVALUATION

corrosion issue. It is assumed that there will be no condensation in the unit; therefore, the recuperative heat exchanger will not undergo stress corrosion cracking because insufficient moisture will be present.

This position is justified because of the temperature of the gas during operation will be greater than the dew point. Corrosion will not take place or initiate when no electrolyte is present.

5 End Grain Corrosion Analysis

End grain corrosion is preferential aqueous corrosion that occurs along the worked direction of wrought stainless steels exposed to highly oxidizing acid conditions. End grain corrosion typically is not a major concern, it propagates along the rolling direction of the plate, not necessarily through the cross sectional thickness. In addition, end grain corrosion is exclusive to metallic product forms with exposed end grains from shearing or mechanical cutting. The heat exchanger design uses cooling channels and does not expose the pressure boundary cut ends to offgas. Also, end grain corrosion will not take place in the component because of the absence of sufficient moisture.

End grain corrosion is not expected to occur in the recuperative heat exchanger because the temperature of the gas will be greater than the dew point of the gas therefore corrosion will not occur in the absence of an electrolyte.

6 Weld Corrosion Analysis

The welds used in the fabrication will follow the WTP specifications and standards for quality workmanship. The materials selected for this fabrication are compatible with the weld filler metals and ASME/AWS practice. Using the welding practices specified for the project there should not be gross micro-segregation, precipitation of secondary phases, formation of unmixed zones, or volatilization of the alloying elements that could lead to localized corrosion of the weld.

This position is justified because the operating temperature and dry air conditions will not corrode because of the lack of the electrolyte for corrosion.

7 Microbiologically Influenced Corrosion Analysis

Microbiologically influenced corrosion (MIC) refers to corrosion affected by the presence or activity, or both, of microorganisms.

Typically, with the exception of cooling water systems and stagnant water, MIC is not observed in operating systems.

The recuperative heat exchanger will operate at elevated temperatures and the offgas is dry. In this system, the stated operating conditions are not suitable for microbial growth.

8 Fatigue/Corrosion Fatigue Analysis

Corrosion-fatigue is the result of the combined action of cyclic stresses and a corrosive environment. The fatigue process is thought to cause rupture of the protective passive film, upon which stainless steel can actively corrode in the localized area of the film rupture. The corrosive environment may also act to reduce the stress necessary for film rupture. The result is that a metal exposed to a corrosive environment and cyclic mechanical load may initiate cracking at conditions at stress levels less than the endurance limit for the material.

The recuperative heat exchanger is not cyclically operated; offgas flow is constant, steady and dry. Thermal cycles and therefore thermal stress is also low and associated with the start-up and shut down of the offgas system. Corrosion fatigue will not be observed in the recuperative heat exchanger (24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS*).

The conclusion that corrosion fatigue will not be a problem is based on the low mechanical and thermal cycling, as well as the lack of an electrolyte for corrosion.

9 Vapor Phase Corrosion Analysis

Vapor phase corrosion considers the gas and vapor constituents that form acidic condensate and the alloy corrosion resistance. The aggressive constituents are HCl, HF, and HNO_3; however these are present in low concentrations in the gas. The formation of acidic condensate requires moisture condensing on the surface and mixing with the adsorbed surface constituents to produce an aggressive environment. Condensation on the surface is not likely during normal operation.

Vapor phase corrosion will not occur in the recuperative heat exchanger conditions because the operation conditions for this component preclude the presence of sufficient moisture and concentrations of acid gas forming components.

10 Erosion Analysis

Erosion is the progressive loss of material from a surface resulting from mechanical interaction between a particle and that surface. Solid particle erosion can occur in air, steam, and water fluid systems. The WTP waste is a slurry consisting of water, waste oxide particles, and / or precipitated salts. When the fluid propels the solid particles at a sufficient velocity and the particle mass is sufficient, the surface can be damaged by the combined effect of millions of individual erosion "scars". Prior to reaching the recuperative heat exchanger the offgas passes through a high efficiency particulate filter (HEPA) and therefore should be free of particulates.

The solids content and gas velocity are sufficiently low that erosion is not a concern.

CORROSION EVALUATION

11 Galling of Moving Surfaces Analysis

Galling is a form of wear caused by a combination of friction and adhesion between moving surfaces. Under high compressive forces and movement, the friction temperatures cold-weld the two surfaces together at the surface asperities. As the adhesively bonded surface moves some of the bonded material breaks away. Microscopic examination of the galled surface shows some material stuck or even friction welded to the adjacent surface, while the softer of the two surfaces appears gouged with balled-up or torn lumps of material stuck to its surface.

Galling is most commonly found in metal surfaces that are in sliding contact with each other. It is especially common where there is inadequate lubrication between the surfaces. Softer metals will generally be more prone to galling; austenitic stainless steel is relatively soft and ductile and is known to gall easily. Martensitic stainless steel or precipitation hardened stainless steel or nitrogen strengthened austenitic stainless steels have higher surface hardness and therefore are resistant to galling.

The recuperative heat exchanger does not have any moving surfaces.

12 Fretting/Wear Analysis

Fretting corrosion refers to corrosion damage caused by a slight oscillatory slip between two surfaces. Similar to galling but a much smaller movement, the corrosion products and metal debris break off and act as an abrasive between the surfaces, classic 3-body wear problem. This damage is induced under load and repeated relative surface motion, as induced for example by vibration. Pits or grooves and oxide debris characterize this damage, typically found in machinery, bolted assemblies and ball or roller bearings. Contact surfaces exposed to vibration during transportation are exposed to the risk of fretting corrosion.

The recuperative heat exchanger does not have moving parts and design precludes the use of tube support plates that would normally become a fretting corrosion problem in tube-and-shell heat exchangers. Fretting corrosion is not expected in this component.

13 Galvanic Corrosion Analysis

Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially to another when both metals are in electrical contact, in the presence of an electrolyte. Dissimilar metals and alloys have different electrode potentials, and when two are in contact in an electrolyte, one metal acts as anode and the other as cathode. The electropotential difference between the dissimilar metals is the driving force for an accelerated attack. The potential difference for more than 200 mV is needed for sufficient driving force to make a difference. Galvanic compatibility is one of the attributes used to select the WTP alloys. Austenitic stainless steels in contact with other austenitic stainless steels do not have sufficient electropotential difference to significantly influence the metal loss.

The recuperative heat exchanger plates, frame, and support materials are all fabricated from Type 347 stainless steel. In addition, the gas is dry and contains insufficient moisture to act as an electrolyte. Galvanic corrosion is not expected to be a corrosion issue under these conditions.

14 Cavitation Analysis

Cavitation corrosion is defined as another synergistic process, the combined influence of mechanical disruption of the metal surface and the corrosion of the active metal. Cavitation occurs when the local fluid pressure drops below the vapor pressure of the fluid resulting in a liquid vapor interface or bubbles to form. Their collapse on the metal surface has sufficient energy to rupture the oxide film and depending on alloy, may be capable of removing metal. The fluid chemistry and alloy define corrosion characteristics of the oxide film; where localization of the cavitation produces a condition where the bubble collapse rate is greater than the ability to passivate, the normally passive alloy can experience accelerated loss. This is most likely to occur in pumps, valves (flow control), orifices, ejectors/eductors, and nozzles.

Cavitation is not expected in an offgas system.

15 Creep Analysis

Creep is defined as a time-dependent deformation at elevated temperature and constant stress; creep is a thermally activated process. The temperature at which creep begins depends on the alloy composition. Creep failures and stress rupture failures follow the same mechanism and are influenced by similar variables like temperature. Stress rupture is defined as bi-axial creep restricted to pipe like geometries. Creep is found in components subjected to heat for long periods and the creep rate generally increases as the temperature nears the melting point. The creep temperature is different for each alloy; the Nickel Development Institute has cataloged the creep properties of Type 304, Type 316, and Type 347 austenitic stainless steels (*High-Temperature Characteristics of Stainless Steels*). The material creep properties at 1000 °F indicate a difference of several hundred degrees over the maximum recuperative heat exchanger at 792 °F.

The maximum operating temperature for the recuperative heat exchanger is less than the creep temperature, creep will not occur.

16 Inadvertent Addition of Nitric Acid

Addition of nitric acid to the offgas is not a plausible scenario.

CORROSION EVALUATION

17 Conclusion and Justification

The conclusion of this evaluation is that LVP-HX-00001 can be fabricated from Type 347 stainless steel and that Type 347 stainless steel is capable of providing 40 years of service. Providing the reported dry-air conditions are maintained, Type 347 stainless steel is expected to be resistant to uniform and localized corrosion. The probable uniform corrosion is negligible; a minimum allowance of 0.010 inch for surfaces in contact with the offgas (except heat transfer surfaces) is recommended for conservatism. No corrosion allowance is recommended for the heat transfer surfaces. Conditions in the heat exchanger do not promote erosion so no erosion allowance is necessary.

18 Margin

Per 24590-WTP-SRD-ESH-01-001-02, Appendix H "When erosion and corrosion effects can be shown to be negligible or entirely absent, a design corrosion allowance need not be specified." In the reported dry-air conditions, there is no electrolyte. If there is no electrolyte, there can be no corrosion. The system is designed with a uniform corrosion allowance of 0.010 inch based on the range of inputs, system knowledge, and engineering judgment/experience. The service conditions used for materials selection have been described above and result in negligible uniform loss. The specified minimum corrosion allowance exceeds the minimum required corrosion allowance which provides margin. The uniform corrosion design margin for the operating conditions is sufficient to expect a 40 year operating life and is justified in the referenced calculation.

Localized erosion of this component is not expected. Prior to reaching the recuperative heat exchanger, the offgas passes through a high efficiency particulate filter (HEPA) and, therefore, should be free of particulates. The solids content and gas velocity are sufficiently low that localized erosion is not a concern. Since localized erosion effects are not present, additional localized corrosion protection is not required.

This component contains no fluids or electrolyte to promote localized corrosion. As shown in the PCDS summary table (page 8, below), the unit operates at high temperatures and low humidity (0.04% at the outlet) and is described in the PCDS. While not quantifiable, the largest contributor to the total localized corrosion design margin is the absence of sufficient moisture to form a corrosive electrolyte. During inactive periods of plant operations and prior to initial plant startup, layup and storage procedures will monitor and control condensation.

CORROSION EVALUATION

19 References

1. 24590-CD-POC-MBT0-00007-05-00004, *Manual - Operation, Maintenance and Installation Instructions For LAW Thermal Catalytic Oxidizer / Reducer (TCO) And Ammonia Dilution Skid.*
2. 24590-LAW-3YD-LOP-00001, *System Description For The Law Primary Offgas (LOP) And Secondary Offgas/Vessel Vent (LVP) Systems.*
3. 24590-LAW-M4C-LOP-00001, *LAW Melter Offgas System Design Basis Flowsheets with ECCN 24590-LAW-M4E-LOP-00009.*
4. 24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS.*
5. 24590-LAW-P1-P01T-00005, *LAW Vitrification Building General Arrangement Plan at El. 48 Feet - 0 Inches.*
6. 24590-WTP-GPG-M-047, *Preparation of Corrosion Evaluations.*
7. 24590-WTP-RPT-PR-04-0001-04, *WTP Process Corrosion Data-Volume 4.*
8. 24590-WTP-SRD-ESH-01-001-02, *Safety Requirements Document Volume II.*
9. ASM Metals Handbook, Volume 13, *Corrosion*, 1987, ASM International, Materials Park, OH.
10. Coburn SK. 1978. *Atmospheric Factors Affecting the Corrosion of Engineering Metals - STP 646.* ASTM International, West Conshohocken, PA.
11. Dean SW and Lee TS. 1986. *Degradation of Metals in the Atmosphere - STP 965.* ASTM International, West Conshohocken, PA.
12. Dean SW and Rhea EC. 1980. *Atmospheric Corrosion of Metals - STP 767.* ASTM International, West Conshohocken, PA.
13. NIDI. *High-Temperature Characteristics of Stainless Steels.* Publication No. 9004, Nickel Development Institute. Toronto, Ontario, Canada.
14. Schweitzer PA. 1989. *Corrosion and Corrosion Protection Handbook.* Marcel Dekker, Inc., New York, NY.

Additional Reading

- 24590-LAW-MKD-LVP-00012, *Mechanical Data Sheet for 24590-LAW-MX-LVP-SKID-00002 24590-LAW-MX-LVP-00003 - LAW Catalytic Oxidizer / Reducer.*

CORROSION EVALUATION

PROCESS CORROSION DATA SHEET (extract)

Component(s) (Name/ID #) Catalytic Oxidizer Heat Recovery Exchanger (LVP-HX-00001)

Facility LAW

In Black Cell? NO

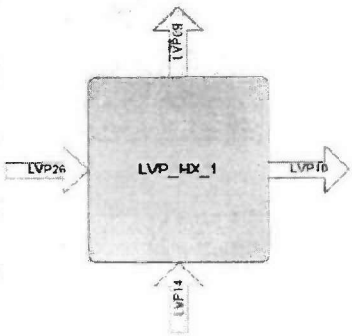
		Stream ID LVP14
Chemicals	Unit	**Gaseous**
CO2	ppmV	22330
HCl	ppmV	7
HF	ppmV	4
NH3	ppmV	237
NO	ppmV	35
NO2	ppmV	0
SO2	ppmV	7
SO3(s)	mg/m^3	2
RH	%	0.04
Suspended Solids	wt%	0
Temperature	°F	792

Figure C- 25 LVP-HX-00001 Gaseous PCDS

Vessel : LVP_HX_1

	Stream ID			
	LVP26	LVP14	LVP09	LVP10
Properties				
Suspended Solids [wt %]	0	0	0	0
Total Salts [wt %]	0.00	0.00	0.00	0.00
Sodium Molarity [M]	n/a	n/a	n/a	n/a
Relative Humidity [%]	13.02	0.04	1.25	0.06
pH	n/a	n/a	n/a	n/a
Anti-Foam Agent [ppm]	0	0	0	0
TOC [lb/h]	2.70E-03	1.35E-04	1.35E-04	2.70E-03
Pressure [bar]	0.92	0.90	0.90	0.92
Temperature [C]	87.22	422.22	211.11	360.00
Temperature [F]	189.00	792.00	412.00	680.00
Water Flow Rate [kg/hr]	303.79	319.15	319.15	303.79
Total Aqueous Flow Rate [kg/hr]	303.79	319.15	319.15	303.79
Total Flow Rate [kg/hr]	5.19E+03	6.20E+03	6.20E+03	5.19E+03
UserNote	VIT VAPOR Activated Carbon Adsorber Discharge	VIT VAPOR Primary NOx SCR Discharge	VIT VAPOR Caustic Scrubber Inlet	VIT VAPOR Energy Recovery Heat Exchanger Cold Offgas Discharge
GASEOUS [ppmV or mg/m3]				
Ar	8266	8401	8401	8266
CH3I	0	0	0	0
Cl2	0	0	0	0
CO	431	18	18	431
CO2	26053	22330	22338	26053
F2	0	0	0	0
H2	0	0	0	0
HCl	9	7	7	9
HCN	0	0	0	0
HF	5	4	4	5
I2	0	0	0	0
N2	699668	711673	711673	699668
NaCl(s)	0	0	0	0
NaCN(s)	0	0	0	0
NaF(s)	0	0	0	0
NaI(s)	0	0	0	0
NH3	22	237	1925	22
NO	2111	35	1714	2111
NO2	10	0	8	10
O2	188778	190901	191317	188778
P2O5(s)	0	0	0	0
PO2	0	0	0	0
SO2	10	7	7	10
SO3(s)	0	2	2	0

Note: Concentrations for constituents representing particulates (as denoted by suffix "(s)" in their name) are reported in units of mg/m3; all others are reported in units of ppmV



GENERAL NOTE FOR USE OF PCDS:

- *The information provided by the PCDS report is intended solely for use in support of the vessel material selection process and Corrosion Evaluations. The inputs, assumptions, and computational/engineering models used in generating the results presented herein are specific to this effort. Use of the information presented herein for any other purpose will require separate consideration and analysis to support justification of its use for the desired, alternative purpose.*
- *The process descriptions in this report cover routine process operations and non-routine (infrequent) process operations, when such exist, that could impact corrosion or erosion of process equipment.*
- *The process descriptions provided in this report are for general information and reflective of the corrosion engineer's analysis for transparency, the information is current only at the time this document is issued. These process descriptions should not be referenced for design.*

6.6.1 Description of Vessel/Equipment

The LAW Secondary Offgas/Vessel Vent Process (LVP) System is designed to treat the offgas from the LAW Primary Offgas Process (LOP) System and the LAW Facility vessel vents. The purpose of the LVP System is to remove almost all remaining particulates, miscellaneous acid gases, nitrogen oxides, VOCs, and mercury from the LAW Facility offgas that have not been removed by the LOP system.

Figure 10 is a sketch of the input and output arrangement of streams for all equipment within the LVP System. Streams that are not primary routes (infrequent transfers) are represented with dashed lines.

Figure 10a LVP System Sketch

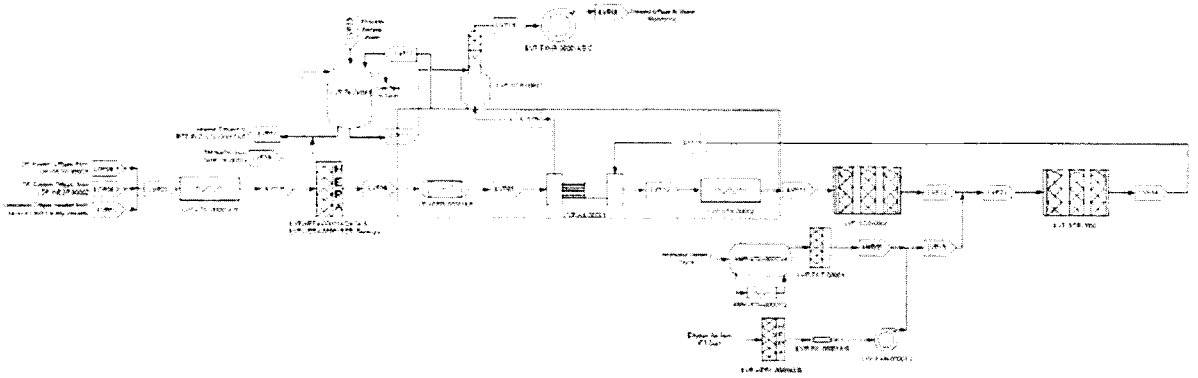
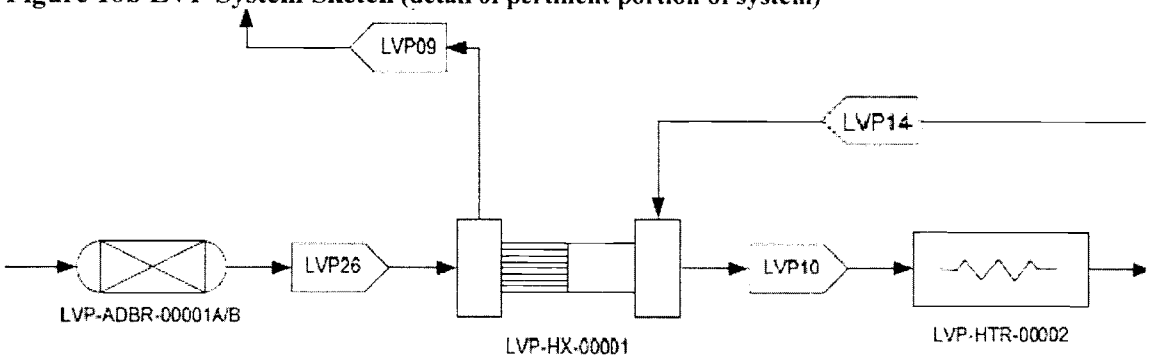


Figure 10b LVP System Sketch (detail of pertinent portion of system)



6.6.2 System Functions

The process functions of this system are as follows:

- Receive LAW Offgas from LOP System and LAW Facility Vessel Ventilation Streams
- Receive Reagents Streams Such as Ammonia or Dilution Air to Ensure Offgas Component Destruction
- Treat Offgas to Ensure Requirements are Met Before Emitting to Atmosphere
- Transfer Offgas to Stack
- Transfer Liquid Effluents to RLD-VSL-00017A/B

These vessels perform additional system functions beyond the process functions, but these are outside the scope of this document. The non-process functions are not discussed any further in this document. However, they are listed below for completeness:

- Confine Hazardous Materials
- Flush System Components
- Report System Data

6.6.3 Description of Process Functions

All process streams have been taken from Process Flow Diagrams 24590-LAW-M5-V17T-00010 and 24590-LAW-M5-V17T-00011 and associated drawing change notices (DCNs) 24590-LAW-M5N-V17T-00012/15/17/29 and 24590-LAW-M5N-V17T-00012/19/23/29, respectively. The P&IDs have also been looked at to obtain the most accurate flow diagram. These are as follows: 24590-LAW-M6-LVP-00001001 / 1002 / 1003 / 1004 / 1005 / 1006 / 2001 / 2002 / 2003 / 2004 / 2005 / 2006 / 3001 / 4001 / 4002 / 4003 / 5001 / 5002 and 24590-BOF-M6-AMR-00002001 / 2002 / 3001 / 3002 / 5001. See Section 7.1.3 for corresponding references in this section. A description of the process function of each piece of equipment is listed as follows:

Equipment	Process Function
LVP-HX-00001	The heat recovery exchanger raises the offgas temperature from LVP-ADBR-00001A/B, using the hot offgas from the catalyst beds (LVP-SCR-00001).

6.6.3.1 Receipt Streams

The LVP system primarily receives LAW offgas from the LOP system and LAW Facility vessel ventilation streams. Other LVP system equipment receives various streams to help process the offgas. The receipt streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-HX-00001

- LVP26 - Offgas from LVP-ADBR-00001A/B
- LVP14 - Offgas from LVP-SCR-00001

6.6.3.1.4 LVP26 - Offgas from LVP-ADBR-00001A/B

Stream LVP26 is the offgas from the adsorbers that enters the heat exchanger.

Molarity
N/A

Temperature
The temperature of stream LVP26 will normally be 169°F (24590-LAW-M4C-LOP-00001, pg. 37, Cell Q33, Ref. 7.1.4(12)). The maximum temperature is 189°F (24590-LAW-M4C-LOP-00001, pg. 41, Cell Q33, Ref. 7.1.4(12)).

Solids Concentration
The solids concentration for stream LVP26 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP26 will normally be 4.47E-2 lb/ft^3 to 4.02E-2 lb/ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI33; pg. 41, Cell AI33, Ref. 7.1.4(12)).

Liquid pH
N/A

6.6.3.1.5 LVP14 - Offgas from LVP-SCR-00001

Stream LVP14 is the offgas from the catalytic reducer that enters the heat exchanger.

Molarity
N/A

Temperature
The temperature of stream LVP14 will normally be 724°F (24590-LAW-M4E-LOP-00009, pg. 11, Cell Q44, Ref. 7.1.4(13)). The maximum temperature is 792°F (24590-LAW-M4E-LOP-00009, pg. 15, Cell Q44, Ref. 7.1.4(13)).

Solids Concentration
The solids concentration for stream LVP14 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP14 will normally be 2.27E-2 lb/ft^3 to 1.95E-2 lb/ft^3 (24590-LAW-M4E-LOP-00009, pg. 11, Cell AI44; pg. 15, Cell AI44, Ref. 7.1.4(13)).

Liquid pH
N/A

6.6.3.1.6 LVP10 - Offgas from LVP-HX-00001

Stream LVP10 is the offgas from the heat exchanger that enters the electric heater.

Molarity
N/A

Temperature
The temperature of stream LVP10 will normally be 624°F (24590-LAW-M4E-LOP-00009, pg. 11, Cell Q36, Ref. 7.1.4(13)). The maximum temperature is 680°F (24590-LAW-M4E-LOP-00009, pg. 15, Cell Q36, Ref. 7.1.4(13)).

Solids Concentration
The solids concentration for stream LVP10 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP10 will normally be 2.56E-2 lb/ft^3 to 2.25E-2 lb/ft^3 (24590-LAW-M4E-LOP-00009, pg. 11, Cell AI36; pg. 15, Cell AI36, Ref. 7.1.4(13)).

Liquid pH
N/A

6.6.3.1.13 LVP09 - Offgas from LVP-SCR-00001 via LVP-HX-00001 to LVP-SCB-00001

This stream is the offgas from the selective catalytic reducer via the heat exchanger to the scrubber.

Molarity
N.A

Temperature
The temperature will normally be 370°F (24590-LAW-M4E-LOP-00009, pg. 11, Cell Q45, Ref. 7.1.4(13)). The maximum temperature is 412°F (24590-LAW-M4E-LOP-00009, pg. 15, Cell Q45, Ref 7.1.4(13)).

Solids Concentration
The solids concentration will normally be near zero or trace solids.

Vapor Density
The vapor density will normally be 3.27E-2 lb ft^3 to 2.84E-2 lb ft^3 (24590-LAW-M4E-LOP-00009, pg. 11, Cell AI44; pg. 15, Cell AI44, Ref. 7.1.4(13)).

Liquid pH
N.A

6.6.3.2 Outlet Streams

The outlet streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-HX-00001

- LVP10 - Offgas from LVP-HX-00001
- LVP09 - Offgas from LVP-SCR-00001

6.6.4 Process Modes

6.6.4.1 Normal Operations

Based on the assessment of streams frequently transferred in and out of the LVP System equipment, the following normal processing modes are considered:

LVP-HX-00001

- LVP26 - Offgas from LVP-ADBR-00001A/B
- LVP14 - Offgas from LVP-SCR-00001
- LVP10 - Offgas from LVP-HX-00001
- LVP09 - Offgas from LVP-SCR-00001

6.6.4.2 Infrequent Operations

None identified.

6.6.5 Summary of Processing Conditions for LVP System

6.6.5.1 Normal Operations

The following table summarizes the normal processing modes for LVP System equipment.

Stream Number	Weight % UDS		Na Molarity		Temperature (°F)	
	normal	upper	normal	upper	normal	upper
LVP-HX-00001						
LVP26 (in) - cold side	0	trace	n/a	n/a	169	189
LVP14 (in) - hot side	0	trace	n/a	n/a	724	792
LVP10 (out) - cold side	0	trace	n/a	n/a	624	680
LVP09 (out) - hot side	0	trace	n/a	n/a	370	412

6.6.5.2 Infrequent Operations

None identified.

6.4.1.3 Catalytic Oxidizer/Reducer (LVP-SKID-00001 and LVP-SKID-00002)

The offgas has potentially high levels of NO_x because the melter decomposes the parent nitrate/nitrite compounds. Some of the resultant NO_x is decomposed to nitrogen and water in the melter, and some is removed by scrubbing in the SBS. VOCs are also present in the offgas stream. Both the VOCs and the remaining NO_x require removal.

The offgas is passed through a catalytic oxidizer/reducer skid (LVP-SKID-00002) housing a heat recovery exchanger (LVP-HX-00001), an electric heater (LVP-HTR-00002), VOC catalyst (LVP-SCO-00001), and SCR catalyst (LVP-SCR-00001). The skid is located in room L-0304F at the 48-foot elevation and approximate dimensions for the skid are 36 ft long by 11 ft high by 8 ft wide. The heat recovery exchanger first raises the offgas temperature using the hot offgas from the catalyst beds. This heat exchanger is designed to be of a plate and frame design to eliminate the problems associated with tube to plate joints. The hot side of the heat exchanger cools the offgas prior to discharge from the skid. [4.3.3.17]

R11727037

CORROSION EVALUATION

LVP-HTR-00002
Catalytic Oxidizer Electric Heater

Contents of this document are Dangerous Waste Permit affecting

Results

Materials Considered:

Material (UNS No.)	Acceptable Material
Type 304L (S30403)	
Type 316L (S31603)	
Type 347 (S34700)	X (exc. heating elements)
Incoloy® 800/825 (N08800/N08825)	X (heating elements)

Recommended Material Types:

Materials in contact with the offgas are: Type 347 (S34700)
Incoloy® 800/825 (N08800/N08825)

Heating elements will be Incoloy® 800/825 (N08800/N08825)

Minimum Corrosion Allowance: 0.010 inch (surfaces in contact with offgas)
No corrosion allowance required for heating elements.

Inputs and References

- Operating Temperature, inlet (°F): (nom/max): 624/680 (24590-LAW-M4E-LOP-00009)
- Operating Temperature, outlet (°F): (nom/max): 750/750 (24590-LAW-M4E-LOP-00009)
- Corrosion allowance (in contact with offgas, excluding heat transfer surfaces): 0.010 inch (24590-WTP-SRD-ESH-01-001-02)
- Corrosion allowance (heat transfer surfaces): 0.00 inch (24590-WTP-GPG-M-047)
- Location: room L-0304F; out cell (24590-LAW-P1-P01T-00005)
- Operating conditions are as stated in the applicable section of *WTP Process Corrosion Data - Volume 4* (24590-WTP-RPT-PR-04-0001-04)

Assumptions and Justification (refer to Section 19 – References)

- Operating conditions presented on the Process Corrosion Datasheet (PCDS) are conservative with respect to corrosion.[7]

Operating Restrictions

- Develop a procedure for decontamination.
- Develop procedure to control lay-up and storage (mitigation of condensation in accordance with *Manual - Operation, Maintenance And Installation Instructions For LAW Thermal Catalytic Oxidizer / Reducer (TCO) And Ammonia Dilution Skid*,24590-CD-POC-MBT0-00007-05-00004); including both before plant is operational and during inactive periods during plant operation.
- Procedures are to be reviewed and accepted by MET prior to use.

Concurrence _____
Operations

REV	DATE	REASON FOR REVISION	ORIGINATE	CHECK	REVIEW	APPROVE
3	06/25/15	To expand material selection information and references to address ORP and Ecology comments.	DLAdler	TErwin	RBDavis	JLeam
2	12/16/14	Complete re-write; no rev bars shown New format Revised design temperature Revise Ops restrictions Incorporate revised PCDS Update references	DLAdler	JRDivine	RBDavis	TErwin
1	7/18/12	Incorporate revised PCDS Update design pressure AEA Notice	DLAdler	RBDavis	NA	DJWilsey
0	3/13/08	Initial Issue	DLAdler	JRDivine	RBDavis	SWVail

CORROSION EVALUATION

Please note that source, special nuclear and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the U.S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

This bound document contains a total of 13 sheets.

CORROSION EVALUATION

Corrosion/Erosion Detailed Discussion

The electric heater is used to supplement the heat recovery exchanger (LVP-HX-00001) primarily during startup and when operating with low NOx concentrations. Once the system is up to temperature, demand on the electric heater will be minimal

1 General/Uniform Corrosion Analysis

a Background

General corrosion or uniform corrosion is corrosion that is distributed more-or-less uniformly over the surface of a material without appreciable localization. This leads to relatively uniform thinning on sheet and plate materials and general thinning on one side or the other (or both) for pipe and tubing. It is recognized by a roughening of the surface and usually by the presence of corrosion products. The mechanism of the attack typically is an electrochemical process that takes place at the surface of the material. Differences in composition or orientation between small areas on the metal surface create micro-anodes and cathodes that facilitate the corrosion process.

b Component-Specific Discussion

Offgas corrosion, like atmospheric corrosion, depends on the development of corrosion cells or electrochemical cells consisting of the base metal, corrosion products, deposition products, anode, cathode, electrolyte, and current path. Stainless steels also have the added influence of the protective passive film. Because the corrosion process is electrochemical, an electrolyte must be present on the surface for corrosion to occur. In the absence of moisture, corrosion will not take place. As an example, where temperatures are less than freezing, corrosion is minor because the ice is not a good conductor; or when the relative humidity is low, the water condensation is negligible and corrosion is negligible. Offgas corrosion is also influenced by the deposition of particulates, dust, and thin monolayers of gas constituents. The physically adsorbed molecules on the surface (HCl, HNO_3, and H_2SO_4) will form an acid droplet from the deliquescence of water molecules. Moisture is needed to activate the corrosion process, typically a relative humidity of 60% to 80% is necessary to support corrosion; below this range corrosion does not occur. The relative humidity range for corrosion is discussed in Coburn (1978), Dean and Lee (1986), Dean and Rhea (1980), Schweitzer (1988), and in the *ASM Metals Handbook, Volume 13*. Normal operating conditions for the components of the thermal catalytic oxidizer (TCO) skid are dry, and relatively humidity is very low (0.04% relative humidity, as shown in the PCDS). The anticipated dry-air conditions are not conducive to general corrosion and none is expected. Further, operating restrictions are in place to ensure that dry-air conditions are maintained.

The stabilized austenitic Type 347 stainless steel is suitable for the offgas conditions. The selection of Type 347 austenitic stainless steel is an enhancement over that of a Type 300 stainless steel. The corrosion rates are a product of the alloy chemistry, and the only difference between Type 347 and Type 304L is the increase in carbon content that improves the high temperature properties. The carbon increase is offset with niobium and tantalum alloyed to decrease the tendency for carbide precipitation during fabrication and welding. Type 347 alloy has improved oxidation resistance and high temperature properties and is a good choice for the TCO components. Type 347 was selected for the following reasons: improved thermal properties, readily available in most product forms, standard stainless steel fabrication practice (tools and processes), and lower cost per pound than the higher nickel or duplex alloys (*High-Temperature Characteristics of Stainless Steels*, NIDI Publication No. 9004).

INCOLOY® alloy 800 is a nickel-iron-chromium alloy with tensile strength between 75 and 100 ksi and good toughness, with elongation between 60 and 30%. The alloy exhibits resistance to oxidation, carburization, and elevated temperature corrosion. The alloy has a carbon content of 0.1% for improved high temperature strength, copper is added to improve the passive/oxide protective film from spalling, titanium is used to stabilize carbide formation, and aluminum is added to control the grain size to optimize stress-rupture properties. The electric heater is operated at elevated temperatures, and both creep and oxidation are considered as part of this corrosion evaluation. The recommended alloy for the elevated temperature sections is Type 347 austenitic stainless steel or Incoloy® alloys. Also, the higher carbon content and added niobium to prevent sensitization improve the oxidation resistance (*High-Temperature Characteristics of Stainless Steels*, NIDI No. 9004, Nickel Development Institute).

At the stated operating temperature, the use of Type 347stainless steel is suitable and is recommended. Incoloy® 800 is recommended for the heating elements.

The skid base frame is not considered as a material in contact with the offgas. If structural materials are not welded to the pressure boundary of the heater, they are outside the scope of this corrosion evaluation

2 Pitting Corrosion Analysis

Pitting is localized corrosion of a metal surface that is confined to a point or small area and that takes the form of cavities. Pitting corrosion will only be a concern if sufficient moisture is present. The heater normally operates at temperatures above the dew point of the dry offgas, and therefore sufficient moisture is not present to act as an electrolyte for corrosion processes to proceed. It is assumed that there will be no condensation in the unit.

Justification for this position is that corrosion will not proceed without an electrolyte present.

3 Crevice Corrosion Analysis

Crevice corrosion is a form of localized corrosion of a metal or alloy surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity of the metal or alloy to the surface of another material or an adjacent surface of the same metal or alloy. Crevice corrosion is similar to pitting in mechanism. Crevice corrosion will only be a concern if sufficient moisture is present. The offgas humidity is controlled so that there will be no condensation.

CORROSION EVALUATION

Justification for this position begins with the understanding that this is an air handling unit operating at elevated temperatures, above the dew point. Corrosion will not take place or initiate when no electrolyte is present.

4 Stress Corrosion Cracking Analysis

Stress corrosion cracking (SCC) is the cracking of a material produced by the combined action of corrosion and sustained tensile stress (residual or applied). In addition, sensitization of the grain boundaries is prevented with the materials recommended. Either an "L" grade, low carbon, stainless steel or a niobium-stabilized stainless steel is specified to negate sensitization from becoming a corrosion issue. It is assumed that there will be no condensation in the unit; therefore, the heater will not undergo stress corrosion cracking because insufficient moisture will be present.

This position is justified because of the temperature of the gas during operation will be greater than the dew point. Corrosion will not take place or initiate when no electrolyte is present.

5 End Grain Corrosion Analysis

End grain corrosion typically is not a major concern, it propagates along the rolling direction of the plate, not necessarily through the cross sectional thickness. In addition, end grain corrosion is exclusive to metallic product forms with exposed end grains from shearing or mechanical cutting. The electric heater design does not expose the pressure boundary cut ends to offgas. Also, end grain corrosion will not take place in the component because of the absence of sufficient moisture.

End grain corrosion is not expected to occur in the heater because the temperature of the gas will be greater than the dew point of the gas therefore corrosion will not occur in the absence of an electrolyte.

6 Weld Corrosion Analysis

The welds used in the fabrication will follow the WTP specifications and standards for quality workmanship. The materials selected for this fabrication are compatible with the weld filler metals and ASME/AWS practice. Using the welding practices specified for the project there should not be gross micro-segregation, precipitation of secondary phases, formation of unmixed zones, or volatilization of the alloying elements that could lead to localized corrosion of the weld.

This position is justified because the operating temperature and dry air conditions will not corrode because of the lack of the electrolyte for corrosion.

7 Microbiologically Influenced Corrosion Analysis

Microbiologically Influenced Corrosion (MIC) refers to corrosion affected by the presence or activity, or both, of microorganisms.

Typically, with the exception of cooling water systems and stagnant water, MIC is not observed in operating systems. The electric heater will operate at elevated temperatures and the offgas is dry. In this system, the stated operating conditions are not suitable for microbial growth.

8 Fatigue/Corrosion Fatigue Analysis

Corrosion-fatigue is the result of the combined action of cyclic stresses and a corrosive environment. The fatigue process is thought to cause rupture of the protective passive film, upon which stainless steel can actively corrode in the localized area of the film rupture. The corrosive environment may also act to reduce the stress necessary for film rupture. The result is that a metal exposed to a corrosive environment and cyclic mechanical load may initiate cracking at conditions at stress levels less than the endurance limit for the material.

The electric heater is not cyclically operated; offgas flow is constant, steady and dry. Thermal cycles and therefore thermal stress is low and associated with the start-up and shut down of the offgas system. Corrosion fatigue will not be observed in the recuperative electric heater (24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS.*).

The conclusion that corrosion fatigue will not be a problem is based on the low mechanical and thermal cycling, as well as the lack of an electrolyte for corrosion.

9 Vapor Phase Corrosion Analysis

Vapor phase corrosion considers the gas and vapor constituents that form acidic condensate and the alloy corrosion resistance. The aggressive constituents are HCl, HF, and HNO_3; however, these are present in low concentrations in the gas and are of less concern because of the dry and heated conditions. The upstream equipment removes acid gas-forming constituents; therefore, vapor phase corrosion is negligible. The formation of acidic condensate requires moisture condensing on the surface and mixing with the adsorbed surface constituents to produce an aggressive environment. Condensation on the surface is not likely during normal operation.

Vapor phase corrosion will not occur in the heater conditions because the operation conditions for this component preclude sufficient moisture and concentrations of acid gas forming components.

CORROSION EVALUATION

10 Erosion Analysis

Erosion is the progressive loss of material from a surface resulting from mechanical interaction between a particle and that surface. Solid particle erosion can occur in air, steam, and water fluid systems. The WTP waste is a slurry consisting of water, waste oxide particles, and / or precipitated salts. When the fluid propels the solid particles at a sufficient velocity and the particle mass is sufficient, the surface can be damaged by the combined effect of millions of individual erosion "scars". Prior to reaching the recuperative electric heater, the offgas passes through a high efficiency particulate filter (HEPA) and therefore should be free of particulates.

The solids content and gas velocity are sufficiently low that erosion is not a concern.

11 Galling of Moving Surfaces Analysis

Galling is a form of wear caused by a combination of friction and adhesion between moving surfaces. Under high compressive forces and movement, the friction temperatures cold-weld the two surfaces together at the surface asperities. As the adhesively bonded surface moves some of the bonded material breaks away. Microscopic examination of the galled surface shows some material stuck or even friction welded to the adjacent surface, while the softer of the two surfaces appears gouged with balled-up or torn lumps of material stuck to its surface.

Galling is most commonly found in metal surfaces that are in sliding contact with each other. It is especially common where there is inadequate lubrication between the surfaces. Softer metals will generally be more prone to galling; austenitic stainless steel is relatively soft and ductile and is known to gall easily. Martensitic stainless steel or precipitation hardened stainless steel or nitrogen strengthened austenitic stainless steels have higher surface hardness and therefore are resistant to galling.

The electric heater does not have any moving surfaces.

12 Fretting/Wear Analysis

Fretting corrosion refers to corrosion damage caused by a slight oscillatory slip between two surfaces. Similar to galling but a much smaller movement, the corrosion products and metal debris break off and act as an abrasive between the surfaces, classic 3-body wear problem. This damage is induced under load and repeated relative surface motion, as induced for example by vibration. Pits or grooves and oxide debris characterize this damage, typically found in machinery, bolted assemblies and ball or roller bearings. Contact surfaces exposed to vibration during transportation are exposed to the risk of fretting corrosion.

The electric heater does not have moving parts and design precludes the use of tube support plates that would normally become a fretting corrosion problem in tube-and-shell heat exchangers. Fretting corrosion is not expected in this component.

13 Galvanic Corrosion Analysis

Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially to another when both metals are in electrical contact, in the presence of an electrolyte. Dissimilar metals and alloys have different electrode potentials, and when two are in contact in an electrolyte, one metal acts as anode and the other as cathode. The electropotential difference between the dissimilar metals is the driving force for an accelerated attack. The potential difference for more than 200 mV is needed for sufficient driving force to make a difference. Galvanic compatibility is one of the attributes used to select the WTP alloys. Austenitic stainless steels in contact with other austenitic stainless steels do not have sufficient electropotential difference to significantly influence the metal loss.

The gas is dry and contains insufficient moisture to act as an electrolyte. Galvanic corrosion is not expected to be a corrosion issue under these conditions.

14 Cavitation Analysis

Cavitation corrosion is defined as another synergistic process, the combined influence of mechanical disruption of the metal surface and the corrosion of the active metal. Cavitation occurs when the local fluid pressure drops below the vapor pressure of the fluid resulting in a liquid vapor interface or bubbles to form. Their collapse on the metal surface has sufficient energy to rupture the oxide film and depending on alloy, may be capable of removing metal. The fluid chemistry and alloy define corrosion characteristics of the oxide film; where localization of the cavitation produces a condition where the bubble collapse rate is greater than the ability to passivate, the normally passive alloy can experience accelerated loss. This is most likely to occur in pumps, valves (flow control), orifices, ejectors/eductors, and nozzles.

Cavitation is not expected in an offgas system

15 Creep Analysis

Creep is defined as a time-dependent deformation at elevated temperature and constant stress, creep is a thermally activated process. The temperature at which creep begins depends on the alloy composition. Creep failures and stress rupture failures follow the same mechanism and influenced by similar variables like temperature. Stress rupture is defined as bi-axial creep restricted to pipe like geometries. Creep is found in components subjected to heat for long periods and the creep rate generally increases as the temperature nears the melting point. The creep temperature is different for each alloy, the Nickel Development Institute has cataloged the creep properties of Type 304, Type 316, and Type 347 austenitic stainless steels (*High-Temperature Characteristics of Stainless Steels*,

CORROSION EVALUATION

NIDI No. 9004, Nickel Development Institute). The material creep properties at 1000 °F indicate a difference of several hundred degrees over the maximum heater temperature of 750 °F.

The maximum operating temperature for the heater is less than the creep temperature; creep will not occur.

16 Inadvertent Addition of Nitric Acid

Addition of nitric acid to the offgas lines is not a plausible scenario.

17 Conclusion and Justification

The conclusion of this evaluation is that for other than the heating elements, LVP-HTR-00002 can be fabricated from Type 347 stainless steel and that Type 347 stainless steel is capable of providing 40 years of service. Incoloy® 800 is recommended for the heating elements. Providing the reported dry-air conditions are maintained, Type 347 stainless steel is expected to be resistant to uniform and localized corrosion. The probable uniform corrosion is negligible; a minimum allowance of 0.010 inch for surfaces in contact with the offgas (except heat transfer surfaces) is recommended for conservatism. No corrosion allowance is recommended for the heat transfer surfaces. Conditions in the heater do not promote erosion so no erosion allowance is necessary.

Incoloy® 800 with a 30-35% nickel content produces an alloy resistant to both chloride stress-corrosion cracking and to embrittlement from precipitation of sigma phase. Incoloy® 800 is primarily used in applications with temperatures up to 1500 °F. Incoloy® 800 (UNS N08800), which is often used for heat exchangers, heating-element sheathing, carburizing equipment, and nuclear steam-generator tubing, is recommended for the heating elements (*High-Temperature Characteristics of Stainless Steels*, NIDI No. 9004, Nickel Development Institute).

18 Margin

Per 24590-WTP-SRD-ESH-01-001-02, Appendix H "When erosion and corrosion effects can be shown to be negligible or entirely absent, a design corrosion allowance need not be specified." In the reported dry-air conditions, there is no electrolyte. If there is no electrolyte, there can be no corrosion. The system is designed with a uniform corrosion allowance of 0.010 inch based on the range of inputs, system knowledge, and engineering judgment/experience. The service conditions used for materials selection have been described above and result in negligible uniform loss. The specified minimum corrosion allowance exceeds the minimum required corrosion allowance which provides margin. The uniform corrosion design margin for the operating conditions is sufficient to expect a 40 year operating life and is justified in the referenced calculation.

Localized erosion of this component is not expected. Prior to reaching the heater, the offgas passes through a high efficiency particulate filter (HEPA) and, therefore, should be free of particulates. The solids content and gas velocity are sufficiently low that localized erosion is not a concern. Since localized erosion effects are not present, additional localized corrosion protection is not required.

This component contains no fluids or electrolyte to promote localized corrosion. As shown in the PCDS summary table (page 8, below), the unit operates at high temperatures and low humidity (0.04% at the outlet) and is described in the PCDS. While not quantifiable, the largest contributor to the total localized corrosion design margin is the absence of sufficient moisture to form a corrosive electrolyte. During inactive periods of plant operations and prior to initial plant startup, layup and storage procedures will monitor and control condensation.

CORROSION EVALUATION

19 References:

1. 24590-CD-POC-MBT0-00007-05-00004, *Manual - Operation, Maintenance and Installation Instructions for LAW Thermal Catalytic Oxidizer / Reducer (TCO) and Ammonia Dilution Skid.*
2. 24590-LAW-3YD-LOP-00001, *System Description for the LAW Primary Offgas (LOP) and Secondary Offgas/Vessel Vent (LVP) Systems.*
3. 24590-LAW-M4C-LOP-00001, *LAW Melter Offgas System Design Basis Flowsheets, with change notice 24590-LAW-M4E-LOP-00009*
4. 24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS.*
5. 24590-LAW-P1-P01T-00005, *LAW Vitrification Building General Arrangement Plan at El. 48 Feet - 0 Inches.*
6. 24590-WTP-GPG-M-047, *Preparation of Corrosion Evaluations.*
7. 24590-WTP-RPT-PR-04-0001-04, *WTP Process Corrosion Data-Volume 4.*
8. 24590-WTP-SRD-ESH-01-001-02, *Safety Requirements Document Volume II.*
9. ASM Metals Handbook, Volume 13, *Corrosion*. 1987. ASM International, Materials Park, OH.
10. Coburn SK. 1978. *Atmospheric Factors Affecting the Corrosion of Engineering Metals - STP 646*. ASTM International, West Conshohocken, PA
11. Dean SW and Lee TS. 1986. *Degradation of Metals in the Atmosphere - STP 965*. ASTM International, West Conshohocken, PA.
12. Dean SW and Rhea EC. 1980. *Atmospheric Corrosion of Metals - STP 767*. ASTM International, West Conshohocken, PA.
13. NIDI. *High-Temperature Characteristics of Stainless Steels*, Publication No. 9004, Nickel Development Institute. Toronto, Ontario, Canada.
14. Schweitzer PA. 1989. *Corrosion and Corrosion Protection Handbook*. Marcel Dekker, Inc., New York, NY.

Additional Reading

- 24590-LAW-MKD-LVP-00012, *Mechanical Data Sheet for 24590-LAW-MX-LVP-SKID-00002 24590-LAW-MX-LVP-00003 - LAW Catalytic Oxidizer / Reducer.*

CORROSION EVALUATION

Component(s) (Name/ID #) Catalytic Oxidizer Electric Heater (LVP-HTR-00002)

Facility LAW

In Black Cell? NO

		Stream ID LVP11
Chemicals	Unit	**GASEOUS**
CO2	ppmV	26,053
HCl	ppmV	9
HF	ppmV	5
NH3	ppmV	22
NO	ppmV	2111
NO2	ppmV	10
O2	ppmV	188,778
SO2	ppmV	10
RH	%	0.04
Suspended Solids	wt%	0
Temperature	°F	750

CORRESPONDENCE EVALUATION

Figure C- 28 LVP-HTR-00002 Gaseous PCDS

Vessel : LVP_HTR_2

	Stream ID	
	LVP10	LVP11
Properties		
Suspended Solids [wt %]	0	0
Total Salts [wt %]	0.00	0.01
Sodium Molarity [M]	n/a	n/a
Relative Humidity [%]	0.06	0.04
pH	n/a	n/a
Anti-Foam Agent [ppm]	0	0
TOC [kg/h]	2.70E-03	2.70E-03
Pressure [bar]	0.92	0.92
Temperature [C]	360.00	398.89
Temperature [F]	680.00	750.00
Water Flow Rate [kg/hr]	303.79	303.79
Total Aqueous Flow Rate [kg/hr]	303.79	303.79
Total Flow Rate [kg/hr]	5.19E+03	5.19E+03
UserNote	VIT VAPOR Energy Recovery Heat Exchanger Cold Offgas Discharge	VIT VAPOR Catalyst Heat Electric Heater Offgas Discharge
GASEOUS [ppmV or mg/m³]		
Ar	8266	8266
CH3I	0	0
Cl2	0	0
CO	431	431
CO2	26053	26053
F2	0	0
H2	0	0
HCl	9	9
HCN	0	0
HF	5	5
I2	0	0
N2	699668	699668
NaCl(s)	0	0
NaCN(s)	0	0
NaF(s)	0	0
NaI(s)	0	0
NH3	22	22
NO	2111	2111
NO2	10	10
O2	188778	188778
P2O5(s)	0	0
PO2	0	0
SO2	10	10
SO3(s)	0	0

Note: Concentrations for constituents representing particulates (as denoted by suffix "(s)" in their name) are reported in units of mg/m3; all others are reported in units of ppmV

GENERAL NOTE FOR USE OF PCDS:

- *The information provided by the PCDS report is intended solely for use in support of the vessel material selection process and Corrosion Evaluations. The inputs, assumptions, and computational/engineering models used in generating the results presented herein are specific to this effort. Use of the information presented herein for any other purpose will require separate consideration and analysis to support justification of its use for the desired, alternative purpose.*
- *The process descriptions in this report cover routine process operations and non-routine (infrequent) process operations, when such exist, that could impact corrosion or erosion of process equipment.*
- *The process descriptions provided in this report are for general information and reflective of the corrosion engineer's analysis for transparency, the information is current only at the time this document is issued. These process descriptions should not be referenced for design.*

6.6 LVP System

6.6.1 Description of Vessel/Equipment

The LAW Secondary Offgas/Vessel Vent Process (LVP) System is designed to treat the offgas from the LAW Primary Offgas Process (LOP) System and the LAW Facility vessel vents. The purpose of the LVP System is to remove almost all remaining particulates, miscellaneous acid gases, nitrogen oxides, VOCs, and mercury from the LAW Facility offgas that have not been removed by the LOP system.

Figure 10 is a sketch of the input and output arrangement of streams for all equipment within the LVP System. Streams that are not primary routes (infrequent transfers) are represented with dashed lines.

Figure 10a LVP System Sketch

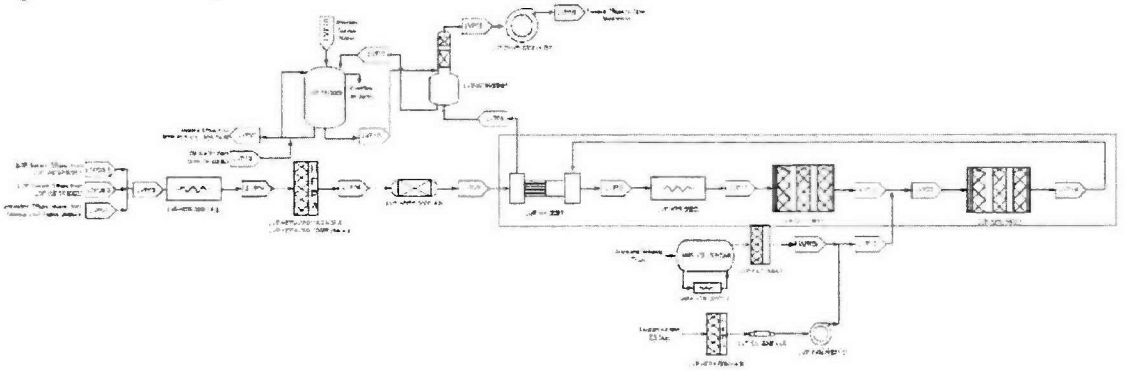
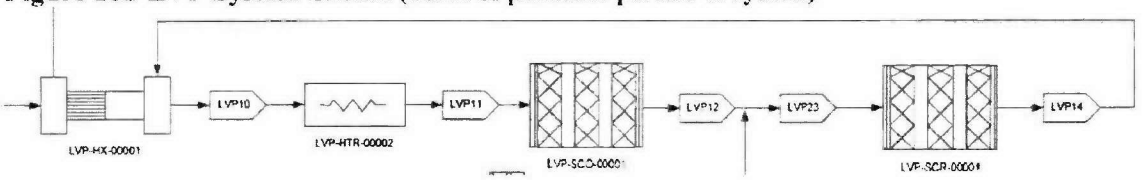


Figure 10b LVP System Sketch (detail of pertinent portion of system)



6.6.2 System Functions

The process functions of this system are as follows:

- Receive LAW Offgas from LOP System and LAW Facility Vessel Ventilation Streams
- Receive Reagents Streams Such as Ammonia or Dilution Air to Ensure Offgas Component Destruction
- Treat Offgas to Ensure Requirements are Met Before Emitting to Atmosphere
- Transfer Offgas to Stack
- Transfer Liquid Effluents to RLD-VSL-00017A/B

These vessels perform additional system functions beyond the process functions, but these are outside the scope of this document. The non-process functions are not discussed any further in this document. However, they are listed below for completeness:

- Confine Hazardous Materials
- Flush System Components
- Report System Data

6.6.3 Description of Process Functions

All process streams have been taken from Process Flow Diagrams 24590-LAW-M5-V17T-00010 and 24590-LAW-M5-V17T-00011 and associated drawing change notices (DCNs) 24590-LAW-M5N-V17T-00012/15/17/29 and 24590-LAW-M5N-V17T-00012/19/23/29, respectively. The P&IDs have also been looked at to obtain the most accurate flow diagram. These are as follows: 24590-LAW-M6-LVP-00001001, 1002, 1003, 1004, 1005, 1006, 2001, 2002, 2003, 2004, 2005, 2006, 3001, 4001, 4002, 4003, 5001, 5002 and 24590-BOF-M6-AMR-00002001, 2002, 3001, 3002, 5001. See Section 7.1.3 for corresponding references in this section. A description of the process function of each piece of equipment is listed as follows:

Equipment	Process Function
LVP-HTR-00002	The electric heater is used to supplement the heat recovery exchanger (LVP-HX-00001) primarily during startup and when operating with low NO_x concentrations. Once the system is up to temperature, demand on the electric heater will be minimal.

6.6.3.1 Receipt Streams

The LVP system primarily receives LAW offgas from the LOP system and LAW Facility vessel ventilation streams. Other LVP system equipment receives various streams to help process the offgas. The receipt streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-HTR-00002

- LVP10 - Offgas from LVP-HX-00001

6.6.3.1.6 LVP10 - Offgas from LVP-HX-00001

Stream LVP10 is the offgas from the heat exchanger that enters the electric heater.

Molarity
N/A

Temperature
The temperature of stream LVP10 will normally be 624°F (24590-LAW-M4E-LOP-00009, pg. 11, Cell Q36, Ref. 7.1.4(13)). The maximum temperature is 680°F (24590-LAW-M4E-LOP-00009, pg. 15, Cell Q36, Ref. 7.1.4(13)).

Solids Concentration
The solids concentration for stream LVP10 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP10 will normally be 2.56E-2 lb/ft^3 to 2.25E-2 lb/ft^3 (24590-LAW-M4E-LOP-00009, pg. 11, Cell AI36; pg. 15, Cell AI36, Ref. 7.1.4(13)).

Liquid pH
N/A

6.6.3.2 Outlet Streams

The outlet streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

6.6.3.1.7 LVP11 - Offgas from LVP-HTR-00002

Stream LVP11 is the offgas from the electric heater to the selective catalytic oxidizer.

Molarity
N/A

Temperature
The temperature of stream LVP11 will normally be 750°F (24590-LAW-M4C-LOP-00001, pg. 37, Cell Q37, Ref. 7.1.4(12)). The maximum temperature is 750°F (24590-LAW-M4C-LOP-00001, pg. 41, Cell Q37, Ref. 7.1.4(12)).

Solids Concentration
The solids concentration for stream LVP11 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP11 will normally be 2.29E-2 lb/ft^3 to 2.10E-2 lb/ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI37; pg. 41, Cell AI37, Ref. 7.1.4(12)).

Liquid pH
N/A

[Relevant section of the system process conditions table is shown]

6.6.5 Summary of Processing Conditions for LVP System

6.6.5.1 Normal Operations

The following table summarizes the normal processing modes for LVP System equipment.

Stream Number	Weight % UDS		Na Molarity		Temperature (°F)	
	normal	upper	normal	upper	normal	upper
LVP-HTR-00002						
LVP10 (in)	0	trace	n/a	n/a	624	680
LVP11 (out)	0	trace	n/a	n/a	750	750

CORRESPONDENCE EVALUATION

6.4.1.3 Catalytic Oxidizer/Reducer (LVP-SKID-00001 and LVP-SKID-00002)

The offgas has potentially high levels of NO_x because the melter decomposes the parent nitrate/nitrite compounds. Some of the resultant NO_x is decomposed to nitrogen and water in the melter, and some is removed by scrubbing in the SBS. VOCs are also present in the offgas stream. Both the VOCs and the remaining NO_x require removal.

The offgas is passed through a catalytic oxidizer/reducer skid (LVP-SKID-00002) housing a heat recovery exchanger (LVP-HX-00001), an electric heater (LVP-HTR-00002), VOC catalyst (LVP-SCO-00001), and SCR catalyst (LVP-SCR-00001). The skid is located in room L-0304F at the 48-foot elevation and approximate dimensions for the skid are 36 ft long by 11 ft high by 8 ft wide. The heat recovery exchanger first raises the offgas temperature using the hot offgas from the catalyst beds. This heat exchanger is designed to be of a plate and frame design to eliminate the problems associated with tube to plate joints. The hot side of the heat exchanger cools the offgas prior to discharge from the skid. [4.3.3.17]

The electric heater is used to supplement the heat recovery exchanger primarily during startup and when operating with low NO_x concentrations. Once the system is up to temperature, demand on the electric heater will be minimal.

R11727038

CORROSION EVALUATION

LVP-SCO-00001
Thermal Catalytic Oxidizer

Contents of this document are Dangerous Waste Permit affecting

Results

Materials Considered:

Material (UNS No.)	Acceptable Material
Type 304L (S30403)	
Type 316L (S31603)	
Type 347 (S34700)	X

Recommended Material Types:

Housings: Type 347 stainless steel

Minimum Corrosion Allowance: 0.010 inch

Inputs and References

- Operating temperature, inlet (°F): (nom/max): 750/750 (24590-LAW-M4E-LOP-00009)
- Operating temperature, outlet (°F): (nom/max): 758/765 (24590-LAW-M4E-LOP-00009)
- Corrosion allowance (in contact with offgas: 0.010 inch (24590-WTP-SRD-ESH-01-001-02)
- Location: out cell; Room L-0304F (24590-LAW-P1-P01T-00005)
- Operating conditions are as stated in the applicable section of *WTP Process Corrosion Data - Volume 4* (24590-WTP-RPT-PR-04-0001-04)

Assumptions and Supporting Justification (refer to Section 19—References)

- Operating conditions presented on the Process Corrosion Datasheet (PCDS) are conservative with respect to corrosion.[7]

Operating Restrictions

- Develop a procedure for decontamination.
- Develop procedure to control lay-up and storage (mitigation of condensation in accordance with *Manual - Operation, Maintenance And Installation Instructions For LAW Thermal Catalytic Oxidizer / Reducer (TCO) And Ammonia Dilution Skid*,24590-CD-POC-MBT0-00007-05-00004); including both before plant is operational and during inactive periods during plant operation.
- Procedures are to be reviewed and accepted by MET prior to use.

Concurrence _____
Operations

REV	DATE	REASON FOR REVISION	ORIGINATE	CHECK	REVIEW	APPROVE
4	06/25/15	To expand material selection information and references to address ORP and Ecology comments.	DLAdler	TErwin	RBDavis	JLeam
3	12/16/14	Complete re-write; no rev bars shown New format Incorporate updated PCDS Incorporate updated MDS Revise Ops Restrictions Update references	DLAdler	JRDivine	RBDavis	TErwin
2	7/18/12	Incorporate revised PCDS Update mat'l recommendation Update design temp/pressure AEA Notice Minor format and editorial changes	DLAdler	RBDavis	NA	DJWilsey
1	3/13/08	Update design pressure/temp Incorporate revised PCDS	DLAdler	JRDivine	RBDavis	SWVail
0	1/25/05	Initial Issue	DLAdler	HMKrafft	APR	SWVail

CORROSION EVALUATION

Please note that source, special nuclear and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the U.S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

This bound document contains a total of 14 sheets.

CORROSION EVALUATION

Corrosion/Erosion Detailed Discussion

The selective catalytic oxidizer is used to oxidize volatile organic carbons and carbon monoxide.

1 General/Uniform Corrosion Analysis

a Background

General corrosion or uniform corrosion is corrosion that is distributed more-or-less uniformly over the surface of a material without appreciable localization. This leads to relatively uniform thinning on sheet and plate materials and general thinning on one side or the other (or both) for pipe and tubing. It is recognized by a roughening of the surface and usually by the presence of corrosion products. The mechanism of the attack typically is an electrochemical process that takes place at the surface of the material. Differences in composition or orientation between small areas on the metal surface create micro-anodes and cathodes that facilitate the corrosion process.

b Component-Specific Discussion

Offgas corrosion, like atmospheric corrosion, depends on the development of corrosion cells or electrochemical cells consisting of the base metal, corrosion products, deposition products, anode, cathode, electrolyte, and current path. Stainless steels also have the added influence of the protective passive film. Because the corrosion process is electrochemical, an electrolyte must be present on the surface for corrosion to occur. In the absence of moisture, corrosion will not take place. As an example, where temperatures are less than freezing, corrosion is minor because the ice is not a good conductor; or when the relative humidity is low, the water condensation is negligible and corrosion is negligible. Offgas corrosion is also influenced by the deposition of particulates, dust, and thin monolayers of gas constituents. The physically adsorbed molecules on the surface (HCl, HNO_3, and H_2SO_4) will form an acid droplet from the deliquescence of water molecules. Moisture is needed to activate the corrosion process, typically a relative humidity of 60% to 80% is necessary to support corrosion; below this range corrosion does not occur. The relative humidity range for corrosion is discussed in Coburn (1978), Dean and Lee (1986), Dean and Rhea (1980), Schweitzer (1988), and in the *ASM Metals Handbook, Volume 13*. Normal operating conditions for the components of the thermal catalytic oxidizer (TCO) skid are dry, and relative humidity is very low (0.04% relative humidity as shown in the PCDS). The anticipated dry-air conditions are not conducive to general corrosion and none is expected. Further, operating restrictions are in place to ensure that dry-air conditions are maintained.

The stabilized austenitic Type 347 stainless steel is suitable for the offgas conditions. The selection of Type 347 austenitic stainless steel is an enhancement over that of a Type 300 stainless steel. The corrosion rates are a product of the alloy chemistry, and the only difference between Type 347 and Type 304L is the increase in carbon content that improves the high temperature properties. The carbon increase is offset with niobium and tantalum alloyed to decrease the tendency for carbide precipitation during fabrication and welding. Type 347 alloy has improved oxidation resistance and high temperature properties and is a good choice for the TCO components. Type 347 was selected for the following reasons: improved thermal properties, readily available in most product forms, standard stainless steel fabrication practice (tools and processes), and lower cost per pound than the higher nickel or duplex alloys (*High-Temperature Characteristics of Stainless Steels*, Publication No. 9004, Nickel Development Institute).

The thermal catalytic oxidizer is operated at elevated temperatures; oxidation is considered as part of this corrosion evaluation. The recommended alloy for the elevated temperature sections is Type 347 austenitic stainless steel. The higher carbon content and the addition of niobium to prevent sensitization act to improve the oxidation resistance.

The skid base frame is not considered as a material in contact with the offgas. If structural materials are not welded to the pressure boundary of the thermal catalytic oxidizer, they are outside the scope of this corrosion evaluation.

2 Pitting Corrosion Analysis

Pitting is localized corrosion of a metal surface that is confined to a point or small area and that takes the form of cavities. Pitting corrosion will only be a concern if sufficient moisture is present. The component normally operates at temperatures above the dew point of the dry offgas, and therefore sufficient moisture is not present to act as an electrolyte for corrosion processes to proceed. It is assumed that there will be no condensation in the unit.

Justification for this position is that corrosion will not proceed without an electrolyte present.

3 Crevice Corrosion Analysis

Crevice corrosion is a form of localized corrosion of a metal or alloy surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity of the metal or alloy to the surface of another material or an adjacent surface of the same metal or alloy. Crevice corrosion is similar to pitting in mechanism. Crevice corrosion will only be a concern if sufficient moisture is present. The offgas humidity is controlled so that there will be no condensation.

Justification for this position begins with the understanding that this is an air handling unit operating at elevated temperatures, above the dew point. Corrosion will not take place or initiate when no electrolyte is present.

CORROSION EVALUATION

4 Stress Corrosion Cracking Analysis

Stress corrosion cracking (SCC) is the cracking of a material produced by the combined action of corrosion and sustained tensile stress (residual or applied). In addition, sensitization of the grain boundaries is prevented with the materials recommended. Either an "L" grade, low carbon, stainless steel or a niobium-stabilized stainless steel is specified to negate sensitization from becoming a corrosion issue. It is assumed that there will be no condensation in the unit; therefore, the thermal catalytic oxidizer will not undergo stress corrosion cracking because insufficient moisture will be present.

This position is justified because of the temperature of the gas during operation will be greater than the dew point. Corrosion will not take place or initiate when no electrolyte is present.

5 End Grain Corrosion Analysis

End grain corrosion typically is not a major concern, it propagates along the rolling direction of the plate, not necessarily through the cross sectional thickness. In addition, end grain corrosion is exclusive to metallic product forms with exposed end grains from shearing or mechanical cutting. The thermal catalytic oxidizer design does not expose the pressure boundary cut ends to offgas. Also, end grain corrosion will not take place in the component because insufficient moisture is present.

End grain corrosion is not expected to occur because the temperature of the gas will be greater than the dew point of the gas therefore corrosion will not occur in the absence of an electrolyte.

6 Weld Corrosion Analysis

The welds used in the fabrication will follow the WTP specifications and standards for quality workmanship. The materials selected for this fabrication are compatible with the weld filler metals and ASME/AWS practice. Using the welding practices specified for the project there should not be gross micro-segregation, precipitation of secondary phases, formation of unmixed zones, or volatilization of the alloying elements that could lead to localized corrosion of the weld.

This position is justified because the operating temperature and dry air conditions will not corrode because of the lack of the electrolyte for corrosion.

7 Microbiologically Influenced Corrosion Analysis

Microbiologically influenced corrosion (MIC) refers to corrosion affected by the presence or activity, or both, of microorganisms. Typically, with the exception of cooling water systems and stagnant water, MIC is not observed in operating systems.

The thermal catalytic oxidizer will operate at elevated temperatures and the offgas is dry. In this system, the stated operating conditions are not suitable for microbial growth.

8 Fatigue/Corrosion Fatigue Analysis

Corrosion-fatigue is the result of the combined action of cyclic stresses and a corrosive environment. The fatigue process is thought to cause rupture of the protective passive film, upon which stainless steel can actively corrode in the localized area of the film rupture. The corrosive environment may also act to reduce the stress necessary for film rupture. The result is that a metal exposed to a corrosive environment and cyclic mechanical load may initiate cracking at conditions at stress levels less than the endurance limit for the material.

The thermal catalytic oxidizer is not cyclically operated; offgas flow is constant, steady and dry. Thermal cycles and therefore thermal stress is also low and associated with the start-up and shut down of the offgas system. Corrosion fatigue will not be observed in the thermal catalytic oxidizer (24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS.*).

The conclusion that corrosion fatigue will not be a problem is based on the low mechanical and thermal cycling, as well as the lack of an electrolyte for corrosion.

9 Vapor Phase Corrosion Analysis

Vapor phase corrosion considers the gas and vapor constituents that form acidic condensate and the alloy corrosion resistance. The aggressive constituents are HCl, HF, and HNO_3; however these are present in low concentrations in the gas. The formation of acidic condensate requires moisture condensing on the surface and mixing with the adsorbed surface constituents to produce an aggressive environment. Condensation on the surface is not likely during normal operation.

Vapor phase corrosion will not occur in the thermal catalytic oxidizer conditions because the operation conditions for this component preclude sufficient moisture and concentrations of acid gas forming components.

CORROSION EVALUATION

10 Erosion Analysis

Erosion is the progressive loss of material from a surface resulting from mechanical interaction between a particle and that surface. Solid particle erosion can occur in air, steam, and water fluid systems. The WTP waste is a slurry consisting of water, waste oxide particles, and / or precipitated salts. When the fluid propels the solid particles at a sufficient velocity and the particle mass is sufficient, the surface can be damaged by the combined effect of millions of individual erosion "scars". Prior to reaching the thermal catalytic oxidizer the offgas passes through a high efficiency particulate filter (HEPA) and therefore should be free of particulates.

The solids content and gas velocity are sufficiently low that erosion is not a concern.

11 Galling of Moving Surfaces Analysis

Galling is a form of wear caused by a combination of friction and adhesion between moving surfaces. Under high compressive forces and movement, the friction temperatures cold-weld the two surfaces together at the surface asperities. As the adhesively bonded surface moves some of the bonded material breaks away. Microscopic examination of the galled surface shows some material stuck or even friction welded to the adjacent surface, while the softer of the two surfaces appears gouged with balled-up or torn lumps of material stuck to its surface.

Galling is most commonly found in metal surfaces that are in sliding contact with each other. It is especially common where there is inadequate lubrication between the surfaces. Softer metals will generally be more prone to galling; austenitic stainless steel is relatively soft and ductile and is known to gall easily. Martensitic stainless steel or precipitation hardened stainless steel or nitrogen strengthened austenitic stainless steels have higher surface hardness and therefore are resistant to galling.

The thermal catalytic oxidizer does not have any moving surfaces.

12 Fretting/Wear Analysis

Fretting corrosion refers to corrosion damage caused by a slight oscillatory slip between two surfaces. Similar to galling but a much smaller movement, the corrosion products and metal debris break off and act as an abrasive between the surfaces, classic 3-body wear problem. This damage is induced under load and repeated relative surface motion, as induced for example by vibration. Pits or grooves and oxide debris characterize this damage, typically found in machinery, bolted assemblies and ball or roller bearings. Contact surfaces exposed to vibration during transportation are exposed to the risk of fretting corrosion.

The thermal catalytic oxidizer does not have moving parts and design precludes the use of tube support plates that would normally become a fretting corrosion problem in tube-and-shell heat exchangers. Fretting corrosion is not expected in this component.

13 Galvanic Corrosion Analysis

Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially to another when both metals are in electrical contact, in the presence of an electrolyte. Dissimilar metals and alloys have different electrode potentials, and when two are in contact in an electrolyte, one metal acts as anode and the other as cathode. The electropotential difference between the dissimilar metals is the driving force for an accelerated attack. The potential difference for more than 200 mV is needed for sufficient driving force to make a difference. Galvanic compatibility is one of the attributes used to select the WTP alloys. Austenitic stainless steels in contact with other austenitic stainless steels do not have sufficient electropotential difference to significantly influence the metal loss.

The thermal catalytic oxidizer materials are all Type 347 stainless steel. In addition, the gas is dry and contains insufficient moisture to act as an electrolyte. Galvanic corrosion is not expected to be a corrosion issue under these conditions.

14 Cavitation Analysis

Cavitation corrosion is defined as another synergistic process, the combined influence of mechanical disruption of the metal surface and the corrosion of the active metal. Cavitation occurs when the local fluid pressure drops below the vapor pressure of the fluid resulting in a liquid vapor interface or bubbles to form. Their collapse on the metal surface has sufficient energy to rupture the oxide film and depending on alloy, may be capable of removing metal. The fluid chemistry and alloy define corrosion characteristics of the oxide film; where localization of the cavitation produces a condition where the bubble collapse rate is greater than the ability to passivate, the normally passive alloy can experience accelerated loss. This is most likely to occur in pumps, valves (flow control), orifices, ejectors/eductors, and nozzles.

Cavitation is not expected in an offgas system

15 Creep Analysis

Creep is defined as a time-dependent deformation at elevated temperature and constant stress. creep is a thermally activated process. The temperature at which creep begins depends on the alloy composition. Creep failures and stress rupture failures follow the same mechanism and influenced by similar variables like temperature. Stress rupture is defined as bi-axial creep restricted to pipe like geometries. Creep is found in components subjected to heat for long periods and the creep rate generally increases as the temperature nears the melting point. The creep temperature is different for each alloy, the Nickel Development Institute has cataloged the creep properties of Type 304, Type 316, and Type 347 austenitic stainless steels (*High-Temperature Characteristics of Stainless Steels*.

CORROSION EVALUATION

NIDI No. 9004, Nickel Development Institute). The material creep properties at 1000 °F indicate a difference of several hundred degrees over the maximum thermal catalytic oxidizer temperature of 765 °F.

The maximum operating temperature for the thermal catalytic oxidizer is less than the creep temperature, creep will not occur.

16 Inadvertent Nitric Acid Addition

Addition of nitric acid to the offgas lines is not a plausible scenario.

17 Conclusion and Justification

The conclusion of this evaluation is that LVP-SCO-00001 can be fabricated from Type 347 stainless steel and that Type 347 stainless steel is capable of providing 40 years of service. Providing the reported dry-air conditions are maintained, Type 347 stainless steel is expected to be resistant to uniform and localized corrosion. The probable uniform corrosion is negligible; a minimum allowance of 0.010 inch for surfaces in contact with the offgas is recommended for conservatism. No corrosion allowance is recommended for the heat transfer surfaces. Conditions in the thermal catalytic oxidizer do not promote erosion so no erosion allowance is necessary.

18 Margin

Per 24590-WTP-SRD-ESH-01-001-02, Appendix H "When erosion and corrosion effects can be shown to be negligible or entirely absent, a design corrosion allowance need not be specified." In the reported dry-air conditions, there is no electrolyte. If there is no electrolyte, there can be no corrosion. The system is designed with a uniform corrosion allowance of 0.010 inch based on the range of inputs, system knowledge, and engineering judgment/experience. The service conditions used for materials selection have been described above and result in negligible uniform loss. The specified minimum corrosion allowance exceeds the minimum required corrosion allowance which provides margin. The uniform corrosion design margin for the operating conditions is sufficient to expect a 40 year operating life and is justified in the referenced calculation.

Localized erosion of this component is not expected. Prior to reaching the thermal catalytic oxidizer, the offgas passes through a high efficiency particulate filter (HEPA) and, therefore, should be free of particulates. The solids content and gas velocity are sufficiently low that localized erosion is not a concern. Since localized erosion effects are not present, additional localized corrosion protection is not required.

This component contains no fluids or electrolyte to promote localized corrosion. As shown in the PCDS summary table (page 8, below), the unit operates at high temperatures and low humidity (0.04% at the outlet) and is described in the PCDS. While not quantifiable, the largest contributor to the total localized corrosion design margin is the absence of sufficient moisture to form a corrosive electrolyte. During inactive periods of plant operations and prior to initial plant startup, layup and storage procedures will monitor and control condensation.

CORROSION EVALUATION

19 References:

1. 24590-CD-POC-MBT0-00007-05-00004, *Manual - Operation, Maintenance and Installation Instructions for LAW Thermal Catalytic Oxidizer / Reducer (TCO) and Ammonia Dilution Skid.*
2. 24590-LAW-3YD-LOP-00001, *System Description for the Law Primary Offgas (LOP) And Secondary Offgas/Vessel Vent (LVP) Systems*
3. 24590-LAW-M4C-LOP-00001, *LAW Melter Offgas System Design Basis Flowsheets, with change notice 24590-LAW-M4E-LOP-00009.*
4. 24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS.*
5. 24590-LAW-P1-P01T-00005, *LAW Vitrification Building General Arrangement Plan at El. 48 Feet - 0 Inches.*
6. 24590-WTP-GPG-M-047, *Preparation of Corrosion Evaluations.*
7. 24590-WTP-RPT-PR-04-0001-04, *WTP Process Corrosion Data-Volume 4*
8. 24590-WTP-SRD-ESH-01-001-02, *Safety Requirements Document Volume II*
9. ASM Metals Handbook, Volume 13, *Corrosion*. 1987. ASM International, Materials Park, OH.
10. Coburn SK. 1978. *Atmospheric Factors Affecting the Corrosion of Engineering Metals - STP 646*. ASTM International, West Conshohocken, PA.
11. Dean SW and Lee TS. 1986. *Degradation of Metals in the Atmosphere - STP 965*. ASTM International, West Conshohocken, PA.
12. Dean SW and Rhea EC. 1980. *Atmospheric Corrosion of Metals - STP 767*. ASTM International, West Conshohocken, PA.
13. NIDI. *High-Temperature Characteristics of Stainless Steels*, Publication No. 9004, Nickel Development Institute. Toronto, Ontario, Canada
14. Schweitzer PA. 1989. *Corrosion and Corrosion Protection Handbook*. Marcel Dekker, Inc., New York, NY.

Additional Reading

- 24590-LAW-MKD-LVP-00012, *Mechanical Data Sheet for 24590-LAW-MX-LVP-SKID-00002 24590-LAW-MX-LVP-00003 - LAW Catalytic Oxidizer / Reducer*

CORROSION EVALUATION

PROCESS CORROSION DATA SHEET (extract)

Component(s) (Name/ID #) Thermal catalytic oxidizer (LVP-SCO-00001)

Facility LAW

In Black Cell? NO

		Stream ID LVP12
Chemicals	Unit	**GASEOUS**
CO2	ppmV	26468
HCl	ppmV	9
HF	ppmV	5
NH3	ppmV	22
NO	ppmV	2111
NO2	ppmV	10
O2	ppmV	188628
SO2	ppmV	8
SO3(s)	mg/m^3	3
RH	%	0.04
Suspended Solids	wt%	0
Temperature	°F	765

Figure C- 31 LVP-SCO-00001 Gaseous PCDS

Vessel : LVP_SCO_1

	Stream ID	
	LVP11	LVP12
Properties		
Suspended Solids [wt %]	0	0
Total Salts [wt %]	0.00	0.00
Sodium Molarity [M]	n/a	n/a
Relative Humidity [%]	0.04	0.04
pH	n/a	n/a
Anti-Foam Agent [ppm]	0	0
TOC [kg/h]	2.70E-03	1.35E-04
Pressure [bar]	0.92	0.91
Temperature [C]	398.89	407.22
Temperature [F]	750.00	765.00
Water Flow Rate [kg/hr]	303.79	303.79
Total Aqueous Flow Rate [kg/hr]	303.79	303.79
Total Flow Rate [kg/hr]	5.19E+03	5.19E+03
UserNote	VIT VAPOR Catalyst Unit Electric Heater Offgas Discharge	VIT VAPOR VOC Thermal Catalytic Oxidizer Unit Offgas Discharge
GASEOUS [ppmV or mg/m^3]		
Ar	8189	8267
CH3I	0	0
Cl2	0	0
CO	257	22
CO2	15680	26468
F2	0	0
H2	0	0
HCl	9	9
HCN	0	0
HF	5	5
I2	0	0
N2	694400	699732
NaCl(s)	0	0
NaCN(s)	0	0
NaF(s)	0	0
NaI(s)	0	0
NH3	21	22
NO	2041	2111
NO2	9	10
O2	187781	188628
P2O5(s)	0	0
PO2	0	0
SO2	0	8
SO3(s)	0	3

Note: Concentrations for constituents representing particulates (as denoted by suffix "(s)" in their name) are reported in units of mg/m^3; all others are reported in units of ppmV

GENERAL NOTE FOR USE OF PCDS:

- *The information provided by the PCDS report is intended solely for use in support of the vessel material selection process and Corrosion Evaluations. The inputs, assumptions, and computational/engineering models used in generating the results presented herein are specific to this effort. Use of the information presented herein for any other purpose will require separate consideration and analysis to support justification of its use for the desired, alternative purpose.*
- *The process descriptions in this report cover routine process operations and non-routine (infrequent) process operations, when such exist, that could impact corrosion or erosion of process equipment.*
- *The process descriptions provided in this report are for general information and reflective of the corrosion engineer's analysis for transparency, the information is current only at the time this document is issued. These process descriptions should not be referenced for design.*

6.6 LVP System

6.6.1 Description of Vessel/Equipment

The LAW Secondary Offgas/Vessel Vent Process (LVP) System is designed to treat the offgas from the LAW Primary Offgas Process (LOP) System and the LAW Facility vessel vents. The purpose of the LVP System is to remove almost all remaining particulates, miscellaneous acid gases, nitrogen oxides, VOCs, and mercury from the LAW Facility offgas that have not been removed by the LOP system.

Figure 10 is a sketch of the input and output arrangement of streams for all equipment within the LVP System. Streams that are not primary routes (infrequent transfers) are represented with dashed lines.

Figure 10a LVP System Sketch

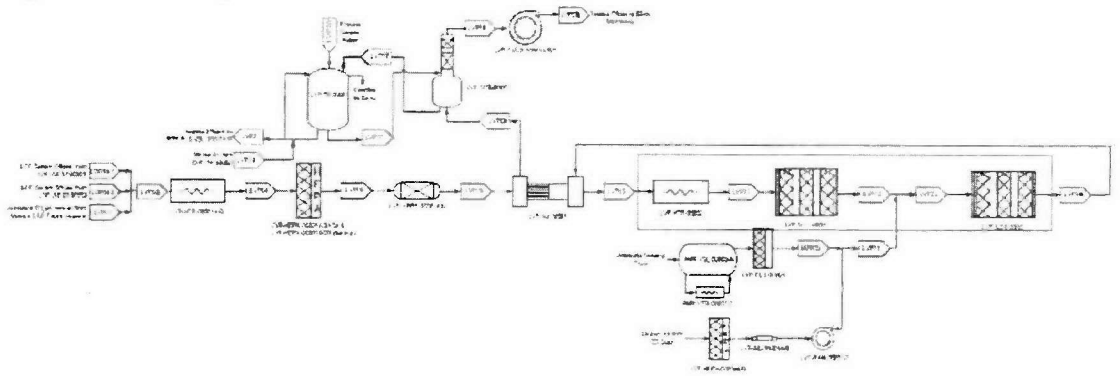
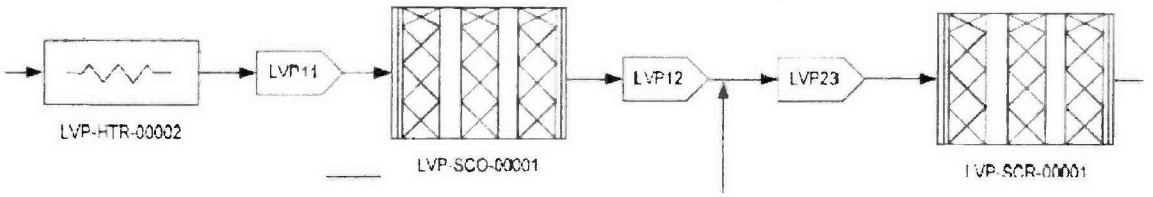


Figure 10b LVP System Sketch (detail of pertinent portion of system)



6.6.2 System Functions

The process functions of this system are as follows:

- Receive LAW Offgas from LOP System and LAW Facility Vessel Ventilation Streams
- Receive Reagents Streams Such as Ammonia or Dilution Air to Ensure Offgas Component Destruction
- Treat Offgas to Ensure Requirements are Met Before Emitting to Atmosphere
- Transfer Offgas to Stack
- Transfer Liquid Effluents to RLD-VSL-00017A/B

These vessels perform additional system functions beyond the process functions, but these are outside the scope of this document. The non-process functions are not discussed any further in this document. However, they are listed below for completeness:

- Confine Hazardous Materials
- Flush System Components
- Report System Data

6.6.3 Description of Process Functions

All process streams have been taken from Process Flow Diagrams 24590-LAW-M5-V17T-00010 and 24590-LAW-M5-V17T-00011 and associated drawing change notices (DCNs) 24590-LAW-M5N-V17T-00012/15/17/29 and 24590-LAW-M5N-V17T-00012/19/23/29, respectively. The P&IDs have also been looked at to obtain the most accurate flow diagram. These are as follows: 24590-LAW-M6-LVP-00001001 / 1002 / 1003 / 1004 / 1005 / 1006 / 2001 / 2002 / 2003 / 2004 / 2005 / 2006 / 3001 / 4001 / 4002 / 4003 / 5001 / 5002 and 24590-BOF-M6-AMR-00002001 / 2002 / 3001 / 3002 / 5001. See Section 7.1.3 for corresponding references in this section. A description of the process function of each piece of equipment is listed as follows:

Equipment	Process Function
LVP-SCO-00001	The selective catalytic oxider is used to oxidize volatile organic carbons and carbon monoxide.

6.6.3.1 Receipt Streams

The LVP system primarily receives LAW offgas from the LOP system and LAW Facility vessel ventilation streams. Other LVP system equipment receives various streams to help process the offgas. The receipt streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-SCO-00001

- LVP11 - Offgas from LVP-HTR-00002

6.6.3.1.7 LVP11 - Offgas from LVP-HTR-00002

Stream LVP11 is the offgas from the electric heater to the selective catalytic oxidizer.

Molarity
N/A

Temperature
The temperature of stream LVP11 will normally be 750°F (24590-LAW-M4C-LOP-00001, pg. 37, Cell Q37, Ref. 7.1.4(12)). The maximum temperature is 750°F (24590-LAW-M4C-LOP-00001, pg. 41, Cell Q37, Ref. 7.1.4(12)).

Solids Concentration
The solids concentration for stream LVP11 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP11 will normally be 2.29E-2 lb/ft^3 to 2.10E-2 lb/ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI37; pg. 41, Cell AI37, Ref. 7.1.4(12)).

Liquid pH
N/A

6.6.3.2 Outlet Streams

The outlet streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-SCO-00001

- LVP12 - Offgas from LVP-SCO-00001

6.6.3.1.9 LVP12 - Offgas from LVP-SCO-00001

Stream LVP12 is the offgas from the selective catalytic oxidizer prior to being mixed with ammonia and air.

Molarity
N/A

Temperature
The temperature of stream LVP12 will normally be 758°F (24590-LAW-M4C-LOP-00001, pg. 37, Cell Q38, Ref. 7.1.4(12)). The maximum temperature is 765°F (24590-LAW-M4C-LOP-00001, pg. 41, Cell Q38, Ref. 7.1.4(12)).

Solids Concentration
The solids concentration for stream LVP12 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP12 will normally be 2.26E-2 lb/ft^3 to 2.06E-2 lb/ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI38; pg. 41, Cell AI38, Ref. 7.1.4(12)).

Liquid pH
N/A

6.6.4 Process Modes

6.6.4.1 Normal Operations

Based on the assessment of streams frequently transferred in and out of the LVP System equipment, the following normal processing modes are considered:

LVP-SCO-00001

- LVP11 - Offgas from LVP-HTR-00002
- LVP12 - Offgas from LVP-SCO-00001

6.6.4.2 Infrequent Operations

None identified.

6.6.5.1 Normal Operations

The following table summarizes the normal processing modes for LVP System equipment.

Stream Number	Weight % UDS		Na Molarity		Temperature (°F)	
	normal	upper	normal	upper	normal	upper
LVP-SCO-00001						
LVP11 (in)	0	trace	n/a	n/a	750	750
LVP12 (out)	0	trace	n/a	n/a	758	765

6.6.5.2 Infrequent Operations

None identified.

CORROSION EVALUATION

6.4.1.3 Catalytic Oxidizer/Reducer (LVP-SKID-00001 and LVP-SKID-00002)

The offgas has potentially high levels of NO_x because the melter decomposes the parent nitrate/nitrite compounds. Some of the resultant NO_x is decomposed to nitrogen and water in the melter, and some is removed by scrubbing in the SBS. VOCs are also present in the offgas stream. Both the VOCs and the remaining NO_x require removal.

The offgas is passed through a catalytic oxidizer/reducer skid (LVP-SKID-00002) housing a heat recovery exchanger (LVP-HX-00001), an electric heater (LVP-HTR-00002), VOC catalyst (LVP-SCO-00001), and SCR catalyst (LVP-SCR-00001). The skid is located in room L-0304F at the 48-foot elevation and approximate dimensions for the skid are 36 ft long by 11 ft high by 8 ft wide. The heat recovery exchanger first raises the offgas temperature using the hot offgas from the catalyst beds. This heat exchanger is designed to be of a plate and frame design to eliminate the problems associated with tube to plate joints. The hot side of the heat exchanger cools the offgas prior to discharge from the skid. [4.3.3.17]

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R11727039

CORRODION EVALUATION

LVP-SCR-00001
NOx Selective Catalytic Reducer

Contents of this document are Dangerous Waste Permit affecting

Results

Materials Considered:

Material (UNS No.)	Acceptable Material
Type 304L (S30403)	
Type 316L (S31603)	
Type 347 (S34700)	X

Recommended Material Types:

Housing: Type 347 stainless steel

Recommended Corrosion Allowance: 0.010 inch

Inputs and References

- Operating temperature, inlet (°F): (nom/max): 622/633 (24590-LAW-M4E-LOP-00009)
- Operating temperature, outlet (°F): (nom/max): 724/792 (24590-LAW-M4E-LOP-00009)
- Corrosion allowance (in contact with offgas: 0.010 inch (24590-WTP-SRD-ESH-01-001-02)
- Location: out cell; Room L-0304F (24590-LAW-P1-P01T-00005)
- Operating conditions are as stated in the applicable section of *WTP Process Corrosion Data - Volume 4* (24590-WTP-RPT-PR-04-0001-04)

Assumptions and Supporting Justification (refer to Section 19—References)

- Source data presented on the Process Corrosion Datasheet (PCDS) are conservative with respect to corrosion.[5]

Operating Restrictions

- Develop a procedure for decontamination.
- Develop procedure to control lay-up and storage (mitigation of condensation in accordance with *Manual - Operation, Maintenance And Installation Instructions For LAW Thermal Catalytic Oxidizer / Reducer (TCO) And Ammonia Dilution Skid*,24590-CD-POC-MBT0-00007-05-00004); including both before plant is operational and during inactive periods during plant operation.
- Procedures are to be reviewed and accepted by MET prior to use.

Concurrence D. L. Dau
Operations

REV	DATE	REASON FOR REVISION	ORIGINATE	CHECK	REVIEW	APPROVE
3	06/25/15	To expand material selection information and references to address ORP and Ecology comments.	DLAdler	TErwin	RBDavis	JLeam
2	12/16/14	Complete re-write; no rev bars shown New format Incorporate updated PCDS Incorporate updated MDS Revise Ops Restrictions Update references	DLAdler	JRDivine	RBDavis	TErwin
1	7/18/12	Incorporate revised PCDS Update design temp/pressure AEA Notice Minor format and editorial changes	DLAdler	RBDavis	NA	DJWilsey
0	3/13/08	Initial issue	DLAdler	JRDivine	RBDavis	SWVail

CORROSION EVALUATION

Please note that source, special nuclear and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the U.S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

This bound document contains a total of 16 sheets.

CORROSION EVALUATION

Corrosion/Erosion Detailed Discussion

The selective catalytic reducer is used to reduce nitrogen oxides.

1 General/Uniform Corrosion Analysis

a Background

General corrosion or uniform corrosion is corrosion that is distributed more-or-less uniformly over the surface of a material without appreciable localization. This leads to relatively uniform thinning on sheet and plate materials and general thinning on one side or the other (or both) for pipe and tubing. It is recognized by a roughening of the surface and usually by the presence of corrosion products. The mechanism of the attack typically is an electrochemical process that takes place at the surface of the material. Differences in composition or orientation between small areas on the metal surface create micro-anodes and cathodes that facilitate the corrosion process.

b Component-Specific Discussion

Offgas corrosion, like atmospheric corrosion, depends on the development of corrosion cells or electrochemical cells consisting of the base metal, corrosion products, deposition products, anode, cathode, electrolyte, and current path. Stainless steels also have the added influence of the protective passive film. Because the corrosion process is electrochemical, an electrolyte must be present on the surface for corrosion to occur. In the absence of moisture, corrosion will not take place. As an example, where temperatures are less than freezing, corrosion is minor because the ice is not a good conductor; or when the relative humidity is low, the water condensation is negligible and corrosion is negligible. Offgas corrosion is also influenced by the deposition of particulates, dust, and thin monolayers of gas constituents. The physically adsorbed molecules on the surface (HCl, HNO_3, and H_2SO_4) will form an acid droplet from the deliquescence of water molecules. Moisture is needed to activate the corrosion process, typically a relative humidity of 60% to 80% is necessary to support corrosion; below this range corrosion does not occur. The relative humidity range for corrosion is discussed in Coburn (1978), Dean and Lee (1986), Dean and Rhea (1980), Schweitzer (1988), and in the *ASM Metals Handbook, Volume 13*. Normal operating conditions for the components of the thermal catalytic oxidizer (TCO) skid are dry, and relative humidity is very low (0.04% relative humidity, as shown in the PCDS). The anticipated dry-air conditions are not conducive to general corrosion and none is expected. Further, operating restrictions are in place to ensure that dry-air conditions are maintained.

The stabilized austenitic Type 347 stainless steel is suitable for the offgas conditions. The selection of Type 347 austenitic stainless steel is an enhancement over that of a Type 300 stainless steel. The corrosion rates are a product of the alloy chemistry, and the only difference between Type 347 and Type 304L is the increase in carbon content that improves the high temperature properties. The carbon increase is offset with niobium and tantalum alloyed to decrease the tendency for carbide precipitation during fabrication and welding. Type 347 alloy has improved oxidation resistance and high temperature properties and is a good choice for the TCO components. Type 347 was selected for the following reasons: improved thermal properties, readily available in most product forms, standard stainless steel fabrication practice (tools and processes), and lower cost per pound than the higher nickel or duplex alloys (*High-Temperature Characteristics of Stainless Steels*, Publication No. 9004, Nickel Development Institute).

The selective catalytic reducer is operated at elevated temperatures; oxidation is considered as part of this corrosion evaluation. The recommended alloy for the elevated temperature sections is Type 347 or Type 347H austenitic stainless steel. The higher carbon content and the addition of niobium to prevent sensitization act to improve the oxidation resistance.

The skid base frame is not considered as a material in contact with the offgas. If structural materials are not welded to the pressure boundary of the heat exchanger, they are outside the scope of this corrosion evaluation.

2 Pitting Corrosion Analysis

Pitting is localized corrosion of a metal surface that is confined to a point or small area and that takes the form of cavities. Pitting corrosion will only be a concern if sufficient moisture is present. The selective catalytic reducer normally operates at temperatures above the dew point of the dry offgas, and therefore insufficient moisture is present to act as an electrolyte for corrosion processes to proceed. It is assumed that there will be no condensation in the unit.

Justification for this position is that corrosion will not proceed without an electrolyte present.

3 Crevice Corrosion Analysis

Crevice corrosion is a form of localized corrosion of a metal or alloy surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity of the metal or alloy to the surface of another material or an adjacent surface of the same metal or alloy. Crevice corrosion is similar to pitting in mechanism. Crevice corrosion will only be a concern if sufficient moisture is present. The offgas humidity is controlled so that there will be no condensation.

Justification for this position begins with the understanding that this is an air handling unit operating at elevated temperatures, above the dew point. Corrosion will not take place or initiate when no electrolyte is present.

4 Stress Corrosion Cracking Analysis

Stress corrosion cracking (SCC) is the cracking of a material produced by the combined action of corrosion and sustained tensile stress (residual or applied). In addition, sensitization of the grain boundaries is prevented with the materials recommended. Either

CORROSION EVALUATION

an "L" grade, low carbon, stainless steel or a niobium-stabilized stainless steel is specified to negate sensitization from becoming a corrosion issue. It is assumed that there will be no condensation in the unit; therefore, the selective catalytic reducer will not undergo stress corrosion cracking because insufficient moisture will be present.

This position is justified because of the temperature of the gas during operation will be greater than the dew point. Corrosion will not take place or initiate when no electrolyte is present.

5 End Grain Corrosion Analysis

End grain corrosion typically is not a major concern, it propagates along the rolling direction of the plate, not necessarily through the cross sectional thickness. In addition, end grain corrosion is exclusive to metallic product forms with exposed end grains from shearing or mechanical cutting. The selective catalytic reducer design does not expose the pressure boundary cut ends to offgas. Also, end grain corrosion will not take place in the component because insufficient moisture is present.

End grain corrosion is not expected to occur in the selective catalytic reducer because the temperature of the gas will be greater than the dew point of the gas therefore corrosion will not occur in the absence of an electrolyte.

6 Weld Corrosion Analysis

The welds used in the fabrication will follow the WTP specifications and standards for quality workmanship. The materials selected for this fabrication are compatible with the weld filler metals and ASME/AWS practice. Using the welding practices specified for the project there should not be gross micro-segregation, precipitation of secondary phases, formation of unmixed zones, or volatilization of the alloying elements that could lead to localized corrosion of the weld.

This position is justified because the operating temperature and dry air conditions will not corrode because of the lack of the electrolyte for corrosion.

7 Microbiologically Influenced Corrosion Analysis

Microbiologically Influenced Corrosion (MIC) refers to corrosion affected by the presence or activity, or both, of microorganisms. Typically, with the exception of cooling water systems and stagnant water, MIC is not observed in operating systems.

The selective catalytic reducer will operate at elevated temperatures and the offgas is dry. In this system, the stated operating conditions are not suitable for microbial growth.

8 Fatigue/Corrosion Fatigue Analysis

Corrosion-fatigue is the result of the combined action of cyclic stresses and a corrosive environment. The fatigue process is thought to cause rupture of the protective passive film, upon which stainless steel can actively corrode in the localized area of the film rupture. The corrosive environment may also act to reduce the stress necessary for film rupture. The result is that a metal exposed to a corrosive environment and cyclic mechanical load may initiate cracking at conditions at stress levels less than the endurance limit for the material.

The selective catalytic reducer is not cyclically operated; offgas flow is constant, steady and dry. Thermal cycles and therefore thermal stress is also low and associated with the start-up and shut down of the offgas system. Corrosion fatigue will not be observed in the selective catalytic reducer (24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS*).

The conclusion that corrosion fatigue will not be a problem is based on the low mechanical and thermal cycling, as well as the lack of an electrolyte for corrosion.

9 Vapor Phase Corrosion Analysis

Vapor phase corrosion considers the gas and vapor constituents that form acidic condensate and the alloy corrosion resistance. The aggressive constituents are HCl, HF, and HNO_3; however these are present in low concentrations in the gas. The formation of acidic condensate requires moisture condensing on the surface and mixing with the adsorbed surface constituents to produce an aggressive environment. Condensation on the surface is not likely during normal operation.

Vapor phase corrosion will not occur in the selective catalytic reducer because the operation conditions for this component preclude the presence of sufficient moisture and concentrations of acid gas forming components.

10 Erosion Analysis

Erosion is the progressive loss of material from a surface resulting from mechanical interaction between a particle and that surface. Solid particle erosion can occur in air, steam, and water fluid systems. The WTP waste is a slurry consisting of water, waste oxide particles, and / or precipitated salts. When the fluid propels the solid particles at a sufficient velocity and the particle mass is sufficient, the surface can be damaged by the combined effect of millions of individual erosion "scars". Prior to reaching the selective catalytic reducer the offgas passes through a high efficiency particulate filter (HEPA) and therefore should be free of particulates.

The solids content and gas velocity are sufficiently low that erosion is not a concern.

CORROSION EVALUATION

11 Galling of Moving Surfaces Analysis

Galling is a form of wear caused by a combination of friction and adhesion between moving surfaces. Under high compressive forces and movement, the friction temperatures cold-weld the two surfaces together at the surface asperities. As the adhesively bonded surface moves some of the bonded material breaks away. Microscopic examination of the galled surface shows some material stuck or even friction welded to the adjacent surface, while the softer of the two surfaces appears gouged with balled-up or torn lumps of material stuck to its surface.

Galling is most commonly found in metal surfaces that are in sliding contact with each other. It is especially common where there is inadequate lubrication between the surfaces. Softer metals will generally be more prone to galling; austenitic stainless steel is relatively soft and ductile and is known to gall easily. Martensitic stainless steel or precipitation hardened stainless steel or nitrogen strengthened austenitic stainless steels have higher surface hardness and therefore are resistant to galling.

The selective catalytic reducer does not have any moving surfaces.

12 Fretting/Wear Analysis

Fretting corrosion refers to corrosion damage caused by a slight oscillatory slip between two surfaces. Similar to galling but a much smaller movement, the corrosion products and metal debris break off and act as an abrasive between the surfaces, classic 3-body wear problem. This damage is induced under load and repeated relative surface motion, as induced for example by vibration. Pits or grooves and oxide debris characterize this damage, typically found in machinery, bolted assemblies and ball or roller bearings. Contact surfaces exposed to vibration during transportation are exposed to the risk of fretting corrosion.

The selective catalytic reducer does not have moving parts and design precludes fretting corrosion problem. Fretting corrosion is not expected in this component.

13 Galvanic Corrosion Analysis

Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially to another when both metals are in electrical contact, in the presence of an electrolyte. Dissimilar metals and alloys have different electrode potentials, and when two are in contact in an electrolyte, one metal acts as anode and the other as cathode. The electropotential difference between the dissimilar metals is the driving force for an accelerated attack. The potential difference for more than 200 mV is needed for sufficient driving force to make a difference. Galvanic compatibility is one of the attributes used to select the WTP alloys. Austenitic stainless steels in contact with other austenitic stainless steels do not have sufficient electropotential difference to significantly influence the metal loss.

The selective catalytic reducer materials are all fabricated from Type 347 stainless steel. In addition, the gas is dry and contains insufficient moisture to act as an electrolyte. Galvanic corrosion is not expected to be a corrosion issue under these conditions.

14 Cavitation Analysis

Cavitation corrosion is defined as another synergistic process, the combined influence of mechanical disruption of the metal surface and the corrosion of the active metal. Cavitation occurs when the local fluid pressure drops below the vapor pressure of the fluid resulting in a liquid vapor interface or bubbles to form. Their collapse on the metal surface has sufficient energy to rupture the oxide film and depending on alloy, may be capable of removing metal. The fluid chemistry and alloy define corrosion characteristics of the oxide film: where localization of the cavitation produces a condition where the bubble collapse rate is greater than the ability to passivate, the normally passive alloy can experience accelerated loss. This is most likely to occur in pumps, valves (flow control), orifices, ejectors/eductors, and nozzles.

Cavitation is not expected in an offgas system

15 Creep Analysis

Creep is defined as a time-dependent deformation at elevated temperature and constant stress, creep is a thermally activated process. The temperature at which creep begins depends on the alloy composition. Creep failures and stress rupture failures follow the same mechanism and influenced by similar variables like temperature. Stress rupture is defined as bi-axial creep restricted to pipe like geometries. Creep is found in components subjected to heat for long periods and the creep rate generally increases as the temperature nears the melting point. The creep temperature is different for each alloy, the Nickel Development Institute has cataloged the creep properties of Type 304, Type 316, and Type 347 austenitic stainless steels (*High-Temperature Characteristics of Stainless Steels*, NIDI No. 9004, Nickel Development Institute). The material creep properties at 1000 °F indicate a difference of several hundred degrees over the maximum temperature for the selective catalytic reducer of 792 °F.

The maximum operating temperature for the selective catalytic reducer is less than the creep temperature, creep will not occur.

16 Inadvertent Addition of Nitric Acid

Addition of nitric acid to the offgas is not a plausible scenario.

CORROSION EVALUATION

17 Conclusion and Justification

The conclusion of this evaluation is that LVP-SCR-00001 can be fabricated from Type 347 stainless steel and that Type 347 stainless steel is capable of providing 40 years of service. Providing the reported dry-air conditions are maintained, Type 347 stainless steel is expected to be resistant to uniform and localized corrosion. The probable uniform corrosion is negligible; a minimum allowance of 0.010 inch for surfaces in contact with the offgas is recommended for conservatism. Conditions in the selective catalytic reducer do not promote erosion so no erosion allowance is necessary.

18 Margin

Per 24590-WTP-SRD-ESH-01-001-02, Appendix H "When erosion and corrosion effects can be shown to be negligible or entirely absent, a design corrosion allowance need not be specified." In the reported dry-air conditions, there is no electrolyte. If there is no electrolyte, there can be no corrosion. The system is designed with a uniform corrosion allowance of 0.010 inch based on the range of inputs, system knowledge, and engineering judgment/experience. The service conditions used for materials selection have been described above and result in negligible uniform loss. The specified minimum corrosion allowance exceeds the minimum required corrosion allowance which provides margin. The uniform corrosion design margin for the operating conditions is sufficient to expect a 40 year operating life and is justified in the referenced calculation.

Localized erosion of this component is not expected. Prior to reaching the selective catalytic reducer, the offgas passes through a high efficiency particulate filter (HEPA) and, therefore, should be free of particulates. The solids content and gas velocity are sufficiently low that localized erosion is not a concern. Since localized erosion effects are not present, additional localized corrosion protection is not required.

This component contains no fluids or electrolyte to promote localized corrosion. As shown in the PCDS summary table below (page 8, below), the unit operates at high temperatures and low humidity (0.04% at the outlet) and is described in the PCDS. While not quantifiable, the largest contributor to the total localized corrosion design margin is the absence of sufficient moisture to form a corrosive electrolyte. During inactive periods of plant operations and prior to initial plant startup, layup and storage procedures will monitor and control condensation.

CORRODION EVALUATION

19 References:

1. 24590-CD-POC-MBT0-00007-05-00004, *Manual - Operation, Maintenance and Installation Instructions for LAW Thermal Catalytic Oxidizer / Reducer (TCO) and Ammonia Dilution Skid.*
2. 24590-LAW-3YD-LOP-00001, *System Description for the Law Primary Offgas (LOP) And Secondary Offgas/Vessel Vent (LVP) Systems*
3. 24590-LAW-M4C-LOP-00001, *LAW Melter Offgas System Design Basis Flowsheets with ECCN 24590-LAW-M4E-LOP-00009.*
4. 24590-LAW-MVC-LVP-00004, *LVP-SKID-00002, LAW Thermal Catalytic Oxidizer / Reducer, Stress Analysis with ANSYS.*
5. 24590-WTP-RPT-PR-04-0001-04, *WTP Process Corrosion Data - Volume 4*
6. 24590-WTP-SRD-ESH-01-001-02, *Safety Requirements Document Volume II*
7. ASM Metals Handbook. Volume 13, *Corrosion*. 1987. ASM International, Materials Park, OH.
8. Coburn SK. 1978. *Atmospheric Factors Affecting the Corrosion of Engineering Metals - STP 646*. ASTM International, West Conshohocken, PA.
9. Dean SW and Lee TS. 1986. *Degradation of Metals in the Atmosphere - STP 965*. ASTM International, West Conshohocken, PA.
10. Dean SW and Rhea EC. 1980. *Atmospheric Corrosion of Metals - STP 767*. ASTM International, West Conshohocken, PA.
11. NIDI. *High-Temperature Characteristics of Stainless Steels*, Publication No. 9004, Nickel Development Institute. Toronto, Ontario, Canada
12. Schweitzer PA. 1989. *Corrosion and Corrosion Protection Handbook*. Marcel Dekker, Inc., New York, NY.

Additional Reading

- 24590-LAW-MKD-LVP-00012, *Mechanical Data Sheet for 24590-LAW-MX-LVP-SKID-00002 24590-LAW-MX-LVP-00003 - LAW Catalytic Oxidizer / Reducer*

CORROSION EVALUATION

PROCESS CORROSION DATA SHEET (extract)

Component(s) (Name/ID #) NOx SELECTIVE CATALYTIC REDUCER (LVP-SCR-00001)

Facility LAW

In Black Cell? NO

		Stream ID LVP14
Chemicals	Unit	GASEOUS
CO2	ppmV	22338
HCl	ppmV	7
HF	ppmV	4
NH3	ppmV	1925
NO	ppmV	1714
NO2	ppmV	8
SO2	ppmV	7
SO3(s)	mg/m^3	2
RH	%	0.04
Suspended Solids	wt%	0
Temperature	°F	792

CORRESPONDENCE EVALUATION

Figure C- 34 LVP-SCR-00001 Gaseous PCDS

	Stream ID	
	LVP23	LVP14
Properties		
Suspended Solids [wt %]	0	0
Total Salts [wt %]	0.00	0.00
Sodium Molarity [M]	n/a	n/a
Relative Humidity [%]	0.05	0.04
pH	n/a	n/a
Anti-Foam Agent [ppm]	0	0
TOC [kg/h]	1.35E-04	1.35E-04
Pressure [bar]	0.91	0.90
Temperature [C]	333.89	422.22
Temperature [F]	633.00	792.00
Water Flow Rate [kg/hr]	309.10	319.15
Total Aqueous Flow Rate [kg/hr]	309.10	319.15
Total Flow Rate [kg/hr]	6.20E+03	6.20E+03
UserNote	VIT VAPOR Primary NOx SCR Inlet	VIT VAPOR Primary NOx SCR Discharge
GASEOUS [ppmV or mg/m^3]		
Ar	8401	8401
CH3I	0	0
Cl2	0	0
CO	18	18
CO2	22338	22338
F2	0	0
H2	0	0
HCl	7	7
HCN	0	0
HF	4	4
I2	0	0
N2	711673	711673
NaCl(s)	0	0
NaCN(s)	0	0
NaF(s)	0	0
NaI(s)	0	0
NH3	1925	1925
NO	1714	1714
NO2	8	8
O2	191317	191317
P2O5(s)	0	0
PO2	0	0
SO2	7	7
SO3(s)	2	2

Note: Concentrations for constituents representing particulates (as denoted by suffix "(s)" in their name) are reported in units of mg/m^3; all others are reported in units of ppmV

GENERAL NOTE FOR USE OF PCDS:

- *The information provided by the PCDS report is intended solely for use in support of the vessel material selection process and Corrosion Evaluations. The inputs, assumptions, and computational/engineering models used in generating the results presented herein are specific to this effort. Use of the information presented herein for any other purpose will require separate consideration and analysis to support justification of its use for the desired, alternative purpose.*
- *The process descriptions in this report cover routine process operations and non-routine (infrequent) process operations, when such exist, that could impact corrosion or erosion of process equipment.*
- *The process descriptions provided in this report are for general information and reflective of the corrosion engineer's analysis for transparency, the information is current only at the time this document is issued. These process descriptions should not be referenced for design.*

6.6 LVP System

6.6.1 Description of Vessel/Equipment

The LAW Secondary Offgas/Vessel Vent Process (LVP) System is designed to treat the offgas from the LAW Primary Offgas Process (LOP) System and the LAW Facility vessel vents. The purpose of the LVP System is to remove almost all remaining particulates, miscellaneous acid gases, nitrogen oxides, VOCs, and mercury from the LAW Facility offgas that have not been removed by the LOP system.

Figure 10 is a sketch of the input and output arrangement of streams for all equipment within the LVP System. Streams that are not primary routes (infrequent transfers) are represented with dashed lines.

Figure 10a LVP System Sketch

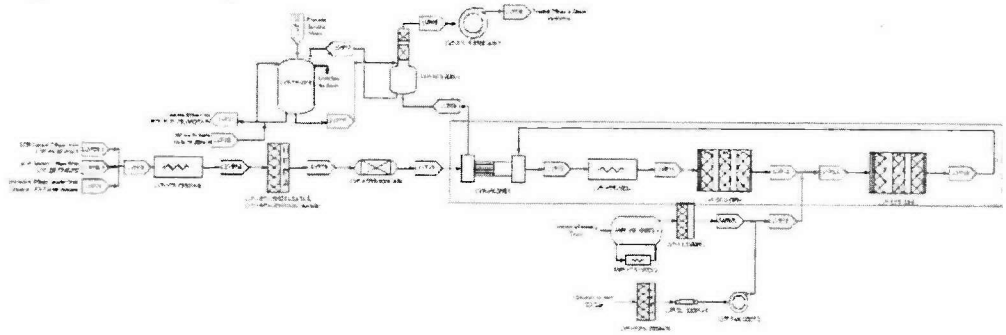
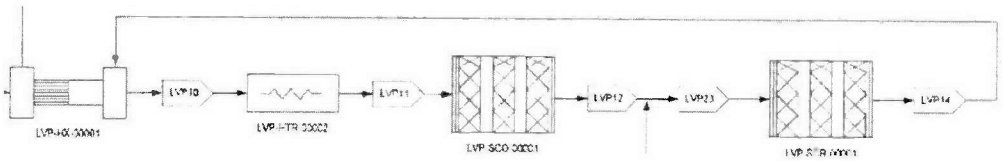


Figure 10b LVP System Sketch (detail of pertinent portion of system)



6.6.2 System Functions

The process functions of this system are as follows:

- Receive LAW Offgas from LOP System and LAW Facility Vessel Ventilation Streams
- Receive Reagents Streams Such as Ammonia or Dilution Air to Ensure Offgas Component Destruction
- Treat Offgas to Ensure Requirements are Met Before Emitting to Atmosphere
- Transfer Offgas to Stack
- Transfer Liquid Effluents to RLD-VSL-00017A/B

These vessels perform additional system functions beyond the process functions, but these are outside the scope of this document. The non-process functions are not discussed any further in this document. However, they are listed below for completeness:

- Confine Hazardous Materials
- Flush System Components
- Report System Data

6.6.3 Description of Process Functions

All process streams have been taken from Process Flow Diagrams 24590-LAW-M5-V17T-00010 and 24590-LAW-M5-V17T-00011 and associated drawing change notices (DCNs) 24590-LAW-M5N-V17T-00012/15/17/29 and 24590-LAW-M5N-V17T-00012/19/23/29, respectively. The P&IDs have also been looked at to obtain the most accurate flow diagram. These are as follows: 24590-LAW-M6-LVP-00001001 / 1002 / 1003 / 1004 / 1005 / 1006 / 2001 / 2002 / 2003 / 2004 / 2005 / 2006 / 3001 / 4001 / 4002 / 4003 / 5001 / 5002 and 24590-BOF-M6-AMR-00002001 / 2002 / 3001 / 3002 / 5001. See Section 7.1.3 for corresponding references in this section. A description of the process function of each piece of equipment is listed as follows:

Equipment	Process Function
LVP-SCR-00001	The selective catalytic reducer is used to reduce nitrogen oxides.

6.6.3.1 Receipt Streams

The LVP system primarily receives LAW offgas from the LOP system and LAW Facility vessel ventilation streams. Other LVP system equipment receives various streams to help process the offgas. The receipt streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-SCR-00001 (Note: the sub-bullets denote the streams that compose the above bullet)

- LVP23 - Offgas from LVP-SCO-00001 and Ammonia Air Mixture
  - LVP12 - Offgas from LVP-SCO-00001
  - LVP13 - Ammonia/Air Mixture
    - AMR03 - Ammonia Vapor from AMR-VSL-00001/2 via LVP-FILT-00001
    - Air from C3 Duct via LVP-HEPA-00004A/B, LVP-SIL-00001A/B, and LVP-FAN-00001/2

6.6.3.1.8 LVP23 - Offgas from LVP-SCO-00001 and Ammonia/Air Mixture

Stream LVP23 is the offgas from the selective catalytic oxidizer mixed with ammonia and air, then sent to the selective catalytic reducer.

Molarity
N/A

Temperature
The temperature of stream LVP23 will normally be 622°F (24590-LAW-M4E-LOP-00009, pg. 11, Cell Q43, Ref. 7.1.4(13)). The maximum temperature is 633°F (24590-LAW-M4E-LOP-00009, pg. 15, Cell Q43, Ref. 7.1.4(13)).

Solids Concentration
The solids concentration for stream LVP23 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP23 will normally be 2.54E-2 lb/ft^3 to 2.30E-2 lb/ft^3 (24590-LAW-M4E-LOP-00009, pg. 11, Cell AI43; pg. 15, Cell AI43, Ref. 7.1.4(13)).

Liquid pH
N/A

6.6.3.1.9 LVP12 - Offgas from LVP-SCO-00001

Stream LVP12 is the offgas from the selective catalytic oxidizer prior to being mixed with ammonia and air.

Molarity
N/A

Temperature
The temperature of stream LVP12 will normally be 758°F (24590-LAW-M4C-LOP-00001, pg. 37, Cell Q38, Ref. 7.1.4(12)). The maximum temperature is 765°F (24590-LAW-M4C-LOP-00001, pg. 41, Cell Q38, Ref. 7.1.4(12)).

Solids Concentration
The solids concentration for stream LVP12 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP12 will normally be 2.26E-2 lb/ft^3 to 2.06E-2 lb/ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI38; pg. 41, Cell AI38, Ref. 7.1.4(12)).

Liquid pH
N/A

Solids Concentration
The solids concentration for stream LVP13 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP13 will normally be 5.18E-2 lb/ft^3 to 4.57E-2 lb/ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI42; pg. 41, Cell AI42, Ref. 7.1.4(12)).

Liquid pH
N/A

6.6.3.1.11 AMR03 - Ammonia Vapor from AMR-VSL-00003/4 via LVP-FILT-00001

Stream AMR03 is the ammonia vapor prior to being mixed with plant air.

Molarity
N/A

Temperature
The temperature of stream AMR03 will normally be 77°F (24590-LAW-M4C-LOP-00001, pg. 37, Cell Q42, Ref. 7.1.4(12)). The maximum temperature is 125°F (24590-LAW-M4C-LOP-00001, pg. 41, Cell Q42, Ref. 7.1.4(12)).

Solids Concentration
The solids concentration for stream AMR03 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream AMR03 will normally be 3.12E-2 lb/ft^3 to 2.63E-2 lb ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI41; pg. 41, Cell AI41, Ref. 7.1.4(12)).

Liquid pH
N/A

6.6.3.1.12 Air from C3 Duct via LVP-HEPA-00004A/B, LVP-SIL-00001A/B, and LVP-FAN-00001/2

This stream is the filtered C3 air made into plant service quality air.

Molarity
N/A

Temperature
The temperature will normally be 80°F (24590-LAW-M4C-LOP-00001, pg. 37, Cell Q39, Ref. 7.1.4(12)). The maximum temperature is 95°F (24590-LAW-M4C-LOP-00001, pg. 41, Cell Q39, Ref. 7.1.4(12))

Solids Concentration
The solids concentration will normally be near zero or trace solids.

Vapor Density
The vapor density will normally be 5.24E-2 lb ft^3 to 4.66E-2 lb ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI39; pg. 41, Cell AI39, Ref. 7.1.4(12)).

Liquid pH
N/A

6.6.3.2 Outlet Streams

The outlet streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-SCR-00001

- LVP14 - Offgas from LVP-SCR-00001

6.6.3.1.5 LVP14 - Offgas from LVP-SCR-00001

Stream LVP14 is the offgas from the catalytic reducer that enters the heat exchanger.

Molarity
N/A

Temperature
The temperature of stream LVP14 will normally be 724°F (24590-LAW-M4E-LOP-00009, pg. 11, Cell Q44, Ref. 7.1.4(13)). The maximum temperature is 792°F (24590-LAW-M4E-LOP-00009, pg. 15, Cell Q44, Ref. 7.1.4(13)).

Solids Concentration
The solids concentration for stream LVP14 will normally be near zero or trace solids.

Vapor Density
The vapor density of stream LVP14 will normally be 2.27E-2 lb/ft^3 to 1.95E-2 lb/ft^3 (24590-LAW-M4E-LOP-00009, pg. 11, Cell AI44; pg. 15, Cell AI44, Ref. 7.1.4(13)).

Liquid pH
N/A

6.6.4 Process Modes

6.6.4.1 Normal Operations

Based on the assessment of streams frequently transferred in and out of the LVP System equipment, the following normal processing modes are considered:

LVP-SCR-00001

- LVP23 - Offgas from LVP-SCO-00001 and Ammonia Air Mixture
  - LVP12 - Offgas from LVP-SCO-00001
  - LVP13 - Ammonia Air Mixture
    - AMR03 - Ammonia Vapor from AMR-VSL-00001/2 via LVP-FILT-00001
    - Air from C3 Duct via LVP-HEPA-00004A/B, LVP-SIL-00001A/B, and LVP-FAN-00001/2
- LVP14 - Offgas from LVP-SCR-00001

6.6.4.2 Infrequent Operations

None identified.

6.6.5 Summary of Processing Conditions for LVP System

6.6.5.1 Normal Operations

The following table summarizes the normal processing modes for LVP System equipment.

Stream Number	Weight % UDS		Na Molarity		Temperature (°F)	
	normal	upper	normal	upper	normal	upper
LVP-SCR-00001						
LVP12 (in)	0	trace	n.a	n.a	758	765
LVP13 (in)	0	trace	n.a	n.a	80	97
LVP23 (sum in)	0	trace	n.a	n.a	622	633
LVP14 (out)	0	trace	n.a	n.a	724	792

6.6.5.2 Infrequent Operations

None identified.

CORROSION EVALUATION

6.4.1.3 Catalytic Oxidizer/Reducer (LVP-SKID-00001 and LVP-SKID-00002)

The offgas has potentially high levels of NO_x because the melter decomposes the parent nitrate/nitrite compounds. Some of the resultant NO_x is decomposed to nitrogen and water in the melter, and some is removed by scrubbing in the SBS. VOCs are also present in the offgas stream. Both the VOCs and the remaining NO_x require removal.

The offgas is passed through a catalytic oxidizer/reducer skid (LVP-SKID-00002) housing a heat recovery exchanger (LVP-HX-00001), an electric heater (LVP-HTR-00002), VOC catalyst (LVP-SCO-00001), and SCR catalyst (LVP-SCR-00001). The skid is located in room L-0304F at the 48-foot elevation and approximate dimensions for the skid are 36 ft long by 11 ft high by 8 ft wide. The heat recovery exchanger first raises the offgas temperature using the hot offgas from the catalyst beds. This heat exchanger is designed to be of a plate and frame design to eliminate the problems associated with tube to plate joints. The hot side of the heat exchanger cools the offgas prior to discharge from the skid. [4.3.3.17]

The electric heater is used to supplement the heat recovery exchanger primarily during startup and when operating with low NO_x concentrations. Once the system is up to temperature, demand on the electric heater will be minimal.

The heated offgas is passed through the VOC catalyst to oxidize VOCs and carbon monoxide to carbon dioxide and water vapor. The VOC catalyst is a platinum-based material deposited on a metal monolith, which is held in frames and inserted/removed through access doors. The VOC catalyst is designed to achieve a VOC DRE of 95%.

The offgas is then injected with a mixture of ammonia vapor and C3 air from an ammonia/air dilution skid (LVP-SKID-00003) housing ammonia dilution fans (LVP-FAN-00001, -00002) and a mixing chamber. C3 supply air is used as this abatement skid is located downstream of the HEPA filtration. Instrumentation is located at the inlet and outlet of the unit to determine the NO_x concentrations and at the outlet to determine the ammonia and VOC concentrations. A control valve regulates the supply of the ammonia to the SCR catalyst based on either NO_x or ammonia levels in the exit gas. The ammonia to air ratio and ammonia flow rate are maintained below predetermined setpoints by the PPJ system. Trip of either interlock will isolate ammonia flow. Areas containing ammonia lines are monitored to detect gasket, seal, or other leaks at an early stage so that they can identified and corrected. [4.3.1.3]

Following ammonia injection, the offgas is passed through the SCR catalyst to reduce NO_x to nitrogen and water vapor. The SCR catalyst is a titanium oxide-based material deposited on a metal monolith, which is held in frames and inserted/removed through access doors. The SCR catalyst is designed to achieve a NO_x reduction of 98%.

Possible catalyst poisons for both the VOC and SCR catalysts include mercury, SO_x, and halogens. In particular, SO_2 concentrations above 1000 ppm and SO_3 concentrations above 50 ppm are detrimental to the catalysts. Because this is one of the last treatment steps in the offgas system, other poisons are not a concern.

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History Sheet

Rev	Date	Reason for the revision	Revised by
0	8 October 2002	Supersedes 24590-WTP-RPT-ENG-01-004, Rev 0, *WTP Material Balance and Process Flowsheet Bases, Requirements, and Results*. This document provides the most current flowsheet bases, assumptions and requirements information.	E Lee, E Berrios
1	4 December 2002	Incorporation of changes consistent with change in plant reconfiguration which includes the following: • 2+2 configuration (two LAW melters and two HLW melters) from Trend 24590-02-00617, DOE ORP 02-AMPD-133 [20 Oct 2002] • *Sample and Analysis Plan*, Rev 2 • *Waste Form Compliance Plan*, Rev 1	E Lee, M Binsfield
2	25 August 2003	Updates the flowsheet with reconciled ion exchange data, removal of technetium ion exchange process systems, design maturation, and improvements in flowsheet modeling to support annual deliverables 2.5, 2.6, and 2.7. Five new sections have been added to describe radioactive solid waste, RLD and NLD liquid effluents, pretreatment in-cell crane, development of reliability, availability, and maintainability data, and pretreatment non-radioactive liquid disposal systems and information. Sections pertaining to ion exchange (CXP, CNP, TXP, TEP), liquid waste disposal (PWD, RLD, NLD), melter process (LMP, HMP), and melter offgas treatment (LOP, LVP, HOP) systems are considered completely rewritten. All other sections have revision bars to reflect changes associated with this revision.	M Binsfield
3	29 June 2005	Provides the most current flowsheet bases, assumptions, and requirements information. Changes resulting from R&T Report Data Reconciliation include the following: Incorporation of Oxidative Leach, HLW Glass Formulation - added Nepheline, Zircon and Spinel crystallinity constraints on glass, added viscosity limits into the glass formulation, added logic that meets Contract waste loading limits per SOW Spec. 1, Table TS-1.1, Glass Former Minerals and Impurities, Melter Feed Rheology, Update of Offgas DFs and Chemistry, UFP Variable Flux, Melter Organic Chemistry Update Changes resulting from Design Changes include the following: HLW Concentrate Receipt Vessel Elimination, Mixing Updates - PJMs and Sparging, UFP Caustic Leach Feed Forward, PT Front End Solids Management, Analytical Laboratory Non-Dilution Approach, Incorporation of ISARD	M Davidsmeyer

History Sheet

Rev	Date	Reason for the revision	Revised by
		changes for the Analytical Laboratory, UFP Heel Ejection and Recirculation Loop Drain, Updated RAM Data per Design Evolution	
		All sections have revision bars to reflect changes associated with this revision.	
4	5 Dec 2008	Provides for the most current flowsheet bases, assumptions, and requirements information.	IZ Stone
		Changes resulting from R&T Report Data Reconciliation include the following:	
		Update BARD LAW Melter section to have the correct document number for the referenced "Results from Analysis of a Hanford Tank 241-AN-102 Melter Scale Glass Waste Form". (3.2)	
		R&T report update- RTC-14: Compositional Variation Test on DuraMelter 100 with LAW Sub-Envelope A3 Feed in Support of the LAW Pilot Melter (3.1)	
		UFP R&T report update- RTC-0261: AN-107 Active Waste Sr/TRU Precipitation and Ultrafiltration (U) (2.3)	
		Semi-Volatile Organic Compounds Generated by Radiolysis of IX Resins (2.5)	
		Flammable Gas Generation in System LMP (3.2)	
		LAW Evaluation on the Influence of Technetium on Cesium Volatility (3.2)	
		HLW Evaluation on the Influence of Technetium on Cesium Volatility (4.2)	
		Alternative Ultrafilter Cleaning Tests (2.3)	
		Oxidative Leach Factor (2.3)	
		Operating Temperature Range for TLP Evaporator (2.12)	
		IHLW Delisting Compliance Text (4.1)	
		Particle Size Data for High-Level Waste Feed (2.1)	
		Update Boric Acid and Carbonate for Glass Formers LAW (3.1)	
		Update Boric Acid and Carbonate for Glass Formers HLW (4.1)	
		Energy Updates for HLW Decon Vessels (4.6)	
		Update HLW Melter DF's (4.2)	
		Update Table 4.3-1 "HLW Vitrification Material Flow Decontamination Factors by Component (4.3)	
		Rheology Water For HLW (4.1)	
		CNP Process Description (2.6)	

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		CNP Caustic Addition (2.6)	
		Hydrogen Gas Generation In Pretreatment Vessel Vent (4.3)	
		Revised Tc-99 Melter DF for LAW (3.2)	
		On Going Work on the Use of Antifoam Agent (2.4)	
		Antifoam Effectiveness During Oxidative Leaching Process (2.4)	
		PCT and TCLP Results of Glass Samples From Actual Waste (4.1)	
		Regulatory Off-Gas Emission During LAW Simulant Testing (3.3)	
		Regulatory Off-Gas Emission During HLW Simulant Testing (4.3)	
		GFC Feed from glass former mixers to MFPV (3.1)	
		GFC Feed from glass former mixers to MFPV (4.1)	
		FEP Semi-integrated Pilot Plant Final Report Update - RTC-0372 (2.2)	
		Glass Former Reagent System Update (6.1)	
		TLP Semi-integrated Pilot Plant Final Report Update - RTC-0372 (2.12)	
		Pilot scale Precipitation and Filtration Test Results on AN-107 Simulant (2.3)	
		Update of Henry's Law Constants and Temperature Dependence Values for Organics (7.1)	
		Time Update for Sample Hold Point PT 2 in Vessels FRP-VSL-00002A/B/C/D per ISARD, Rev 1 (2.1)	
		Time Update for Sample Hold Point PT 6b in Vessels UFP-VSL-00062A/B/C per ISARD, Rev 1 (2.3)	
		Time Update for Sample Hold Points PT 13 in Vessel HLP-VSL-00028 & PT 17 in Vessel HLP-VSL-00022 per ISARD, Rev 1 (2.4)	
		Time Update for Sample Hold Point PT 31b in Vessels RDP-VSL-00002A/B/C per ISARD, Rev 1 (2.11)	
		Time Update for Sample Hold Point PT 35 in Vessels RLD-VSL-00017A/B per ISARD, Rev 1 (2.17)	
		Time Update for Sample Hold Points PT LAW 1 & LAW 6 in Vessels LCP-VSL-00001/2 per ISARD, Rev 1 (3.1)	
		Time Update for Sample Hold Points HLW 2a & HLW 2b in Vessel HFP-VSL-00001/5 per ISARD, Rev 1 (4.1)	
		Add line flushing/ air purging test to ongoing work (2.3)	

History Sheet

Rev	Date	Reason for the revision	Revised by
		Addition of technical basis for antifoam in UFP (2.3)	
		Additional Oxidative Leaching Technical Basis (2.3)	
		Editorial and content changes in Section 2.6 on the CNP System (2.6)	
		Reconcile RTC-331 - *Evaporation, Rheology, and Vitrification of a Pretreated Radioactive Hanford Tank 241-AN-104 Sample Mixed with Simulated LAW SBS Recycle* (2.12)	
		Additional Filter Cleaning Tests RTC-310 (2.3)	
		Major Update of BARD Section 2.1 (2.1)	
		Add LAW Waste Qualification Comparison Information (3.2)	
		Editorial Changes and Content Updates for Section 2.16 (NAR, STR, SPR, SNR, SHR, DIW, AFR) (2.16)	
		Add Glass Bubbling versus Production Rate information (3.2)	
		BARD Update to Revision 4, HLP, (2.4)	
		Editorial Changes and Content Updates for Section 2.17 (RLD, NLD) (2.17)	
		LMP Miscellaneous Updates (3.2)	
		Editorial Changes and Content Updates for Section 4.5 (RLD-30 NLD-30) (4.5)	
		Editorial changes and Content updates for Section 3.3 (3.3)	
		Update LAW Melter Decontamination Factors (3.2)	
		Update LAW Primary Offgas System Decontamination Factors (3.3)	
		Update HLW Melter Decontamination Factors (4.2)	
		Update HLW Melter Decontamination Factors for ACM and G2 (4.3)	
		Cs-137 DF for FEP Evaporators (2.2)	
		Cs-137 DF for TLP Evaporators (2.12)	
		Update LAW Nitrate, Nitrite, and Ammonia Discussion (3.2)	
		Update HLW Nitrate, Nitrite, and Ammonia Discussion (4.2)	
		Reliability, Availability, and Maintainability Data (10.0)	
		Editorial Changes and Content Updates for Section 5.1 (Analytical laboratory) (5.1)	
		HMP Miscellaneous Updates for Rev 4 of the BARD (4.2)	
		Add Dilution and Sugar R&T Information (3.1)	

History Sheet

Rev	Date	Reason for the revision	Revised by
		Add Correct Reference (2.6)	
		Update: Reliability, Availability and Maintainability Data (Appendix D)	
		Updating Section 6.2, Process Reagents in BOF (6.2)	
		Updating Section 6.3, Chilled Water in BOF (6.3)	
		Updating Section 6.4, Plant Cooling Water (6.4)	
		Updating Section 6.5, Plant Steam (6.5)	
		Updating section 6.6, Plant Air (6.6)	
		Updating Section 6.7, Process Service Water (6.7)	
		Updating Section 6.8, Medium-Voltage Electrical and Low Voltage Electrical (6.8)	
		Updating Section 6.9, Diesel Fuel Oil (6.9)	
		HFP Miscellaneous Updates for BARD Rev 4 (4.1)	
		Editorial Changes and Content Updates for Section 4.3 (4.3)	
		LAW Rheology and Physical Property Reconciliation (3.1)	
		Air Emissions (7.1)	
		Editorial Changes and Content Updates to Section 4.4 (4.4)	
		Editorial changes and content updates for Section 2.11, RDP (2.11)	
		Editorial Changes and Content Updates to Section 3.6 (3.6)	
		WTP Feed and Chemistry Overview (1.3)	
		Appendix B: Batch Volumes and Set Point Tables (Appendix B)	
		Editorial Changes and Content Updates to Section 4.7 (4.7)	
		Updating WTP System Overview (1.2)	
		Editorial Changes and Content Updates to Section 3.7 (3.7)	
		Content Updates to Appendix E	
		RF Incorporation and CRP Updates for Rev 4 (2.9)	
		Additional Glass Former Reagent System Updates (6.1)	
		Editorial Changes and General Content Updates for Section 3.1 (3.1)	
		Editorial Changes and General Content Updates for Section 2.18 (2.18)	
		Reconcile SCT-MOSRLE60-00-183-02 Data (2.6)	
		Content Updates to Appendix A	

History Sheet

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		Incorporation of Spherical Resorcinol-Formaldehyde as the Ion Exchange Resin for Cesium Removal - Part B (2.5)	
		Slurry Creep and flow blockage in PJM vent lines (2.14)	
		Update BARD with Phase 1 IHLW Model Development (4.1)	
		Content Updates to Appendix C	
		Selected Content Updates to Section 1.1 (1.1)	
		Major Revision of Section 2.3 for BARD Rev 4 (2.3)	
		Implement Chemistry into the Cesium Fresh Resin process (2.9)	
		Update LAW Melter DF for Sulfate (3.1)	
		Section Update (3.2)	
		UFP Model update for BARD Rev 4 (2.3)	
5	27 October 2009	ILAW Property Models 3.1, BARD, Rev 5	IZ Stone
		Update References for Section 2.1, FRP	
		Updates to System 3.4, RLD/NLD, for BARD, Rev 5	
		Updates to System 4.5, RLD-30/NLD-30, for BARD, Rev 5	
		Updates to System 9.2, RLD and NLD, for BARD, Rev 5	
		Editorial Changes to the BARD for Rev 5, Section 6.3	
		Updates to System 2.17, RLD (Pretreatment), for BARD, Rev 5	
		Updates to System 3.7, LRH, LPH, LFH, & LEH, for BARD, Rev 5	
		Updates to System 4.6, HDH, for BARD, Rev 5	
		Updates to Systems 4.8, HRH, HPH, HDH, and HEH, for BARD, Rev 5	
		Update to System 2.14, PJV	
		Update to System 2.13, PVP/PVV	
		Editorial Changes to the BARD for Rev 5, Section 6.4, PCW	
		Editorial Changes to the BARD for Rev 5, Section 6.5, LPS	
		Editorial Changes to the BARD for Rev 5, Section 6.6, PSA	
		Editorial Changes to the BARD for Rev 5, Section 6.7, PSW	
		Updated HLP Section (2.4), HLP, for BARD, Rev 5	
		Incorporate RTC 416 into BARD, Rev 5	
		Update of Section 3.5, CDG, for BARD, Rev 5	
		Update of Section 6.1, GFR, for BARD, Rev 5	

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Rev	Date	Reason for the revision	Revised by
		Update of Section 2.9, CRP, for BARD, Rev 5	
		Update of Section 2.11, RDP, for BARD, Rev 5	
		Update of Section 2.5, CXP, for BARD, Rev 5	
		Update of Section 2.6, CNP, for BARD, Rev 5	
		Update of Section 6.8, MVE, for BARD, Rev 5	
		Update of Section 3.2, LMP, for BARD, Rev 5	
		Update of Section 4.2, HMP, for BARD, Rev 5	
		Update of PWD Section 2.15 of BARD, Rev 5	
		Update of DFO Section 6.9 of the BARD, Rev 5	
		Update of Section 2.2, FEP, for BARD, Rev 5	
		Update of Section 2.12, TLP/TCP, for BARD, Rev 5	
		Update of Section 2.16, PT, for BARD, Rev 5	
		Update of Section 4.7, HLW, for BARD, Rev 5	
		Update of Section 3.6, LAW, for BARD, Rev 5	
		Update of Section 6.2, BOFRe for BARD, Rev 5	
		Update of Section 3.3, LOP/LVP, for BARD, Rev 5	
		Update of Section 4.3, HOP, for BARD, Rev 5	
		Update of Section 9.1, RSW, for BARD, Rev 5	
		Update of Section 10.0, RAM, for BARD, Rev 5	
		Update of Section 2.18, PIH, for BARD, Rev 5	
		Update of Section 5.1, LAB, for BARD, Rev 5	
		Dimethyl Mercury Discussion for UFP, Section 2.3	
		Update to HLW PJV System 4.4 for BARD, Rev 5	
		Update of UFP Section 2.3 for Rev 5, BARD	
		Update of Section 3.1, LFP, for Rev 5 of the BARD	
		0. Update of Section 7.1, EMISS, for Rev 5 of the BARD	
		Update of Section 1.3 for Rev 5 of the BARD	
		Update of Section 4.1 for Rev 5 of the BARD	
6	23 June 2011	New LAW offgas constituents and DF corrections	IZ Stone
		Revision of Section 2.3.5.6	
		Update caustic scrubber DFs for NO2 and CO2	
		New HLW offgas constituents and DF corrections	
		Update phosphate and aluminum solubility correlations	

History Sheet

Rev	Date	Reason for the revision	Revised by
		Update fate of mercury fed to LAW melters	
		Update LOP/LVP fate of mercury	
		Update fate of mercury fed to HLW melters	
		Update HOP fate of mercury	
		2.2 *System FEP: Feed Evaporator Process*	
		Revision to reflect updated system description document	
		Update of LAW melter DFs based on the conversion of CCN 160525 to an engineering calculation	
		Update of HLW melter DFs from revised engineering calculations	
		BARD Rev 6 updates and editorial changes to Section 2.17.	
		BARD Rev 6 updates to Section 2.6	
		BARD Rev 6 update of the LAW liquid waste disposal process	
		BARD Rev 6 update of LAW interfaces with WTP reagents, ammonia reagent, and demineralized water	
		BARD Rev 6 update of HLW pulse jet ventilation	
		BARD Rev 6 update of the HLW liquid waste disposal process	
		BARD Rev 6 update of radioactive solid waste management	
		BARD Rev 6 update of liquid effluents	
		Boehmite kinetics and smart logic	
		Combined HLW DFs	
		Update CXP for BARD Rev 6	
		Update CRP for BARD Rev 6	
		2.12 *System TLP/TCP: Treated LAW Evaporation and Concentrate Storage Process*	
		Update BARD Section 2.1, FRP for BARD Rev 6	
		Update of PT interfaces with WTP reagents and DIW (NAR, STR, SPR, SHR, AFR, and DIW)	

History Sheet

Rev	Date	Reason for the revision	Revised by
		BARD update of system LOP/LVP: LAW primary offgas and secondary offgas process RC (equip) / WL (DFs)	
		BARD update of system LRH, LPH, LFH, & LEH: LAW mechanical handling	
		BARD update of system HOP: HLW melter offgas treatment process RC(mech)/ WL (DFs)	
		BARD update of system HDH: HLW canister decontamination handling system	
		BARD update of system HRH, HPH, HDH, and HEH: HLW mechanical handling	
		BARD Rev 6 update of system CDG: LAW carbon dioxide gas	
		BARD Rev 6 update of system GFR: glass formers reagent system	
		BARD Rev 6 update of reagents received at BOF for use throughout the WTP (AFR, AMR, NAR, SHR, SPR, and STR)	
		BARD Rev 6 update of system CHW: chilled water	
		BARD Rev 6 update of system PCW: plant cooling water	
		BARD Rev 6 update of system LPS, HPS, SCW: plant steam	
		BARD Rev 6 update of system PSA, ISA: plant air	
		7 *System PSW, DIW: Process Service and Demineralized Water*	
		BARD Rev 6 update of system MVE and LVE: medium-voltage electrical and low-voltage electrical	
		BARD Rev 6 update of system DFO: diesel fuel oil	
		Update BARD Section 2.4 for Rev 6	
		BARD Rev 6 update of pretreatment in-cell handling system (PIH)	
		BARD Rev 6 update of Analytical Laboratory	
		Update Section 2.15 for BARD Rev 6	
		3.1 LMFP BARD Rev 6 updates	
		4.1 HMFP BARD Rev 6 updates	
		small scale melter tests	

History Sheet

Rev	Date	Reason for the revision	Revised by
		Update section 2.3 for BARD Rev 6	
		Update of Appendix B for BARD Rev 6	
		Update of Section 2.13 for BARD Rev 6	
		Update of Section 2.14 for BARD Rev 6	
		Update of Appendix F for BARD Rev 6	
		Update to Appendix D, *Reliability, Availability, and Maintainability Data* for the BARD, Rev 6 update	
		Update to Appendix A *PFDs and P&IDs*	
		Updates to Chapter 10, *RAM Data* for BARD Rev 6	
		Update to Appendix E for BARD Rev 6	
		Update to Appendix C for BARD Rev 6 - *Assumptions*	
		LAW component DFs reformatted for BARD Rev 6	
		HLW component DFs reformatted for BARD Rev 6	
		Additional BARD Rev 6 updates to system CDG	
		Temp name - air emissions report	
		BARD Rev 6 update of WTP system overview	
		Appendix B modifications	
		Assumption resolution and closure to Section 2.3 for BARD Rev6	
7	3/29/2013	Updated the front matter to include a disclaimer that places limitations on referencing this document for design input.	
		Updated Introduction and Purpose to address changes made for this new revision	
		Updated overview diagrams	
		Replaced UFP-02A/B "Double Batching" Operation with "Back End Leaching" operation	
		In the HLP system updated cool down times and minimum volumes and references	
		In the LMP system deleted LAW melter energy balance, added a new section that address the loss of semi volatile species from the glass during LAW melter feed interruptions and updated description of LOP HEPA filters.	
		For the HLW melters, deleted the melter energy balance, provided clarification on the different HLW glass densities in the document and provided a new section that varies the melter production rate based on the composition of HLW feed.	

History Sheet

Rev	Date	Reason for the revision	Revised by
		Appendix B, Updated vessel volumes and vessel effluent rates	

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Disclaimer

The information contained in this document is a best effort attempt to capture the inputs needed to accurately simulate the WTP operation and design. The contents are based on a variety of different sources; some of these sources may not meet the stringent requirements for WTP design input. This document is not a hierarchical document listed in the *Technical Baseline Description,* 24590-WTP-RPT-ENG-01-001. The Technical Baseline Description establishes the current approved set of design basis documents, design documents, and facility documents that defines the physical and functional characteristics of the WTP Structures, Systems, and Components (SSC). Therefore do not reference this document for input to the WTP design.

Acronyms and Abbreviations

ACE	acetonitrile/acrylonitrile/acetone
ACI	American Concrete Institute
ACM	Aspen Custom Modeler (Aspen, 1999; Steady-State Flowsheet Model)
ADS	air displacement slurry
AES	Aspen Engineering Suite
AFA	antifoaming agent
AFR	anti-foam reagent system
AHL	analytical hot cell laboratory equipment system
ALARA	as low as reasonably achievable
AMCA	Air Movement and Control Association
AMR	anhydrous ammonia reagent system
ANSI	American National Standards Institute
APC	additional protection class
ARI	Air Conditioning and Refrigeration Institute
ARL	analytical radiological laboratory equipment system
AS	alpha spectrometry
ASCE	American Society of Civil Engineers
ASD	adjustable speed drive
ASME	American Society of Mechanical Engineers
ATA	analytical time available
AV	axial velocity
AWWA	American Water Works Association
BACT	best available control technology
BARCT	best available radionuclide control technology
BARD	*Flowsheet Bases, Assumptions, and Requirements* document
BNFL	British Nuclear Fuels, Limited
BNI	Bechtel National, Inc.
BOC	bubble of concern
BOD	Basis of Design
BOF	Balance of Facilities
BTU	British thermal units
BV	bed volume

C&I	controls and instrumentation
CARB	California Resource Board
CAS	Chemical Abstract Service
CCC	centerline cooling curve
CCP	chiller/compressor plant
CCTV	closed circuit television
CDD	chlorinated dibenzo dioxins
CDF	chlorinated dibenzo furans
CDG	carbon dioxide gas system
CF	conversion factor
CFR	Code of Federal Regulations
CH	contact-handled
CHW	chilled water system
CIX	cesium ion exchange
CL	caustic leaching
CND	conventional non-dilute
CNP	cesium nitric acid recovery process system
COPC	constituents of potential concern
CRP	cesium resin addition process system
CRV	concentrate receipt vessels
CUF	cell unit filter
CWP	Purex cladding waste
CXP	cesium ion exchange process system
DBE	design basis events
DBP	dibutylphosphate
DCN	design change notice
DFO	diesel fuel oil system
DF	decontamination factor
DIW	demineralized water system
DM	DuraMelter
DMHg	dimethyl mercury
DOE	US Department of Energy
DOW	domestic (potable) water system
DQO	data quality objective
DRE	destruction and removal efficiencies

DST	double shell tank
EC	electrical conductivity
EDG	emergency diesel generator
EDTA	ethylenediamine tetra-acetic acid
EFRT	External Flowsheet Review Team
EPC	engineering, procurement, and construction
EQL	estimated quantitation limit
ESP	Environmental Simulation Program
ETF	effluent treatment facility
FEP	waste feed evaporation process system
FH	Fluor Hanford
FRP	waste feed receipt process system
FSAR	final safety analysis report
FT-IR	Fourier transform infrared instrument
FY	fiscal year
GFC	glass forming chemical
GFR	glass formers reagent system
GFSF	glass former storage facility
GKN	(filter brand)
GPC	gas proportional counting
GS	gamma spectroscopy
HCl	hydrochloric acid
HCP	HLW concentrate receipt process system
HDH	HLW canister decontamination handling system
HEDTA	N2 hydroxyethyl ethylenediamine tri-acetic acid
HEH	HLW canister export handling system
HEME	high-efficiency mist eliminator
HEPA	high-efficiency particulate air (filter)
HF	hydrofluoric acid
HFP	HLW melter feed process system
HGR	hydrogen generation rates
HIC	high-integrity containers
HLP	HLW lag storage and feed blending process system
HLW	high-level waste
HMP	HLW melter process system

HOP	HLW melter offgas treatment process system
HP	high pressure
HPAV	hydrogen in pipes and ancillary vessels
HpCDD	heptachlorodibenzodioxin
HpCDF	heptachlorodibenzofuran
HPH	HLW canister pour handling system
HPS	high-pressure steam system
HRH	HLW canister receipt handling system
HSSWAC	Hanford Site solid waste acceptance criteria
HVAC	heating, ventilation, and air-conditioning
HxCDD	hexachlorodibenzodioxin
HxCDF	Hexachlorodibenzofuran
IAP	ion activity product
IC	ion chromatography
ICD	interface control document
ICN	integrated control network
ICP	inductively coupled plasma
IDA	iminodiacetic acid
IEEE	Institute of Electrical and Electronic Engineers, Inc.
IHLW	immobilized high-level waste
ILAW	immobilized low-activity waste
INEEL	Idaho National Engineering and Environmental Laboratory
IRP	issue response plan
ISA	instrument service air
ISA	International Society for Measurement and Control
ISARD	integrated sampling and analysis requirements document
ITS	important to safety
IX	ion exchange
Lab	Analytical Laboratory
LAW	low-activity waste
LC	load centers
LCO	limited conditions for operation
LCP	LAW concentrate receipt process system
LDR	land disposal restriction
LEH	LAW container export handling system

LERF	liquid effluent retention facility
LFH	LAW container finishing handling system
LFL	lower flammability limit
LFP	LAW melter feed process system
LIH	Analytical Laboratory in-cell handling system
LIMS	Laboratory information management system
LLW	low-level waste
LMP	LAW melter process system
LOOP	loss of offsite power
LOP	LAW primary offgas process system
LP	low pressure
LPH	LAW container pour handling system
LPS	Low-pressure steam system
LRH	LAW container receipt handling system
LSC	liquid scintillation counting
LSH	LAW melter equipment support handling system
LVE	low voltage electrical (480/208/120 V) system
LVP	LAW secondary offgas/vessel vent process system
MCR	model change request
MDL	method detection limit
MEK	methyl ethyl ketone
MFD	mechanical flow diagram
MFPV	melter feed preparation vessel
MFV	melter feed vessel
MIBK	4-methyl-2-pentanone
MIC	microbiologically induced corrosion
MMHg	monomethyl mercury
MRQ	model run request
MS	mass spectrometry
MSDS	material safety data sheet
MSM	master-slave manipulator
MTBF	mean time between failures
MTBM	mean time between maintenance
MTG	metric tons of glass
MTTM	mean time to maintain

MTTR	mean time to repair
MVE	medium voltage electrical system
MW	molecular weight
MXG	miscellaneous gases system
MXR	miscellaneous reagents system
NAR	nitric acid reagent system
NAS	sodium aluminosilicate
NCAW	neutralized current acid waste
NLD	non-radioactive liquid waste disposal system
NPRD	nonelectronic parts reliability database
NLD	nonradioactive liquid waste disposal system
NEC	National Electric Code
NFPA	National Fire Protection Association
NPH	normal paraffin hydrocarbon
NTA	nitrilotriacetate acid
NTU	nephelometric turbidity unit
NUREG	Nuclear Regulatory Commision document
NAS	sodium aluminosilicates
OCDD	octachlorodibenzodioxin
OCDF	octachlorodibenzofuran
OD	outer diameter
OEE	operational equipment efficiency
OL	outer length
OL	oxidative leaching
OR	Operations Research
ORA	operational risk analysis
ORD	operations requirements documents
ORP	(US Department of Energy) Office of River Protection
OSHA	Occupational Safety and Health Administration (US Department of Labor)
P&ID	piping and instrumentation diagram
PCB	polychlorinated biphenyl
PCJ	process control system
PCT	product consistency test
PCW	plant cooling water system
PDMS	polydimethylsiloxane

PDSA	preliminary documented safety analysis
PeCDD	pentachlorodibenzodioxin
PeCDF	pentachlorodibenzofuran
PEP	Pretreatment Engineering Platform
PF	power factor
PFD	process flow diagram
PFH	pretreatment filter cave handling system
PFP	Plutonium Finishing Plant
PIC	product of incomplete combustion
PIH	Pretreatment In-Cell Handling System
PJM	pulse jet mixer
PJV	pulse jet ventilation system
PNL	electrical panels
PNNL	Pacific Northwest National Laboratory
PPG	polypropylene glycol
PSA	plant service air
PSW	process service water system
PT	pretreatment
PUREX	Plutonium-Uranium Extraction (Facility)
PVP	pretreatment vessel vent process system
PVV	process vessel vent exhaust system
PWD	plant wash disposal system
QARD	quality assurance requirements description
QL	quality level
R&T	Research and Technology
RAM	reliability, availability, and maintainability
RAMI	reliability, availability, maintainability, and inspectability
RAWP	risk assessment work plan
RBD	reliability black diagram
RCRA	Resource Conservation and Recovery Act of 1976
RDP	spent resin collection and dewatering process system
REDOX	reduction-oxidation
RF	release fraction
RF	resorcinol formaldehyde
RFD	reverse flow diverter

RH	remote handled
RL	radiological laboratory
RL	reporting limit
RLD	radioactive liquid waste disposal system
RPM	revolutions per minute
RRC	regulatory requirements
RSW	radioactive solid waste
RWH	radioactive solid waste handling
RWPF	remote waste processing facility
RWW	raw water system
SBS	submerged bed scrubber
scfm	standard cubic feet per minute
SCO	selective catalytic oxidation unit
SC PSA	safety-class plant service air system
SCR	selective catalytic reduction unit
SCW	steam condensate system
SDG	standby diesel generator
SDJ	stack discharge monitoring system
SHR	sodium hydroxide reagent system
SIPP	Secondary Integrated Pilot Plant
SLATE	System Level Automation Tool for Enterprises
SLS	solid-liquid separation
SNR	sodium nitrite reagent system
SOW	statement of work
SPR	sodium permanganate reagent system
SRD	safety requirements document
SRNL	Savannah River National Laboratory
SRTC	Savannah River Technology Center
SSFM	steady-state flowsheet model
SST	single shell tank
STR	strontium nitrite reagent system
T-BACT	best available control technology for toxic air pollutants
TAT	turnaround time
TBP	tribuyl phosphate
TCDD	tetrachlorodibenzodioxin

TCDF	tetrachlorodibenzofuran
TCE	trichloroethane
TCLP	toxicity characteristic leaching procedure
TCO	thermal catalytic oxidizer
TCP	treated LAW concentrate storage process system
TEDF	treated effluent disposal facility
TEMA	tubular exchange manufacturers association
TEP	technetium eluant recovery process system
TFC	Tank Farm Contractor
TFCOUP	*Tank Farm Contractor Operation and Utilization Plan*
TIBDT	Technical Integrated Baseline Development Team
TIC	total inorganic carbon
TLP	treated LAW evaporation process system
TMP	transmembrane pressure
TOC	total organic carbon
TRU	transuranic elements
TSC	total solids content
TWINS	Tank Waste Information Network System
TXP	technetium ion exchange process system
UBC	Uniform Building Code
UDS	undissolved solids
UFP	ultrafiltration process system
UFPV	ultrafiltration feed preparation vessel
UFV	ultrafiltration feed vessel
UPS	uninterruptible power supply
UTS	Universal Treatment Standards
VHT	vapor hydration test
VOC	volatile organic compound
VP	vapor pressure
VRF	volume reduction factor
VSL	Vitreous State Laboratory of The Catholic University of America
WAC	Washington Administrative Code
WAPS	waste acceptance product specification
WASRD	waste acceptance requirements document
WCSF	wet chemical storage facility

WESP	wet electrostatic precipitator
WL	waste loading
WSRC	Washington Savannah River Company
WTB	water treatment building
WTD	waste transfer data
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WVNS	West Valley Nuclear Services
XRD	X-ray diffraction
XRF	X-ray fluorescence

Executive Summary

The purpose of this report is to provide the comprehensive basis for the Process Flowsheet Models, the WTP Dynamic G2 flowsheet and the WTP Operations Research flowsheet that simulate the Hanford Tank Waste Treatment and Immobilization Plant (WTP) which includes the Pretreatment (PT) Facility, Low-Activity Waste (LAW) Facility, High-Level Waste (HLW) Facility, Analytical Laboratory (Lab), and Balance of Facilities (BOF). The bases presented in this document are derived from the WTP *Statement of Work* (DE-AC27-01RV14136) requirements, Research and Technology (R&T) testing results, WTP engineering documents, and assumptions. These models simulate the WTP operation based on the current design, and therefore is a design output rather than an design input for the WTP.

A model that is used for WTP design input is the Aspen Process Performance Simulation (APPS) Model. The APPS model is not based on this document, but instead its bases are documented in Engineering calculations.

One purpose of this document is to satisfy requirements listed for the reoccurring WTP Contract Deliverables 2.5, Operations Research Assessment and 2.6, the WTP Tank Utilization Assessment.

The primary reason for this revision of the WTP *Flowsheet Bases, Assumptions, and Requirements* document (BARD) at this time is to add a disclaimer to notify potential users that the WTP design, potential design changes or safety analysis are not to be based on the contents of this document[1].

However, the document has also been updated to incorporate newer information for the UFP and HLP system as well as new analysis of HMP and LMP that reflect the later information available for simulating these processes. Presently major studies and reviews are underway that are addressing the remaining identified technical issues for Pretreatment and HLW facilities. Construction and design changes are on hold until solutions have been agreed upon. Therefore it was decided, that it was not appropriate to incorporate these changes.

This report provides the WTP and DOE with a consolidated source for the bases, assumptions, and requirements for the WTP (G2,and OR) flowsheets. This information is in turn incorporated into the models that simulate the dynamic operational behavior of the WTP flowsheets. The functions, process descriptions, requirements, and flowsheet bases are presented in an abbreviated form for each of the major systems within the PT, LAW, and HLW Facilities. Also included within the BARD are descriptions of the WTP Lab and BOF.

[1] This document is not a hierarchical document listed in the *Technical Baseline Description,* 24590-WTP-RPT-ENG-01-001. The Technical Baseline Description establishes the current approved set of design basis documents, design documents, and facility documents that defines the physical and functional characteristics of the WTP Structures, Systems, and Components (SSC). Therefore do not reference this document for input to the WTP design.

1 Overview of Flowsheet Bases, Assumptions, and Requirements

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1.1 Introduction and Purpose

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) has been established by contract (DE-AC27-01RV14136) between Bechtel National, Inc. (BNI) and the US Department of Energy, Office of River Protection (DOE-ORP). Under the Contract, BNI is responsible for performing the design, construction, and commissioning of WTP. The plant will treat the Hanford tank waste and subsequently vitrify it. The plant includes a Pretreatment (PT) Facility, a High-Level Waste (HLW) Facility, a Low-Activity Waste (LAW) Facility, an Analytical Laboratory (Lab), and a multiple utilities and services facility called the Balance of Facilities (BOF). In accordance with the WTP *Statement of Work* (SOW) contained within the Contract, BNI developed process and facility models whose bases are found in the *Flowsheet Bases, Assumptions, and Requirements* document (BARD) (24590-WTP-RPT-PT-02-005). This revision of the BARD provides the latest update to the flowsheet basis of the WTP.

Process flowsheet models (Witness Operations Research [OR] and Gensym G2 Dynamic [G2]) are WTP Contract-specified requirements for producing simulations of the operations of the integrated WTP Facilities and are used for the basis of periodic assessments of the WTP. These assessments are used for supporting the WTP process and facility design, evaluation of proposed design and equipment changes, equipment sizing confirmation, process control evaluation, permitting and safety activities, pre-operational planning, technical integration with the Tank Farm Contractor, support of product and secondary waste acceptance activities, and to demonstrate compliance with WTP throughput requirements and the integrated availability requirements. In addition, the model simulations predict the WTP treatment period. The model simulation results are also used as a basis for determining some of the WTP Contractor's earned award fee.

The BARD is a comprehensive, single-source, living document that provides the links between the WTP detailed design, process equipment characteristics, process verification test results, process chemistry, process control strategies, feed characterization knowledge, nuclear safety impacts, emissions controls, regulatory requirements, commissioning, operations planning, and the contractual performance requirements. The BARD is the primary source for documenting inputs to the process simulation models (OR and G2). The BARD provides inputs for the simulations for all primary processing facilities, including the Pretreatment Facility, LAW Facility, HLW Facility, glass former storage, and cold chemicals makeup systems.

Basic engineering documents have been used in developing the flowsheet, including system descriptions, the *Basis of Design* (24590-WTP-DB-ENG-01-001), mechanical systems process flow diagrams, regulatory documents, piping and instrumentation diagrams, and design change notices (DCN). The main source document used to reflect the operating control strategy for the WTP is the *WTP Integrated Processing Strategy Description* (24590-WTP-3YD-50-00002). This document provides the selected monitoring and control approaches for normal operations of the PT, LAW, and HLW Facilities. Process flow diagrams (PFD) were selected as the focal point to maintain consistency and alignment between engineering design and the WTP flowsheet; thus, the WTP flowsheet has been reviewed against the June 2011 revisions of the PFDs to ensure consistency. The development of the WTP flowsheet is an iterative process with feedback. That is, the initial estimate of what the flowsheet would look like started with a set of mechanical system descriptions and best estimates of process knowledge. The flowsheet has evolved with each revision of the BARD, and with the periodic review of the changes and modifications to the WTP.

The BARD is divided into 10 sections plus appendices that present pertinent information related to the WTP processes. Section 1.0 provides an overview of WTP and also points to principal highlights since the last revision. Section 2.0 discusses the bases and assumptions for the PT Facility and its processes.

Sections 3.0 and 4.0 present the bases, assumptions, and functionality for the LAW Facility and HLW Facility, respectively. Section 5.0 discusses the functions and requirements of the Lab and its support interfaces with WTP.

The principal function of Section 6.0 is to provide information about the BOF, which includes a description of its functional relationships to the other WTP facilities. The air emissions bases information, as derived from the steady-state flowsheet model, is presented in Section 7.0. Section 8.0 has been purposely deleted. Included within Section 9.0 are discussions on miscellaneous systems, which include radioactive solid waste management and liquid effluents used in WTP processes. Section 10.0 discusses the operational research model for WTP and includes the bases and assumptions along with how this information is applied to WTP.

Lastly, the appendices include the tabulated reference data sheets for PFDs and DCNs incorporated into the respective BARD sections; a tabulated list of batch (vessel) volumes and setpoint tables; a summary of assumptions set forth in each of the applicable sections; a summary of reliability, availability, and maintainability data; a list of reconciled R&T report results that have been incorporated into the BARD; and a tabulation of line flush locations and volumes.

The highlights reflected in this revision of the BARD are the concerted effort to align the updated system descriptions, mechanical systems PFDs, piping and instrumentation diagrams, DCNs, *Basis of Design* (24590-WTP-DB-ENG-01-001), WTP Contract requirements (DE-AC27-01RV14136), and process verification test results to the cadre of flowsheet computer models.

Since BARD Revision 6, additional design internal reviews and oversight activities have been underway for the purpose of identifying and resolving the remaining technical issues in order to reach an agreement on the final design and operating limits. As a result, only LAW, BOF, and Laboratory facilities are progressing their design and complete the remaining construction activities. The Pretreatment and HLW facilities design and construction activities are on hold until the extensive internal and external reviews are completed. This revision of the BARD is limited to addressing specific documented design changes, corrections of identified errors in the previous revision, new documented data from testing, and the addition of a disclaimer that states the BARD is not to be used as a source for the WTP design.

1.1.1 References

24590-WTP-3YD-50-00002, Rev 1, *WTP Integrated Processing Strategy Description.*

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

DOE. 2000. DOE Contract DE-AC27-01RV14136, *Hanford Tank Waste Treatment and Immobilization Plant,* as amended. US Department of Energy, Richland Operations Office, Richland, WA.

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1.2 WTP System Overview

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) contains three major waste treatment processing areas and two important supporting facilities. The major processing areas are the Pretreatment (PT) Facility; the Low-Activity Waste (LAW) Facility, and the High-Level Waste (HLW) Facility. Additionally, there are the Analytical Laboratory (Lab) and the Balance of Facilities (BOF). Each of these processing areas is summarized below. Graphic illustrations of these processes are shown in Figure 1.2-1, Figure 1.2-2, Figure 1.2-3, and Figure 1.2-4, respectively.

1.2.1 Pretreatment

The Hanford Tank Farm Contractor transfers waste from the waste tanks to the PT Facility. The LAW waste is transferred to the WTP as solutions that may contain some undissolved solids. The LAW is received in the feed receipt process vessels, FRP-VSL-00002A/B/C/D. Typically, about one million gallons of LAW feed is transferred at a single time to the four FRP-VSL-00002 vessels.

The HLW undissolved solids are transferred as a slurry, also containing dissolved solids, into the WTP PT HLW lag storage process (HLP) vessel HLP-VSL-00022 in the PT Facility.

Recycle streams from the PT, LAW, and HLW Facilities and wastes that are both low in sodium concentration and solids content are concentrated in the waste feed evaporator. Normally, the sodium concentration from the waste feed evaporator is about 5 M sodium. However, other processing constraints (for example, undissolved solids concentration and slurry specific gravity) may require a lower sodium concentration.

When the sodium concentration is acceptable for further processing (either as-received or after evaporation), the wastes are processed as follows:

- LAW Envelopes A or B feeds are blended with HLW feeds in an ultrafilter preparation vessel. The ratio of LAW to HLW undissolved solids is established to support both LAW and HLW glass production rates. The solids from the blended HLW and LAW feed streams are normally caustic and oxidative leached (if necessary) and filtered to separate the LAW liquid stream (permeate) from the slurry. The LAW permeate then is processed through the ion exchange (IX) process discussed below. The concentrated solids slurry is washed, and blended with ^{137}Cs concentrate from IX before being transferred to the HLW Facility.
- Envelope C feeds contain organic complexants that cause the Sr and some TRU waste to remain in solution. Envelope C waste undergoes a ^{90}Sr/TRU precipitation process before filtration. The filtration step then separates the ^{90}Sr/TRU solids, manganese oxide solids (a byproduct from the precipitation process), and entrained solids from permeate (LAW stream). The ^{90}Sr/TRU precipitate is washed and stored in preparation for blending with HLW feed before HLW vitrification. The ^{90}Sr/TRU precipitate is not caustic leached. Envelope C permeates are processed through the IX process. At this time, US Department of Energy, Office of River Protection (DOE-ORP) is expecting that the ^{90}Sr/TRU precipitation process will occur in the Tank Farms. The latest ORP feed vector does not classify any of the feed batches as Envelope C. However, ORP requires BNI to maintain the processing capability to treat Envelope C waste.
- After filtration, the permeate passes through the IX process to remove cesium. The Cs eluate, a dilute nitric acid stream, is concentrated by evaporation to recover the nitric acid. The Cs is then transferred and subsequently neutralized in the HLW lag storage and feed blending process system (HLP). This process, which takes place in the blend vessel along with the pretreated HLW solids, will occur

before being transferred to the HLW vitrification process. The last step in the PT Facility is to concentrate the treated LAW liquid by evaporation prior to being transferred to the LAW Facility.

The PT Facility also contains a PT vessel vent process system (PVP), an offgas treatment system, and a stack. Liquid effluents are either recycled back into the facility or sent to the Hanford Site liquid effluent retention facility.

The PT Facility is designed to process LAW feed at a higher rate than can be processed through the WTP LAW Facility. At present, DOE-ORP is developing a plan for supplemental LAW waste treatment. The undefined supplemental LAW treatment process will process treated LAW feed from the WTP PT Facility.

1.2.2 LAW Vitrification

Treated LAW from PT is transferred to the LAW Facility for vitrification. The LAW vitrification process consists of two melter systems operated in parallel. Each melter system has a set of feed preparation vessels, a joule-heated ceramic melter, and an offgas treatment system. The facility also has a secondary offgas system shared by the two melter systems. The following description applies to each of the two LAW melter systems.

Pretreated LAW waste feeds are received into one of two common LAW concentrate receipt vessels within the LAW Facility. Batches of concentrated LAW feed are transferred from these vessels to the melter feed preparation vessels, where glass formers and sucrose are added and blended to form a uniform batch of feed to the LAW melters. The slurry feed is transferred to the melter feed vessels, where it is fed continuously to the LAW melters.

Each LAW melter is designed to operate at a facility design capacity of 15 metric tons per day of immobilized low-activity waste (ILAW). The feed enters the melter from the top and forms a cold cap layer on top of the melt pool. Volatile components in the feed are evaporated or decomposed, then drawn off through the melter offgas system. Nonvolatile components react to form oxides or other compounds dissolved in the glass matrix. Bubblers agitate the mixture to increase the glass production rate. An airlift system pours the glass from the melter into stainless steel containers. Each container holds about 6 metric tons of ILAW.

Each LAW melter system has its own primary offgas equipment, including a film cooler, submerged bed scrubber (SBS), and wet electrostatic precipitator (WESP). Particulates and condensables, including entrained or volatilized radionuclides in the melter offgas stream, are captured in the SBS and WESP. Condensables from the SBS and the WESP are collected in the liquid effluent system and recycled to the treated LAW evaporator in the PT Facility. The primary offgas systems join after the WESP, and are routed to the secondary offgas system. At this point, the LAW vessel vent header joins the offgas. The secondary offgas system provides final filtration, removes halides and mercury, destroys organics, and reduces NO_x. This is done by using high-efficiency particulate air (HEPA) filters, activated carbon columns, a thermal catalytic oxidizer, a selective catalytic reducer, and a caustic scrubber.

After being filled, each ILAW container cools for several days, then a lid is sealed to the top of the container and external contamination is removed by a CO_2 decontamination process.

1.2.3 HLW Vitrification

The HLW Facility receives pretreated HLW feed from the PT Facility. Treated Envelope D slurry and cesium concentrate from the cesium nitric acid recovery process (CNP) make up the feed to the HLW Facility. The HLW vitrification process consists of two joule-heated ceramic melters fed by independent feed and blending vessel trains, a dedicated offgas treatment system for each melter, and a common, secondary effluent collection system. A common canister receipt system supplies canisters to separate melter pouring systems, providing immobilized high-level waste (IHLW) to a common product canister decontamination and export system. HLW feed concentrate is transferred from the PT Facility to the HLW Facility. Batches of HLW feed concentrate are transferred to one of the two melter feed preparation vessels. The feed concentrate is blended with glass forming chemicals and mixed to ensure a uniform mixture. The melter feed slurry is transferred to the melter feed vessel, where it is fed to a dedicated HLW melter.

Each original HLW melter is designed to operate at a melter design capacity of 3 metric tons per day IHLW; the facility is designed to support operation of second-generation melters, each having a design capacity of 3.75 metric tons per day (CCN 153750). The melter feed slurry is introduced at the top of the melter and forms a cold cap on the surface of the melt pool. Water and volatile components evaporate or decompose and are drawn off through the offgas system. Nonvolatile components react to form oxides that become part of the molten glass.

Each HLW melter has a dedicated primary and secondary offgas system where the offgas from the melter passes through a film cooler, SBS, WESP, high-efficiency mist eliminators (HEME), and HEPA filters to remove particulates and radionuclides. It then passes through a secondary offgas system consisting of fans, activated carbon columns, recuperative heat exchangers, a silver mordenite column, a thermal catalytic oxidizer, and a selective catalytic reducer. This secondary system removes halides and mercury, destroys organics, and reduces NO_x.

An airlift system inside the melter transfers molten HLW glass into stainless steel canisters. Each filled canister is then inspected, the glass is sampled as necessary, and the canister is sealed. The canisters from the two melters are decontaminated by a nitric acid/cerium (HNO_3/Ce^{+4}) chemical milling process that dissolves a thin layer of the canister outer wall. Canister decontamination waste effluents are recycled to the PT Facility. The decontaminated canister is then swabbed remotely to determine contamination levels. If the surface contamination is within limits, then the filled canister is transferred to the interim storage area, where it is stored before being transferred to DOE. Canisters that exceed surface contamination limits are reworked until radioactivity levels fall within surface contamination specification limits.

1.2.4 References

24590-WTP-RPT-ENG-06-011, Rev 0, *Engineering Study For Resolution Of EFRT Issue M13-Improvement Of Ultrafilter Surface Area And Flux.*

CCN 132846, *Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput.* 17 March 2006.

CCN 153323, letter, MK Barrett (ORP) to CE Rogers (BNI), *Contract Modification No. M080, Response to Bechtel National, Inc. Recommendation for Implementation of Pretreatment (PT) Capacity Modifications.* 2 March 2007.

CCN 153750, letter, CB Reid (ORP) to CE Rogers (BNI), *Contract Modification No. M083, Response to Bechtel National, Inc.(BNI) Recommendation for Implementation of Additional Capacity Modifications.* 13 March 2007.

CCN 187535, letter, TM Williams (ORP) to NF Grover (BNI), *Pretreatment Caustic Leaching Temperature Revision, Modification M140.* 8 October 2008.

Figure 1.2-1 Pretreatment Process Overview

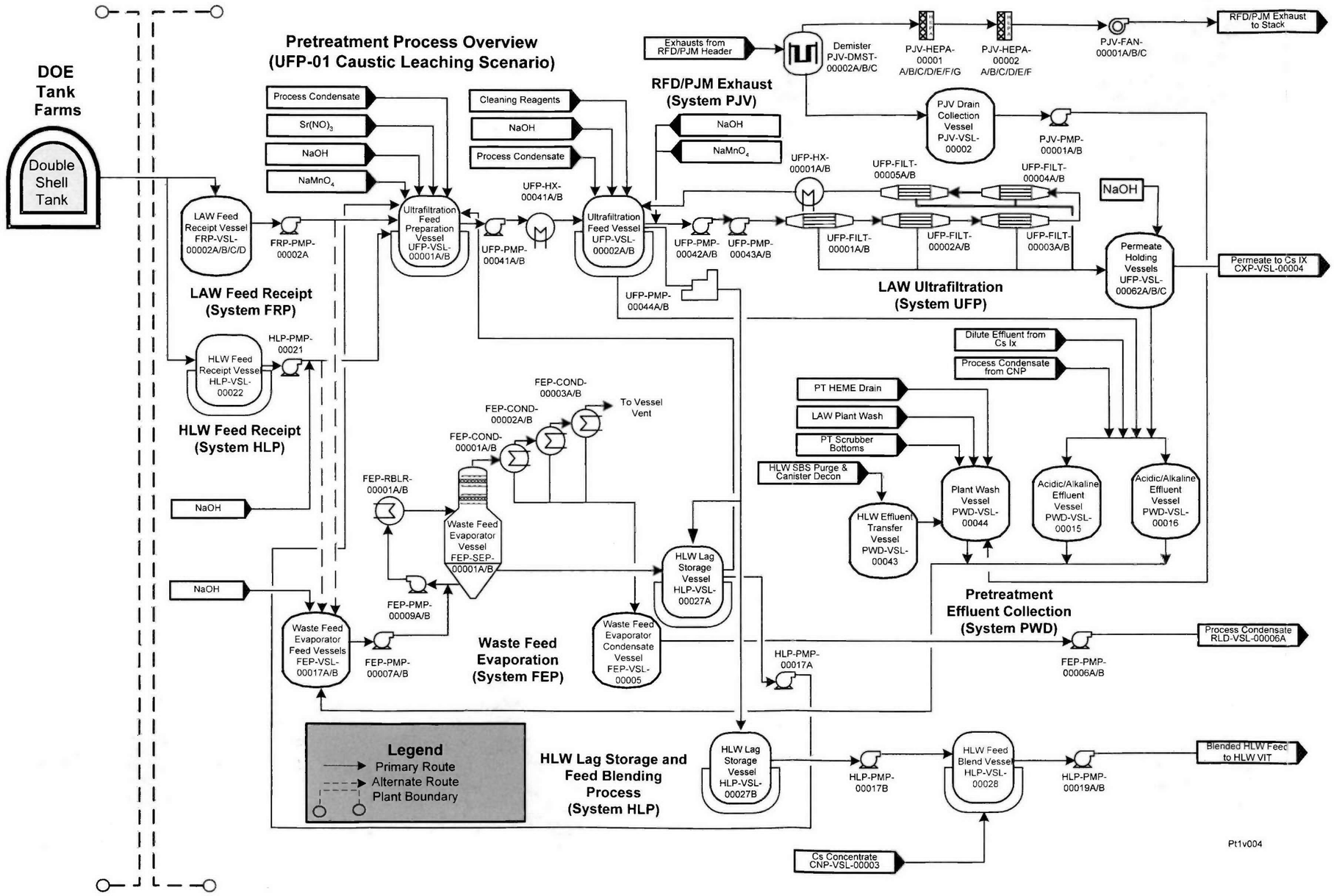


Figure 1.2-2 Pretreatment Process Overview (continued)

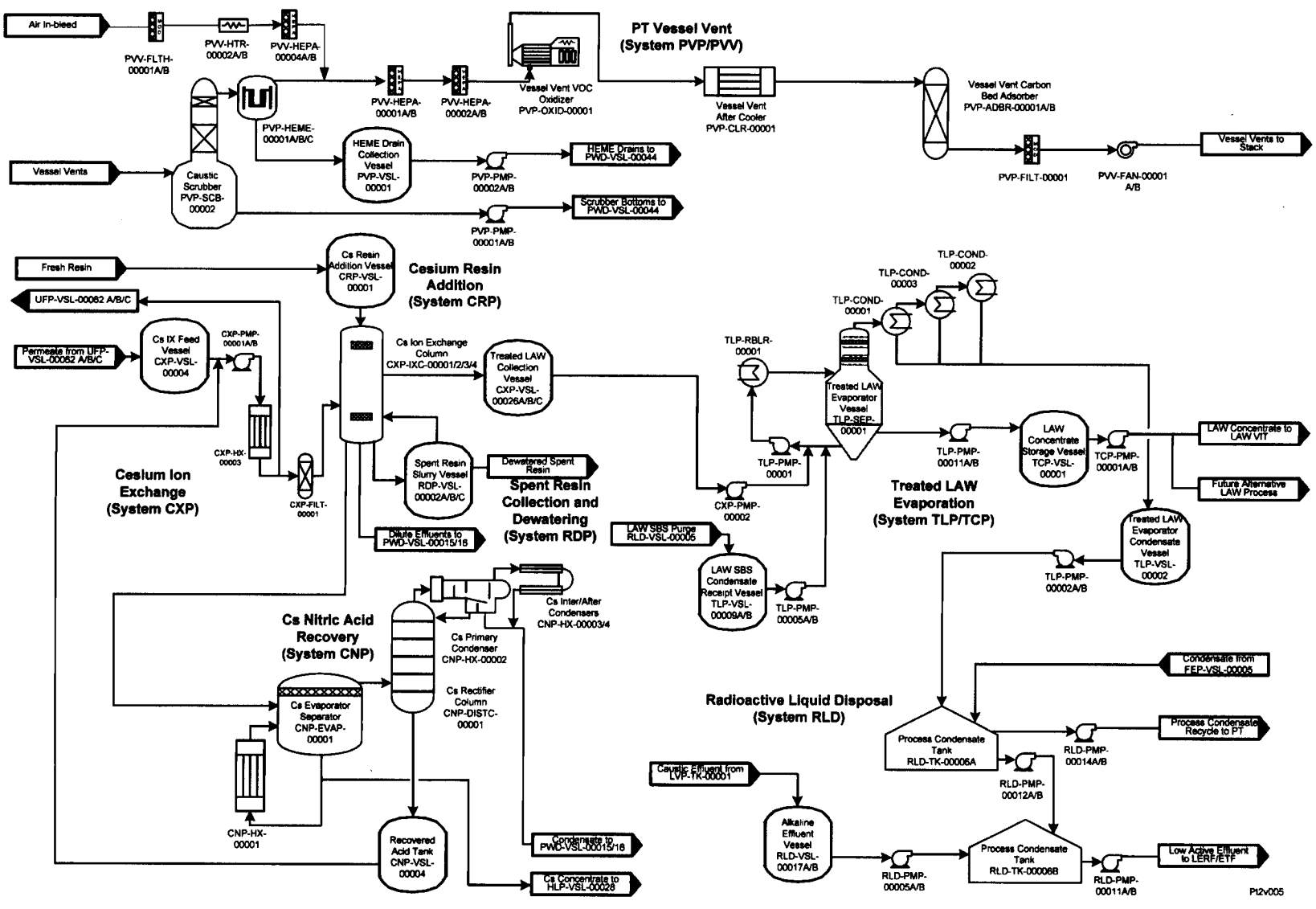


Figure 1.2-3 LAW Vitrification Process Overview

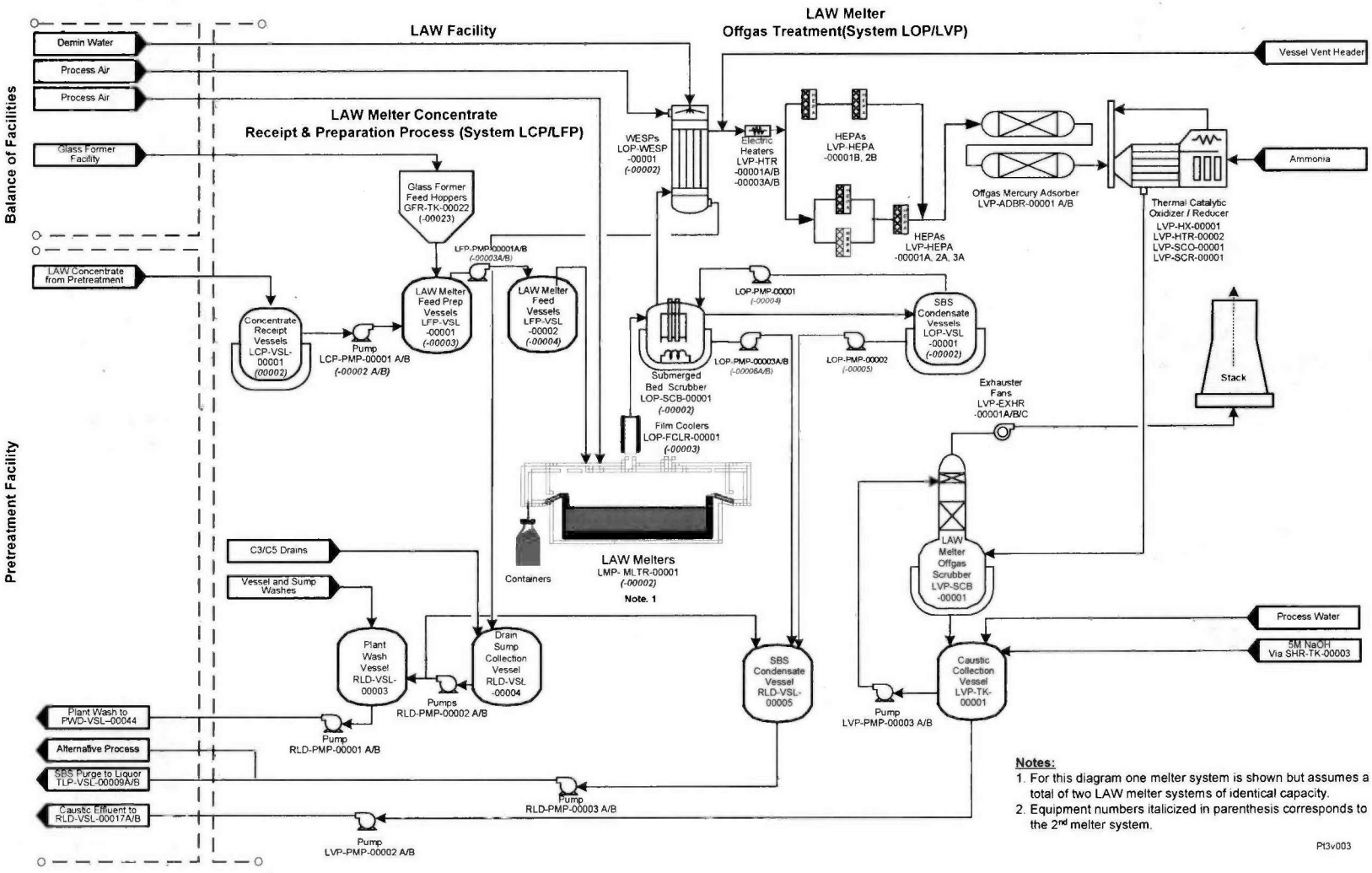
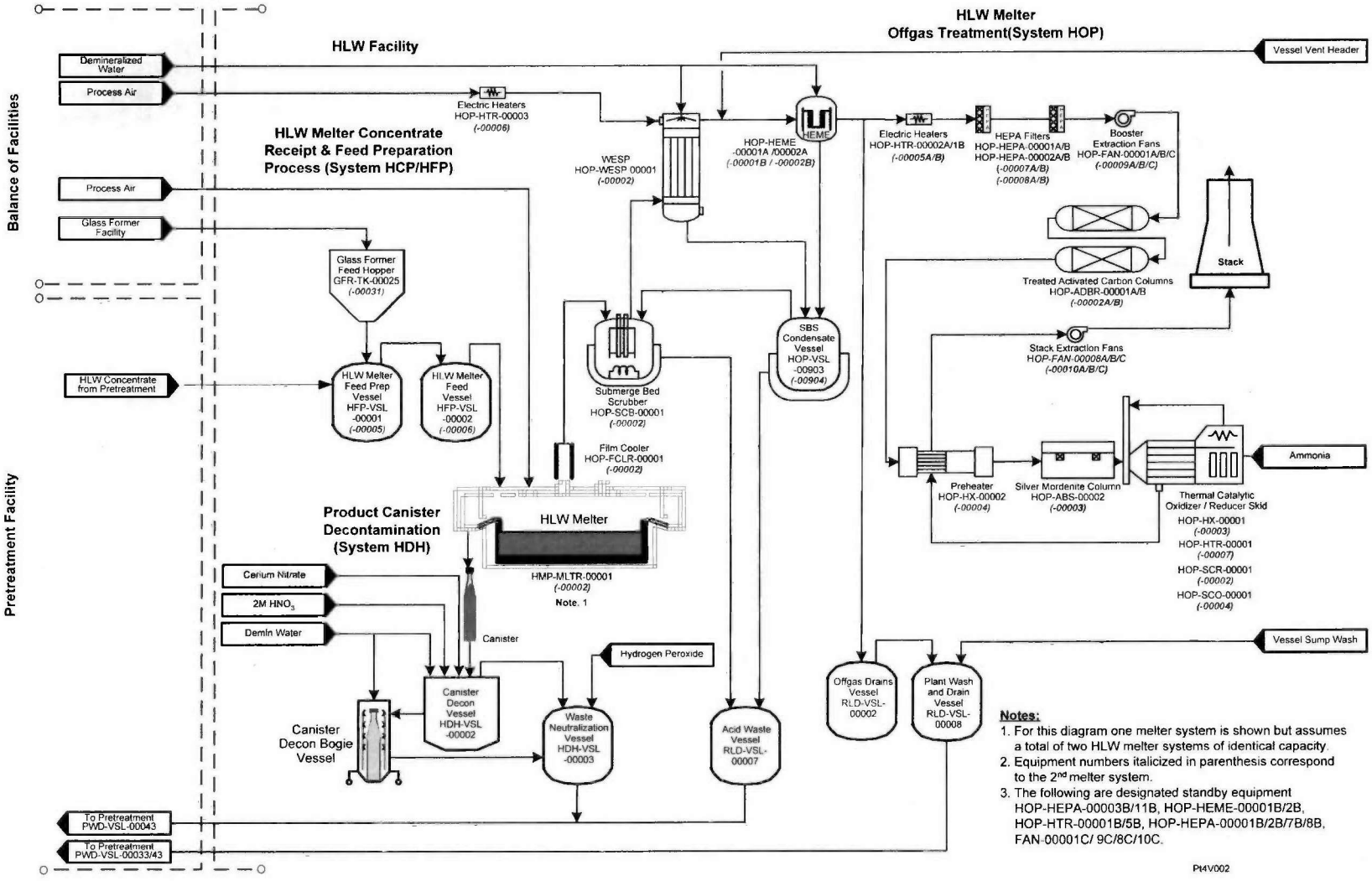


Figure 1.2-4 HLW Vitrification Process Overview



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1.3 Waste Feed Chemistry and Composition

1.3.1 Waste Feed Overview

The waste feed for the Hanford Tank Waste Treatment and Immobilization Plant (WTP) is variable because it is from many different sources (Agnew and others 1997). Since the Hanford project began, three different chemical processes the bismuth phosphate [$BiPO_4$], reduction-oxidation [REDOX], and plutonium uranium extraction [PUREX]) have been used to separate plutonium from spent fuel and targets received from many different nuclear reactors. Each of these processes had different waste streams, and the flowsheets for these processes changed over time. In addition, some of the $BiPO_4$ and PUREX wastes were later retrieved from the Tank Farms for further uranium, cesium, and strontium recovery, resulting in significant blending of the wastes. The retrieved wastes were returned to the tanks with chemical compositions altered by the recovery operations. Evaporators were used to reduce the waste volume, with the amount of evaporation depending on the waste composition and tank volume needs. The length of time that a waste was left in a waste tank at high temperature, in some cases boiling, also impacts the eventual mineral that formed from these wastes.

In addition to the chemical separation plants, many waste components were added to the tanks or blended together as part of an in-tank process to control corrosion, scavenge Cs before cribbing supernatants, pump liquids from single-shell tanks, and to control tank leaks (Agnew and others 1997). The process of retrieving and delivering feed to the WTP will result in blending of these diverse waste forms (Kirkbride and others 2007).
As a result of these previous waste processing activities, the tanks are filled with millions of gallons of waste as sludge, saltcake, and aqueous supernatant. Most of saltcakes' contents are expected to be dissolved before the waste delivery processing that are occurring in the tank farms.to and the sludges will be sluiced to WTP (Kirkbride and others 2007). The sludges consist primarily of oxides, hydroxides, or silicates of Al, Fe, Cr, Bi, Ni, U, Cd, Zr, and many more trace species and radionuclides (24590-101-TSA-W000-0004-114-00021). The supernatants are primarily sodium salts of NO_3^-, NO_2^-, OH^-, CO_3^{-2}, $Al(OH)_4^-$, PO_4^{-3}, SO_4^{-2}, F^-, Cl^-, CrO_4^{-2}, along with potassium and other trace species (Kirkbride and others 2007). Both sludge and saltcake contain large amounts of oxalate ($C_2O_4^{-2}$) and many other organics, including solvents and chelates (24590-WTP-RPT-RT-07-002).

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136, M147) divides this highly varied feed into only four envelopes. Envelope A feed is primarily liquid waste (< 3.8 wt% entrained solids) with lower concentrations of Cs, sulfur, Sr-90, and transuranic elements (TRU) than the concentrations of other waste groups. Envelope B is similar to Envelope A except that it is allowed to have more sulfate, Cs, and some trace elements. Envelope C is similar to Envelope A except that it is allowed to have more dissolved Sr-90 and TRU. All feeds with solids greater than 3.8 wt % are labeled Envelope D regardless of how much Cs, sulfate, Sr-90, or TRU contribute to the concentration. The feed group definitions are found in Specifications 7 and 8 of the SOW. It is noted that the feed envelope classifications, other than envelopes A&D, have largely lost their importance since the privation contract for WTP was canceled.

Given the wide range of feed compositions in the Tank Farms requiring treatment, a recent study investigated the feed composition estimate (called a feed vector) and grouped the feeds into 13 groups based on which element or elements in the feed, after WTP pretreatment, will limit the waste concentration in IHLW (24590-WTP-RPT-PE-07-001). In addition to these 13 groups, there is the low-activity waste (LAW) group, with low undissolved solids concentration, and the lead (Pb) group, that was impacting a single feed batch (24590-WTP-RPT-PE-07-001). The 13 groups are named as follows: aluminum low-leach, aluminum high-leach, chromium, bismuth, fluoride, iron-aluminum, phosphate, iron, zirconium-aluminum, sodium, calcium, uranium, and sulfate. Table 1.3-1 contains the number of

batches of each group and the quantity of IHLW made from each group from the above referenced report. Table 1.3-2 shows the species preventing higher wasting for HLW using System Plan Rev. 6, Case 1, the most recent Feed Vector provided by DOE. Each group is described in the following subsections.

1.3.1.1 Waste Feed Grouping Discussion

1.3.1.1.1 The Aluminum Low-Leach and High-Leach Groups

There are several compound and mineral forms of aluminum in Hanford tank farm wastes. Some of the mineral types are easily leached and others are not. Those batches with a high portion of aluminum minerals that are difficult to leach are in the *aluminum low-leach* (LL) group. These batches likely contain higher percentages of boehmite and cancrinite (two aluminum-bearing minerals).

Some batches contain a lot of more easily leached aluminum, but still make IHLW that is aluminum waste-loading limited simply because there is too little of any other component to be dominant once most of the aluminum is leached. These batches belong to the *aluminum high-leach* (HL) group. The aluminum in these groups is most likely in the form of gibbsite or dawsonite, which are more easily leached in caustic than boehmite or cancrinite.

The determination for which of the two aluminum groups the batch belongs is primarily based on the leach factor provided by the Tank Farm Contractor (24590-WTP-RPT-PE-07-001). Those batches having a aluminum leach factor less than or equal to 46.55 % are placed in the *aluminum-LL* group, while those with a factor greater than 46.55 % are placed in the *aluminum-HL* group. The two aluminum groups are the two most prevalent groups (Table 1.3-1)[1].

1.3.1.1.2 Chromium Group

The *chromium group* is the third most prevalent group (Table 1.3-1). On average, 15 % of the chromium is washed or caustic leached from the solids. It requires oxidative leaching to remove most of the chromium in this group. Even with oxidative leaching, there is still enough chromium remaining in the waste to limit waste loading in high-level waste (HLW) glass. The study determined that the feeds that fall into this group are based on the assumption that 85 % of the chromium is leached during oxidative leaching for all batches (24590-WTP-RPT-PE-07-001). If the effectiveness of oxidative leaching were to vary significantly from the assumed 85 %, the feed batches falling into this group would increase or decrease. Many feeds from other groups contain lots of chromium, however, chromium is not limiting to IHLW waste loading in those feeds after oxidative leaching.

1.3.1.1.3 Bismuth Group

The *bismuth group* is the fourth largest group, and has an average bismuth concentration of 3.67 wt % in the undissolved solids. Waste loading in the IHLW is limited by bismuth for these groups. This group also contains a lot of aluminum and more phosphate than any other group. It actually contains twice as much phosphate in the waste as the *phosphate group*; however, the phosphate compounds in the *bismuth group* are more easily leached (24590-WTP-RPT-PE-07-001). If more bismuth could be put into the glass than that assumed by 24590-WTP-RPT-PE-07-001; then, this group would become more like the *phosphate group*.

[1] Batches in the table as described herein were partitioned between the groups using TFCOUP Rev 6 feed vector and an older version of HLW glass models. Later feed vectors and HLW glass chemistry models will present a different distribution of the batches between the group but the distinction of the groups remains.

1.3.1.1.4 Fluoride Group

The *fluoride group* is the fifth most prevalent group, and is signified by the high concentration of fluoride and other halides in the feed (24590-WTP-RPT-PE-07-001). This group also contains high sulfate and oxalate concentrations in the solids relative to other groups. Fluoride and sulfate are known to form the sparingly soluble double salt Na_3FSO_4 (Toghiani and others 2005). There are several batches in the other groups with more fluoride than those in the *fluoride group*, but have components other than fluoride that limit the IHLW waste loading (24590-WTP-RPT-PE-07-001).

1.3.1.1.5 Iron-Aluminum Group

The aluminum in this group is significantly more leachable than in the *aluminum group*. Hence, iron becomes a major ingredient and participant in this group. Compared to other groups, this group contains higher concentrations of zirconium, thorium, neodymium, and cadmium.

1.3.1.1.6 Phosphate Group

The *bismuth group* contains more phosphate than the *phosphate group*, but the phosphate is less leachable in the *phosphate group*. An average of only 4 % of the phosphate in the *phosphate group* is washed or leached from the solid (24590-WTP-RPT-PE-07-001). The *phosphate group* also contains relatively high concentrations of calcium.

1.3.1.1.7 Iron Group

Unlike other groups, aluminum is not the dominant species in the *iron group* – where the average iron concentration is 1.47 times the aluminum concentration. Compared to other groups, this group contains higher concentrations of zirconium, thorium, mercury, barium, cadmium, cerium, lanthanum, neodymium, and titanium.

1.3.1.1.8 Zirconium-Aluminum Group

The suspended solids contain an average of 3.32 wt % zirconium (Zr^{+4}) and 18 wt % aluminum (Al^{+3}). However, most of the aluminum is leachable (24590-WTP-RPT-PE-07-001), which leaves a higher concentration of zirconium in the waste slurry after pretreatment. The combination of zirconium and aluminum limits the amount of HLW glass made. Therefore, further reduction of either will result in less HLW glass produced.

1.3.1.1.9 Sodium Group

The undissolved solids on average contain 40 wt % sodium (Na^{+}). This is almost 18 times the average aluminum concentration in the group of 2.24 wt %, whereas aluminum is one of the major components in most other groups. The reason for the high sodium content is not fully understood; possible causes include:

- The high sodium content did not allow for thorough washing of the solids with the typical number of washings used in the study that created the groups (24590-WTP-RPT-PE-07-001).
- The sodium is bound in or adheres to other mineral-type solids

- Large quantities of oxalate are present. Sodium oxalate is only semi-soluble and requires a lot of water or higher temperatures to dissolve completelyWaste type not well characterized.

1.3.1.1.10 Calcium Group

The *calcium group* has the highest concentration of nickel and nitrate of all groups. It also contains the second highest concentration of uranium, next to the *uranium group.* The *calcium group* has an average phosphate concentration.

1.3.1.1.11 Uranium Group

This group contains a fair amount of aluminum, but uranium is the most important component once aluminum has been removed by leaching. The average uranium concentration in the suspended solids in the feed is 3.75 wt %.

1.3.1.1.12 Sulfate Group

Only 25 % of the sulfate in this group is dissolved during water washing or caustic leaching from the solids (24590-WTP-RPT-PE-07-001). In addition to sulfate, the sulfate group contains high concentrations of fluorine and uranium.

1.3.1.2 Organics

The Hanford tank farms wastes contain large amounts of organics in both the solid and liquid phases. Like the inorganic content, the organic content of the feed is variable. Figure 1.3-8 provides the total organic carbon (TOC) content of many tank waste samples recorded in the Tank Waste Information Network System (TWINS) database (CHG 2007). This figure lists the liquid concentration of organics from highest to lowest for these samples. The figure segregates all of the samples from tanks 241-AN-102 and 241-AN-107 because these two tanks contain Envelope C feed with high concentrations of chelates. As can be seen in Figure 1.3-8, Envelope C tanks have some of the highest concentrations of organics in all of the liquid samples, but other non-Envelope C tanks also have high organic concentrations.

The 10 tanks with the highest TOC concentration in the supernatant (other than the two Envelope C tanks, AN-102 and AN-107) are U-105, U-106, AN-103, AN-105, C-105, S-106, S-111, SX-101, BY-112, and AZ-102. The bulk of the organic species in the tanks are formate, oxalate, IDA, HEDTA, EDTA, glycolate, citrate, and acetate. The most prevalent organics identified in tank waste are shown in Table 1.3-3. The purpose of Table 1.3-3 is to provide a list of possible organics and potential concentrations that may be in the Tank Farm waste. Do not assume that any one of identified species will actually be present in the waste delivered to the WTP.

Figure 1.3-9 was generated to describe the TOC content of the sludge solids. In that figure, TOC measurements are shown from several thousand sludge samples from the TWINS database (CHG 2007), and sorted from highest to lowest. Oxalate is the most prevalent organic in the solids, so the oxalate concentration was subtracted from the TOC measurements. There are many more oxalate measurements than TOC measurements (Figure 1.3-9). As shown in the figure, both the TOC and oxalate concentrations vary from sample to sample of sludge in the Tank Farms. One conclusion that can be gathered from Figure 1.3-9 is that the TOC content (minus oxalate) can vary by more than six orders of magnitude.

The complexants and carboxylate-containing organics have been speciated in 20 tanks and reported in Tables 3-5 and 3-6 of RPP-21854, *Occurrence and Chemistry of Organic Compounds in Hanford Site Waste Tanks* (Meacham 2004). Those tables have been summarized and shown in Table 1.3-4. There are more measurements of oxalate than any other organic species in the waste.

1.3.1.3 Alkali Cations

The alkali cations in the waste are of interest because they compete with Cs loading on the ion-exchange resin (Section 2.5). It should be noted that radioactive Cs is approximately 25 % of the total Cs in the waste. Table 1.3-5 gives the ratio of alkali metal to Cs obtained from data taken from the *Tank Farm Contractor Operation and Utilization Plan* (TFCOUP) (Kirkbride and others 2007).

While rubidium can compete with Cs for the ion exchange resin due to size and reactivity, there is not enough rubidium in the waste to be a problem. Lithium is smaller and would probably not displace sodium on the media. The major competition with Cs will be from potassium.

1.3.2 Reconciled Feed Vectors

To perform thermodynamic analysis of feeds, the feed composition must be reconciled to ensure that the feed is charge-balanced and in equilibrium. Performing this reconciliation for all feeds in the feed vector provided by the TFCOUP (Kirkbride and others 2007; 24590-WTP-RPT-PE-07-001) is prohibitively time consuming. Nonetheless, representative feeds are needed for the steady-state flowsheet, which performs thermodynamic equilibrium calculations to during simulations of the WTP processess for single-feed scenarios. These reconciled feed vectors are based on sample analysis of selected tanks, specifically tanks 241-AP-101, 241-AY-102, 241-SY-102, and 241-AZ-101. These feeds were selected because they represent different aspects of the flowsheet. Tank 241-SY-102 was selected because it is a feed with a lot of chromium that requires oxidative leaching. Tank 241-AZ-101 was chosen because the supernatant in this tank is representative of Envelope B. However, Tank 241-AZ-101 waste does not require oxidative leaching, but does require caustic leaching. Tanks 241-AY-102 and 241-AP-101 were selected because they were originally selected to be the hot-commissioning feed (the waste in 241-AP-101 has since been pumped into tank 241-AY-102). This feed represents a simple Envelope A/D blend that does not require caustic or oxidative leaching. The following subsections provide the details of each of the reconciled feed vectors.

1.3.2.1 Feed 241-SY-102

The reconciled 241-SY-102 feed vector is based on the characterization data of the waste in 241-SY-102 reported by McKinney (2001). According to the tank characterization report for tank 241-SY-102 (CHG 2004), tank 241-SY-102 was a temporary storage tank at the time the characterization sample was taken, and the supernatant has since been transferred elsewhere. Thus, the supernatant and, to a lesser extent, the soluble components in the sludge are unlikely to represent the components that would come to the WTP with the insoluble sludge compounds. Thus, the feed vector can be used to understand the mechanisms exhibited by a feed that is oxidatively leached, but should not be thought of as representative of a particular feed, even though the feed came from a specific tank. Nonetheless, the sludge in the tank has been relatively stagnant, and this feed may be representative of the insoluble solids that still reside in the tank. This section presents only a minimal description of the feed vector; a more complete description can be found in CCN 110728.

According to the tank characterization report, most of the sludge in this tank came from the Plutonium Finishing Plant, but the upper portion of the solids is a salt layer that precipitated from the supernatant

during various transfers through the vessel. The aluminum in this salt layer stayed in the solid phase when the sample was washed, but the chromium in this layer was removed by water washing (CCN 110728). The sample characterized by McKinney (2001) was a core composite of the supernatant, sludge and saltcake in the tank at the time of the sampling event. The only solids identified in the sample by mineralogical analysis were gibbsite ($Al(OH)_3$) and amorphous aluminum hydroxide (24590-101-TSA-W000-0004-99-00012). The dominant aluminum in the sludge was treated as gibbsite for modeling purposes because gibbsite is less soluble than amorphous aluminum hydroxide. The rest of the solids were based on the soluble concentration of the elements in the supernatant, where the solid chosen was most closely matched with the solubility exhibited by the supernatant sample. The hydroxide concentration in the sample was adjusted to obtain charge balance. The solubility exhibited by a number of the trace elements in the sample (Nd, Cd, Pd, Pr, Zr, Zn, Am, Eu, and Sb) was considerably lower than any reasonable solid for which thermodynamic data is available. Literature data indicates that these elements are impurities in or adsorbed upon more prevalent minerals in the sludge (Jeon and others 2003; Rabung and others 1998). Therefore, these elements were assigned to simple compounds in the solid phase for the feed, and thermodynamic solubility calculations of pure phases were not applied to them. Thermodynamic analysis cannot be applied to these adsorption reactions. The reconciled feed composition for the 241-SY-102 feed vector is shown in Table 1.3-6.

The isotopes must be in equilibrium; however, the isotopic distribution reported in the characterization report was different for the solid and liquid phases. Therefore, the isotopic concentration needs to be reconciled. For some elements, one isotope accounts for the entire measured concentration of that element in the characterization sample, so 100 % of the elemental mass was assigned to that isotope (Tc-99, I-129, Th-232, and Am-241). All carbon-14 was assigned to the carbonate species, and the C-14 to carbonate ratio from the sludge was used, because the C-14 analysis was only available in the sludge. The isotopic concentration from the sludge was used for Sr-90, as well as all isotopes of Eu, U, and Pu, because the sludge accounts for the overwhelming majority of the inventory of these elements. The isotopic ratio for Cs-137 and Cs-135 measured from the supernatant was used, because all Cs was assigned to the liquid in the reconciled feed. For a more detailed description, see CCN 110728. Only those isotopes measured in the characterization sample are included in this feed vector.

Table 1.3-7 compares the supernatant composition to Specification 7 limits of the SOW, and Table 1.3-8 compares the sludge composition to the Specification 8 limits of the SOW. The supernatant was within the Specification 7 limits for Envelope A, with nitrite right at the limit (0.382 mol NO_2^- per mole of Na). In the solid phase, Pu-238 and Pu-239 were over the SOW Specification 8 limit (Table 1.3-8). Plutonium-241 was not targeted by the characterization report (McKinney 2001).

1.3.2.2 Feed 241-AZ-101

The waste in tank 241-AZ-101 is to be blended with other feeds before being sent to WTP (Kirkbride and others 2007). Therefore, this feed should be regarded as an example of how a blend of Envelope B and D feed might behave, rather than as a specific feed representing a specific feed batch. The characterization data reconciled to create this feed is from 24590-101-TSA-W000-0004-87-08. A more detailed description of how the feed was reconciled can be found in CCN 128565.

Mineralogical analysis was performed on washed samples of the 241-AZ-101 sludge (24590-101-TSA-W000-0004-134-01). These results identified the minerals hematite (Fe_2O_3), chromite ($FeCr_2O_4$), gibbsite ($Al(OH)_3$), and boehmite (AlOOH). Thus, the iron, aluminum, and chromium in the sludge were assigned to these phases. The quantity of aluminum assigned to gibbsite versus boehmite was made by assuming (in 24590-101-TSA-W000-0004-87-09) all of the aluminum removed during leaching was gibbsite.

When aluminum was split this way, the leaching performance of the sludge sample could be accurately modeled using thermodynamic software (CCN 128565).

The uranium-bearing solid phase in the sample could not be unambiguously identified, but the X-ray diffraction (XRD) pattern was similar to the mineral schoepite. Schoepite has a similar XRD pattern to the phase disodium diurinate (Diaz-Arcus and Grambow 1998), which was predicted to be the most stable uranium phase in the sludge. Therefore, uranium was assigned to disodium diurinate in the sludge.

Manganese was identified as part of a Mn-bearing clay-like phase (24590-101-TSA-W000-0004-134-01) that has not been identified previously in the literature, and for which no thermodynamic data is available. Manganese was assigned to the solid $Mn(OH)_2$ in the solid because this phase has low solubility in high-caustic waste, like the manganese in the characterization sample. $Mn(OH)_2$ can be thought of as a tracking compound.

The rest of the species in the sample were developed based on how well they matched the solubility of the elements observed in the supernatant (CCN 128565). During this thermodynamic analysis, the measured sodium concentration was adjusted to obtain charge balance for the supernatant and carbonate was chosen for the sludge. These were chosen because the solubilities of other species were best matched when these were used for charge balancing. Lithium, bromide, and boron, while detected in the sample, were not included in the feed vector. Boron likely had leached out of the glassware the sample was stored in. Lithium and bromide are contaminants that were derived from the hydrostatic head fluid used in the tank coring device (Templeton 2000).

The solubility exhibited by a number of the trace elements in the sample (Ce, Hg, Ru, Eu, and Nd) was considerably lower than any reasonable solid for which thermodynamic data is available. Literature data indicates that these elements are impurities in or adsorbed upon more prevalent minerals contained in the sludge (Jeon and others 2003; Kim and others 2004; Rabung and others 1998). Therefore, these elements were assigned to simple compounds in the solid phase for the feed, and thermodynamic solubility calculations of pure phases were not applied to them. Thermodynamic analysis cannot be applied to these adsorption reactions.

The reconciled feed composition is shown in Table 1.3-9. The isotopes must be in equilibrium, yet the isotopic analysis in the characterization report was different for the solid and liquid phases. Therefore, the radioisotope concentration needed to be reconciled. For some elements, one isotope accounts for the entire measured concentration of that element in the characterization sample, so 100 % of the elemental mass was assigned to that isotope (i.e., Tc-99, Se-79, Np-237, and Am-241). All C-14 was assigned to the carbonate species, and the C-14 to carbonate ratio from the supernatant was used because more C-14 was found in the supernatant than sludge. The isotopic concentration from the sludge was used for Sr-90 and Co-60, as well as all isotopes of Eu, U, and Pu, because the sludge accounts the overwhelming majority of the inventory for these elements. The isotopic ratio for Cs-137 measured in the supernatant was used, because all Cs was assigned to the liquid in the reconciled feed. For a more detailed description, see CCN 128565. Only those isotopes measured in the characterization sample are tracked in the feed vector.

Table 1.3-10 compares the supernatant composition to SOW Specification 7 limits, and Table 1.3-11 compares the sludge composition to the Specification 8 limits. All liquid phase species were within the Specification 7 limits for Envelope B. Aluminum was found to exceed the Specification 8 limit (Table 1.3-11), as did Europium-154. However, the Eu-154 was not decay-corrected to the date of delivery because the delivery date had not been specified, and the activity reported is the activity of Eu-

154 at the time of analysis. Europium-154 has a very short half-life, so it is expected that Eu-154 will be within the feed specification at the time of delivery.

1.3.2.3 Feed 241-AP-101

This feed composition results from the reconciliation of waste from report SCT-00008697-01-11-01A. A more in-depth analysis of the reconciliation of this sample can be found in CCN 087360. Since that characterization event, the waste in tank 241-AP-101 has been transferred to tank 241-AY-102, and mixed with the Envelope D batch in that tank. Thus, this feed data is used in conjunction with the 241-AY-102 feed vector.

There is no mineralogical analysis of this tank, as this tank is primarily a supernatant tank. During the thermodynamic speciation of the waste, only very trace amounts of solids were predicted for the vessel, consistent with trace amounts of solids observed in an analysis of this tank by another contractor (Fluor Hanford 2001).

The reconciled waste feed is shown in Table 1.3-12. Sodium was adjusted to achieve charge balance in the speciated feed. Sodium was adjusted because the density could be matched when sodium was used, and because it prevented the precipitation of solids that would occur when other species were adjusted for charge balancing. Also, other analyses of the tank sample (Fluor Hanford 2001) observed more sodium than measured in the reconciled sample (SCT-00008697-01-11-01A). The solution phase species were assigned based on their thermodynamic stability (CCN 087360).

Table 1.3-13 compares the reconciled feed vector for 241-AP-101 to the Envelope A Specification 7 limits. All components were found to be within the specification limits.

1.3.2.4 Feed 241-AY-102

This feed composition results from the reconciliation of waste from report SCT-M0SRLE60-00-110-17. A more in-depth analysis of the reconciliation of this sample can be found in CCN 087361. Since that characterization event, the waste in tank 241-AP-101 has been transferred to tank 241-AY-102, and mixed with the Envelope D batch in that tank. Thus, this feed data is used in conjunction with the 241-AP-101 feed vector.

Mineralogical analysis was not performed on this sample at the time the feed vector was reconciled (CCN 087361), so the solid phase species were assigned based on the solubility exhibited in the supernatant. The hydroxide concentration was adjusted to achieve charge balancing, because the feed more closely matched the gibbsite solubility when hydroxide was used than when other ions were used. Despite this 19 % increase in hydroxide concentration used to charge balance the feed, the sample was still supersaturated with gibbsite (CCN 087361). The excess aluminum was precipitated in the feed until the saturation level was achieved. The reconciled feed composition is shown in Table 1.3-14.

The solubility exhibited by a number of the trace elements in the sample (Ce, Hg, Ru, Pb, Zn, and Nd) was considerably lower than any reasonable solid for which thermodynamic data is available. Literature data indicates that these elements are impurities in or adsorbed upon more prevalent minerals in the sludge (Jeon and others 2003; Kim and others 2004; Rabung and others 1998). Therefore, these elements were assigned to simple compounds in the solid phase for the feed, and thermodynamic solubility calculations of pure phases were not applied to them. Thermodynamic analysis cannot be applied to these adsorption reactions.

The isotopes must be in equilibrium, yet the isotopic analysis in the characterization report was different for the solid and liquid phases. Therefore, the radioisotope concentration needed to be reconciled. For some elements, one isotope accounts for the entire measured concentration of that element in the characterization sample, so 100 % of the elemental mass was assigned to that isotope (Tc-99, Sn-136, Np-237, and Am-241). All C-14 was assigned to the carbonate species, and the C-14 to carbonate ratio from the supernatant was used because more C-14 was found in the supernatant than sludge. The isotopic concentration from the sludge was used for Sr-90, Co-60, as well as all isotopes of Eu, Ni, and Pu, because the sludge accounts the overwhelming majority of the inventory of those elements. The isotopic ratio for Cs-137 measured in the supernatant was used, because all of the Cs was assigned to the liquid in the reconciled feed. The isotopic ratio from the liquid was used for uranium because there was a measured value for U-236 in the liquid but not the sludge phase. For a more detailed description, see CCN 087361. Only those isotopes measured in the characterization sample were tracked in the feed vector.

Table 1.3-15 compares the supernatant composition to Specification 7 limits, and Table 1.3-16 compares the sludge composition to the Specification 8 limits. All liquid phase species were within the Specification 7 limits for Envelope A, except for inorganic carbon, which was 106 % of the limit. Lead (Pb) was found to be over the Specification 8 limit (165 %) in the sludge (Table 1.3-16). Silver, Al, Fe, Hg, and Mn were all close to the limit (> 80 % of the limit) in the unwashed solids.

1.3.3 Waste Feed Physical and Rheological Properties

Most physical properties are not flowsheet observables. However, the mass and volumes in the flowsheet need to be consistent with feeds that can be successfully processed. Two studies have evaluated the physical properties of the feed (24590-101-TSA-W000-0004-114-00021; CCN 159548). One focused on the mineralogy of the waste feed and related this to the particle size and solid density. The other report investigated slurry rheology. The next subsection will review that work. Subsequently, the density and viscosity of the liquid phase will be described.

1.3.3.1 Slurry Rheology and Physical Properties

1.3.3.1.1 Particle Size and Density of Waste Feed Solids

Report 24590-101-TSA-W000-0004-114-00021 investigated the particle size and density of the solids in the waste feed. The researchers did this by investigating all of the waste particle size data they could find on Hanford tank waste. The solid-phase minerals in those tank waste samples were selected based on thermodynamic predictions that had been done previously on the tanks, or from direct mineralogical analysis when available. Based on the elemental analysis of the feeds, the mineralogy of the feed predicted for those elements, and the particle size distribution of the solids, they estimated the particle size of the solid phases expected to be most prevalent in the feed. This prediction was constrained based on known particle size distributions for individual phases determined from microscopic images of the crystals and XRD. To account for nonsymmetries in certain waste particles, crystal structures that were known to be elongated and acircular were assumed to have diameters equivalent to spheres with the same settling velocities (Wu and Wang 2006). Affected species were dawsonite ($NaAlCO_3(OH)_2$), boehmite (AlOOH), and hematite (Fe_2O_3). This is a brief description of the methods used to estimate particle size; a more complete description can be found in 24590-101-TSA-W000-0004-114-00021.

Table 1.3-17 contains the maximum particle size of the phases investigated in the study, along with the crystal density the study compiled from the literature (24590-101-TSA-W000-0004-114-00021). Note that these are just the minerals used within that study. Table 1.3-17 also contains the particle size

distribution determined by the study. Note that the maximum particle size is not always a good representation of the typical partial size in Table 1.3-17. For instance, ZrO_2 has one of the largest maximum particle size (50 micrometers diameter) but 95 % of the ZrO_2 particles have diameters below 28 micrometers, giving ZrO_2 a below average particle size. The difference between sonicated and un-sonicated samples is noted. The sonication of the samples breaks up the aggregates in the waste, so particle size measurements on sonicated samples are much closer to the true size of the individual crystals. Yet the particle sizes for many sonicated samples were still considerably larger than the primary particles observed by microscopy or XRD. For instance, the maximum AlOOH particle size seen experimentally was 0.05 micrometers, but the particle sizes of sonicated samples containing boehmite were all greater than 0.6 micrometers. Hence, these sonicated samples must still be aggregates of smaller boehmite particles despite sonication.

Depending on conditions (e.g., the pH, salt content, and agitation conditions of the solution) oxides and hydroxides of primary particles can form up to 100 micrometers in size. Agglomerates with primary particles larger than 10 to 20 micrometers are rare. Agglomerates can range in specific gravity between ~1.6 and 2.3 (24590-101-TSA-W000-0004-114-00021).

Table 1.3-17 only contains the solids that were modeled in 24590-101-TSA-W000-0004-114-00021. That study included only those solids the authors considered most important to solids-settling issues. A list of all the solids that have been identified in the waste are listed in Appendix C of 24590-101-TSA-W000-0004-114-00021. That report also has a number of images of particles and agglomerates observed in the waste. The particle distribution of the Hanford tank waste is shown in Table 1.3-18. The average density of the particles is calculated as 2.7 g/cm^3.

1.3.3.1.2 Waste Feed Slurry Rheology

Rheology is a measure of the ability of a fluid to flow. A recent study evaluated all of the rheological data of waste feed available (CCN 159548). The rheological properties most relevant are viscosity and shear strength, because these properties can be controlled by changing the chemical composition of the stream. The viscosity of a fluid is determined by measuring the shear stress (τ, in units of pressure, e.g., mPa or Pa) as a function of shear rate (λ, in units of 1/sec). When the shear stress is zero at a shear rate of zero and the shear stress changes linearly with shear rate, the fluid is considered a *Newtonian* fluid (Perry and Green 1999). For Newtonian fluids, the viscosity is the slope of the shear stress/shear rate curve. When the shear stress increases linearly with increasing shear rate but the shear stress is not zero at zero shear rate, the fluid is termed a *Bingham plastic*, where the slope is called the *consistency* (η_c, in units of pressure per unit time, e.g., mPa/sec or cP) and the intercept is called the *shear strength* (τ_y), and described mathematically in Equation 1.3-1.

Equation 1.3-1

$$\tau=\tau_y+\eta c\lambda$$

Slurries to be processed at WTP are frequently Newtonian at low solids concentration and can be approximated as Bingham plastics at high solids concentration (24590-101-TSA-W000-0004-172-00001). However, the shear stress of WTP slurries is frequently non-linear at low shear rates (< ~20/s), so the real shear strength (τ_y) usually varies slightly from the intercept obtained by fitting a line through the shear stress-shear rate curve. This intercept is called the *Bingham yield stress* (τ_B) (24590-101-TSA-W000-0004-172-00001).

The Bingham plastic model is shown in Equation 1.3-2 (Perry and Green 1999). This equation is used when the fluid is only approximately a Bingham plastic rather than a true Bingham plastic. When the fluid is a true Bingham plastic, Equation 1.3-1 is used. When the fluid is a real Bingham plastic, $\tau_y = \tau_B$.

Equation 1.3-2

$$\tau=\tau_B +\eta c\lambda$$

Engineering literature has several names for τ_B and τ_y. On the WTP Project, the convention has most commonly been to call τ_B the *Bingham yield stress* and τ_y the *shear strength* (CCN 081250). This report follows that convention. In the engineering literature, and occasionally at the WTP Project, the name *shear strength* has been used to describe both τ_B and τ_y because they are the same parameter when the fluid is a real Bingham plastic (as opposed to an approximate Bingham plastic, like most real WTP slurries). Most models used to calculate τ_y can also be used to calculate τ_B, but the coefficients will be somewhat different.

The WTP slurries approximately behave as Bingham plastics at high solids concentration. This behavior is due to the high ionic strength and small primary particle size in the sludge, which can cause the particles to flocculate (Tingey and others 2001). As increasing shear is placed on the slurry, the flocs break into smaller particles that are easier to move, causing the slurries to be shear-thinning (Kobayashi and others 1999).

Smaller-sized waste particles tend to result in increased rheology because the smaller particles tend to result in larger-sized flocs (CCN 137198). In CCN 081250, the authors investigated the rheology of a number of feeds and found that both the shear strength and consistency changed with composition. The relative impact of the following components on the consistency and shear strength is roughly as follows: zirconium compounds > boehmite > bismuth compounds > gibbsite > iron hydroxide. Silica and aluminosilicate compounds did not show a strong effect on the rheology. The CCN 081250 also noted that this is the same order as the decrease in particle size of these compounds found by 24590-101-TSA-W000-0004-114-00021. Thus, the rheology was roughly correlated to the particle size of the constituents in the waste; where minerals with small particle size tended to cause an increase in viscosity and shear strength.

The rheology of a number of feeds was fit to Equation 1.3-2, and the resulting coefficients are shown in Table 1.3-19. The waste types in Table 1.3-19 correspond to the names given by Meacham (2003). As can be seen, the rheology of the feed is variable. This table also contains the shear strength of the feed fit to a model in CCN 081250, as well as the weight percent of solids predicted by the model to reach the shear strength of 30 Pa and the consistency of 30 cP. These two values are important because they represent the upper-bound design basis for slurry rheology (CCN 065607).

1.3.3.2 Liquid Phase Rheology and Physical Properties

1.3.3.2.1 Liquid Phase Density

Several different solution phase density models are used, depending on the application. For applications where the waste is not charge balanced, a simple equation (Equation 1.3-3a and Equation 1.3-3b) is used to obtain a specific gravity that reasonably approximates the real specific gravity.

Equation 1.3-3a

$$SpG = 0.00935X + 0.996$$

where:

Equation 1.3-3b

$$X = \left(\left(\sum \text{Mass of Solutes}\right) - \text{Mass } H_2O\right) \Big/ 100 * \sum \text{Mass of Solutes}$$

When the rigorous thermodynamic models are employed within the flowsheets; the density algorithms within commercially available thermodynamic flowsheet software are used. This is done because it is important that the inputs and outputs to the thermodynamic software be self-consistent. This requires that the thermodynamic models use the density models that have been reconciled with the thermodynamic data and equations within the model. Otherwise, the models may not give correct thermodynamic speciation predictions on a volume basis (though they would still be accurate on a mass fraction basis).

For other applications, the Laliberte-Cooper model is used for liquid phase density (Laliberte and Cooper 2004), Equation 1.3-4.

Equation 1.3-4

$$\rho_m = \frac{1}{w_{H_2O}\bar{v}_{H_2O} + \sum_i w_i \bar{v}_{app,i}}$$

where

ρ_m is the solution density in kg m^{-3}
w_i is the mass fraction of electrolyte *i*
$\bar{v}_{app,i}$ is the electrolyte specific volume in m^3 kg^{-1}
w_{H2O} is the water mass fraction
$\bar{v}_{H_2O}$ is the apparent specific volume of water, m^3 kg^{-1}. The apparent electrolyte specific volume ($\bar{v}_{app,i}$), is given by Equation 1.3-5:

Equation 1.3-5

$$\bar{v}_{app,i} = \frac{\left(1 - w_{H_2O}\right) + c_2 + c_3 t}{\left(c_0\left(1 - w_{H_2O}\right) + c_1\right)e^{\left(0.000001(t+c_4)^2\right)}}$$

where c_0 to c_4 are empirical constants. The coefficients c_0 and c_1 are in kg m^{-3}, c_2 is dimensionless, c_3 is in $°C^{-1}$, c_4 is in °C, and t is in °C. This equation assumes that the apparent specific volume of electrolyte "i" depends on the total concentration of electrolytes in solution rather than the concentration of just electrolyte "i". The specific volume of water was calculated from the inverse of the following correlation given in Laliberte and Cooper (2004):

Equation 1.3-6

$$\rho_{H_2O} = \frac{(((((-2.8054253\times10^{-10}t + 1.0556302\times10^{-7})t - 4.6170461\times10^{-5})t - 0.007987040)t + 16.945176)t + 999.83952)}{1 + 0.01687985t}$$

where t is the temperature in °C and ρ is the density of water in kg/m^3. This model has been tested against a statistically designed supernatant dataset (Reynolds and others 2007), and shown to be highly accurate at predicting that dataset ($R^2 > 0.99$). The c_0 through c_4 coefficients used in Equation 1.3-5 for a number of electrolytes relevant to the WTP are shown in Table 1.3-20. A number of coefficients for other electrolytes are available in Laliberte and Cooper (2004). A more detailed description of the Laliberte-Cooper model, as well as methods to determine coefficients can be found in CCN 110711.

For highly acidic streams, the Laliberte-Cooper model is ill-defined using the c_0 through c_4 coefficients currently available. However, recent work has developed new ways to derive model coefficients that will likely result in improved coefficients for acidic systems in the future (Reynolds and Carter 2008).

1.3.3.2.2 Liquid Phase Rheology

The WTP liquid-phase waste is Newtonian (CCN 159548), so its rheology can be described solely by the viscosity. Solution viscosity is not a flowsheet observable, so it is not covered here in detail. However, there is a relationship between solute concentration (which is tracked in the flowsheet) and viscosity. The viscosity of the aqueous solutions increases roughly exponentially with dissolved salt concentration (Goldsack and Franchetto 1977), although each salt affects the viscosity differently from the other salts (Laliberte 2007). The influence of individual salt species is not additive (Laliberte 2007; Nowlan and others 1980), but does appear to be a simple function of the water vapor pressure (Hu and Lee 2003). This is because the viscosity and vapor pressure are both affected by the strength of the chemical bond between the dissolved salts and the water molecules in solution (Hu and Lee 2003). Given that the size of the molecules in water, their ability to move through the water, and the density increase with dissolved salt concentration, the viscosity thus becomes an exponential function of the solution density (Isono and Tamamushi 1967; CCN 159548). A more detailed description of solution viscosity can be found in CCN 159548.

1.3.4 Chemistry Overview

As noted in the previous subsections, the waste feed has substantial variability and contains a wide variety of chemicals. This results in a set of chemical reactions that is complicated. This section provides an overview that is applicable to all primary waste systems in the WTP. This section will not cover chemistry that is specific to individual systems (such as liquid-vapor, ion exchange, or glass chemistry).

The waste feed has a large amount of variability and a large number of components. The feed contains most of the periodic table. Consequently, the chemistry is very complex. Given this complexity, the aqueous-phase elements are tracked in the flowsheet rather than species, but the solution phase species are predicted in the flowsheet models that possess that capability. The predicted liquid phase speciation is derived from commercially available software described in 24590-WTP-MDD-PO-03-003, but not discussed in detail here. As long as the species stay in the liquid phase and as long as the quantity of elements is tracked, the identity of the solution phase species is not of great importance. The place where the identity of the solution phase species becomes important is when the species precipitates. Thus, these speciation calculations are an input to the solid-liquid equilibrium calculations for those species, which are important to the flowsheet because they impact the fate of the elements. The solid-liquid phase equilibria will be discussed in more detail here.

Three types of chemical reactions are relevant to the solid-liquid phase equilibria observed in the WTP flowsheet. These are:

1 Solid-liquid phase equilibria of salts (an example is sodium oxalate),
2 Acid-base phase equilibria (an example is aluminum solubility), and
3 Reduction-Oxidative (REDOX) reactions and equilibria (an example is oxidative leaching).

These subjects will be described in subsections following a more general overview of solubility and dissolution kinetics.

1.3.4.1 Solid-Liquid Solubility and Dissolution Kinetics

The solubility of species can be described using the following equation (Denbigh 1963):

Equation 1.3-7

$$K_{sp} = \frac{A^x * B^y}{A_x B_y}$$

where K_{sp} = the solubility product, also called the equilibrium constant, is a constant that describes the ratio of the dissolved to solid species at equilibrium; A and B are the activities of the components of the solid, and the coefficients x and y are the number of the components in the solid phase. The numerator represents the dissolved species and the denominator represents that solid phase. By convention, the activity of the solid-phase components is given a value of one. The numerator is the product of the activities of the dissolved species, and is also called the ion activity product (IAP). The activities of the dissolved species are a function of the concentration of the species, and at low concentrations are approximately the same as the concentration of dissolved ions. The concentration of dissolved ions is too high in any waste treatment plant waste stream for the concentration to be an appropriate approximation of the activity. Numerous semi-empirical models exist to predict the activity of dissolved ions based on concentrations in water (Newman 1985). The models generally perform these calculations by calculating the activity coefficient (λ) of the dissolved species. The activity coefficients can be substituted into Equation 1.3-7 through the relation (Denbigh 1963):

Equation 1.3-8

$$A = \lambda_A a$$

where 'a' is the liquid-phase concentration of species A. Molality or mole-fraction units for the liquid phase are preferred over molarity units in solubility calculations because volume is not conserved in chemical reactions but mass is (Zemaitis and others 1986). The IAP can be calculated from the Equation 1.3-9 (Denbigh 1963):

Equation 1.3-9

$$IAP = (\lambda_A a)(\lambda_B b)$$

When the only product in the reaction is a solid (i.e., a salt is precipitating) then the IAP = K_{sp}. The K_{sp} is thus related to the change Gibbs free energy of formation in the standard state (ΔG^f) of the reaction as well as temperature (T) from the relation (Denbigh 1963):

Equation 1.3-10

$$K_{sp} = \exp\left(\frac{\Delta G^f}{-RT}\right)$$

where R is the universal gas constant. Solids are often not at equilibrium with the dissolved species. A useful way to discuss the distance from equilibrium is using the *saturation index* (Ω):

Equation 1.3-11

$$\Omega = \frac{A^x * B^y}{K_{sp}}$$

When Ω is greater than one, a solution is said to be supersaturated and a solid is expected to precipitate. When Ω is less than one, the solution is said to be undersaturated and the solid, if present, is expected to partially or fully dissolve.

In general, the change in concentration of species *i* in solution as a function of time due to dissolution of a mineral is given by (Lasaga 1995):

Equation 1.3-12

$$\frac{dc_i}{dt} = k_i \cdot \frac{A}{V}$$

where k_i is the dissolution rate constant of species *i*; A is the reactive surface area of the mineral; V is the volume of solution in contact with the mineral; and dc_i/dt is the change in concentration in solution due to the dissolution.

One of the problems with kinetic studies is that the dissolution rate constant, k_i, is not a constant. Instead, it is influenced by temperature, the degree of saturation of the solution, the pH, and other variables. Equation 1.3-12 can be manipulated and expanded to give Equation 1.3-13 (Lasaga 1995, CCN 150366).

Equation 1.3-13

$$\text{Rate} = k_o \cdot A \cdot e^{-\frac{Ea}{R \cdot T}} \cdot a_{OH}^{n_{OH}} \cdot \prod a_i^{n_i} \cdot g(I) \cdot f(\Delta G)$$

A number of the terms on the right-hand side of this equation will require further explanation below, a discussion derived from Lasaga (1995). This model is well established both theoretically and experimentally (Lasaga 1995), though some of the terms in the equation are themselves fairly complicated mathematical functions that are not always unambiguous.

The reactive surface area (A) is an important contributor to the model. The access of the solution to the particle surface may depend on how aggregated the particles are. Determination of the surface area of actual waste particles can be difficult because of aggregation and because there are many species in the

waste. The particle size, which can be used to calculate surface area, can be calculated from the XRD pattern of the solid (Klug and Alexander 1974).

The hydroxide activity term (a^n_{OH}) captures the effect of hydroxide activity on the dissolution rate. This term only applies if the dissolution is from an acid-base reaction. If the dissolution were occurring in an acid stream rather than a caustic stream, the proton activity would replace the hydroxide activity (Lasaga 1995). Here the hydroxide activity was used because most streams in WTP are caustic streams. The exponent (n) is empirically determined when the solution hydroxide activity is used. Hydroxide promotes the dissolution of (hydro) oxides by complexing the metal at the mineral surface to create a hydroxide-containing transition state. The rate of dissolution is thought to be proportional to the number of these surface complexes (Lasaga 1995). When most modelers use this dissolution rate equation in Equation 1.3-13, the quantity of adsorbed hydroxide is used rather than the solution activity because it is known that the exponential is an integer equal to one when adsorbed hydroxide is used (Furrer and Stumm 1986). For waste samples, the solution concentration of hydroxide is too large to measure the small quantity of adsorbed hydroxide by difference, so the adsorbed hydroxide method is impractical. Consequently, the solution hydroxide activity is used instead for tank waste because the amount of adsorbed hydroxide is roughly proportional to the concentration of dissolved hydroxide.

The symbol $\prod a_i^{n_i}$ represents the activities of other important ions in solution, such as catalysts and inhibitors. Hanford waste has many species dissolved in solution and some of these may have an appreciable effect on dissolution rate.

The closer the system is to equilibrium, the slower the reaction rate. The term $f(\Delta G)$ in Equation 1.3-13 is to take into account the approach of equilibrium on the dissolution kinetics. This symbol represents a general but unknown function of the kinetics on the saturation index (Ω). The exact functional form must be determined empirically. Example empirical equations can be found in Lasaga (1995). This empirical function is determined by regressing data of dissolution rate versus Ω when all other factors in Equation 1.3-13 are held constant. Note, however, that the function is known to change with temperature (Lasaga 1995, Sposito and Casey 1992), so the temperature dependence of the function's coefficients needs to be determined over the range of interest.

The $e^{-(Ea/RT)}$ term in Equation 1.3-13 contains the temperature dependence of the mineral dissolution rate. When all things are constant, the dissolution rate is an exponential function of temperature. As stated above, the effect of solution saturation state on the kinetics is temperature-dependent. Other factors, such as the effect of ionic strength and inhibitors, usually are also temperature-dependent. Thus, the temperature dependence of the dissolution rate may be counterintuitive (CCN 150366).

The kinetics of precipitation have not been as heavily studied relative to Hanford waste as dissolution kinetics. At the moment, the flowsheets have precipitants achieve equilibrium instantly. Future work may address this issue.

1.3.4.1.1 Salt Solubility

Salts precipitate when the concentration of a cation and anion react together to form a solid, because their concentration exceeds their solubility in the liquid phase. The solubility product of salts is well described by Equation 1.3-7. The flowsheet uses reconciled, commercially available, rigorous chemistry models (24590-WTP-MDD-PO-03-003, CCN 128553) whenever practical because they are considerably more accurate than empirical solubility models. These rigorous models have only been reconciled with a few

waste samples at present, and so are not universally useful. These rigorous chemistry models solve Equation 1.3-7 using theoretically determined and experimentally validated activity coefficient models.

Oxalate

An empirical model has been developed for use in the dynamic flowsheet for the salt sodium oxalate. Sodium oxalate is of noted importance because it is semi-soluble in the waste, so it can change phase any time the concentration of sodium or oxalate increases or decreases in the flowsheet. The empirical models are only employed in the dynamic flowsheet because the dynamic flowsheet does not have the capability to employ more rigorous chemistry models. The simplified sodium oxalate solubility equations are:

Equation 1.3-14

$$\ln(c_{C2O4-2}) = \ln(Q) - \ln(\lambda_{C2O4-2}) - 2 * \ln(c_{Na+}) - 2\ln(\lambda_{Na+}) - \ln(T)$$

where ln (Q) is a constant, T is temperature in Kelvin, λ_{Na+} is the activity coefficient of the sodium ion, λ_{C2O4-2} is the activity coefficient of the oxalate ion, c_{Na+} is the concentration of the sodium ion, and c_{C2O4-2} is the concentration of the oxalate ion. These concentration units are expressed in molal units (moles per kilogram of water). The activity coefficients, λ_{C2O4-2} and λ_{Na+}, are themselves functions of composition as described by Equation 1.3-15 and Equation 1.3-16.

Equation 1.3-15

$$\ln(\lambda_{C2O4-2}) = (a + b(Na) + c(Na^2) + d(Na^3))T$$

Equation 1.3-16

$$\ln(\lambda_{Na+}) = (e + f(Na) + g(Na^2) + h(Na^3))T$$

Note that in Equation 1.3-2 and Equation 1.3-3, the symbol "Na" is the concentration of sodium in the supernatant in mole fraction (as apposed to molality used in Equation 1.3-14). Mole fraction units are needed in Equation 1.3-15 and Equation 1.3-16 because the activity coefficients were found to be a simple polynomial function of the mole fraction (CCN 160518). The coefficients a, b, c, d, e, g, and h are constants tabulated in Table 1.3-21. Figure 1.3-10 compares the soluble oxalate concentration to the real waste data tabulated in CCN 160518. A description of the derivation of this simplified sodium oxalate solubility equation can be found in CCN 160518.

Phosphate

In the dynamic flowsheet, phosphate is partitioned into "soft" and "hard" components, designated in the model as "PO4-3" and "PO4-3(HARD)", respectively. Partitioning is done in accordance with the phosphate leach factors given in the Tank Farm Contractor (TFC) feed vector; e.g., the unleachable phosphate is converted to "PO4-3(HARD)". The "soft" or soluble PO4-3 is treated as trisodium phosphate (Na_3PO_4) and the solubility is a function of supernatant sodium, hydroxide, and fluoride concentrations, and temperature (24590-WTP-M4C-V37T-00009, *Phosphate Solubility Algorithm*).

Equation 1.3-17

$$C_{PO4} = \exp(A/T_K + B) * C_{Na}^{\ C} * C_{OH}^{\ D} * C_F^{\ E}$$

Where:

C_{PO4} = Phosphate concentration at equilibrium (gmol/kg H_2O),
C_{Na} = Sodium concentration (gmol/kg H_2O),
C_{OH} = Hydroxide concentration (gmol/kg H_2O),
C_F = Fluoride concentration (gmol/kg H_2O),
T_K = Temperature (K).

Lower bounds are set for C_{OH} = 0.01 gmol/kg H_2O and C_F = 0.01 gmol/kg H_2O. The constants for Equation 1.3-17 are given in Table 1.3-22, while the applicable ranges for the equations parameters are given in Table 1.3-23. Figure 1.3-11 to Figure 1.3-13 illustrate the effect of varying key parameters for **Error! Reference source not found.**Equation 1.3-17 and for previous phosphate correlations used in the dynamic flowsheet (i.e., CCN 177343, *Approximate Sodium Phosphate Solubility Model to Support The 2008 Dynamic Flowsheet Deliverable* and CCN 211818, *Revised Phosphate Algorithm for G2 Model[Supersedes CCN 204880]*).

The phosphate dissolution/precipitation reactions are given as:

$$PO_4^{-3}(s) + 3Na^+(s) \leftrightarrow PO_4^{-3}(l) + 3Na^+(l)$$

If the concentration of PO_4^{-3} (l) is below the calculated solubility, PO_4^{-3} (s) and associated Na^+ (s) dissolve until:

1 Concentration of PO_4^{-3} (l) reaches the solubility [excess PO_4^{-3} (s) and Na^+ (s)] or
2 PO_4^{-3} (s) has completely depleted [PO_4^{-3} (s) limiting]

If the concentration of PO_4^{-3} (l) is above the calculated solubility, PO_4^{-3} (l) and associated Na^+ (l) precipitate until:

3 Concentration of PO_4^{-3} (l) reaches solubility or
4 PO_4^{-3} (l) has completely depleted [PO_4^{-3} (l) limiting]

PO_4^{-3} (l) concentration will not reach solubility when conditions 2 or 4 are encountered. Details related to the development of the phosphate solubility equation are given in 24590-WTP-M4C-V37T-00009.

1.3.4.2 Acid-Base Reactions and Dissolution-Precipitation Equilibrium

The solubility product for dissolution or precipitation reactions that involve acids or bases is the same as described in Equation 1.3-7, except that the top or bottom may have a hydroxide ion. A major solid whose solubility is controlled by acid-base reactions is gibbsite (α-$Al(OH)_3$). The chemical reaction between gibbsite and free hydroxide in solution is given by:

Equation 1.3-18

$$Al(OH)_4^- \longleftrightarrow Al(OH)_{3(s)} + OH^-$$

Besides the aluminate ion [$Al(OH)_4^-$], polymerized forms of soluble aluminum are found at high pH under very high ionic strength conditions (Johnston and others 2002). The equilibrium expression for the above reaction is:

Equation 1.3-19

$$K_{sp} = \frac{(Al(OH)_4^-)}{(OH^-) * 1}$$

The species in the parentheses denote the activity of the species in solution. The one in the denominator is the activity of the solid gibbsite, which is one by definition. Free hydroxide appears in the denominator because hydroxide is a reaction product of the gibbsite precipitation along with gibbsite. The solubility of gibbsite and other acid-base reactions can be predicted by the rigorous thermodynamic models (24590-WTP-MDD-PO-03-003).

Two gibbsite solubility models have been developed for use when the rigorous models are not feasible. One is designed for use at 25 °C and the other for temperatures between 25 °C and 50 °C. The model for 25 °C is described by Equation 1.3-20.

Equation 1.3-20

$$C_{OH} = e * C_{Al} + f * C_{Al}^2 + g * C_{Al}^3$$

where C_{OH} and C_{Al} are the concentration of free hydroxide and aluminate at equilibrium. The coefficients e, f, and g were empirically determined by regression, and their values as well as associated statistics are shown in Table 1.3-24. The development of this model is described in CCN 160514. That reference contains the regression statistic and the goodness of fit for Equation 1.3-20 to data used to develop the regression. Equation 1.3-20 is set up to calculate the quantity of caustic required to keep a given quantity of aluminum soluble. This equation can be reversed to calculate the quantity of aluminum that is soluble at a given concentration of hydroxide. This reverse equation is shown in Equation 1.3-21.
Equation 1.3-21 is invalid at aluminum concentrations above 1.2 molal because the function is undefined above this concentration. The coefficients in Equation 1.3-21 are shown in Table 1.3-25. The derivation of Equation 1.3-21 from Equation 1.3-20 can be found in CCN 160514.

Equation 1.3-21

$$C_{Al} = \sqrt[3]{\left(j + \frac{C_{OH}}{2g}\right) + \sqrt{\left(j + \frac{C_{OH}}{2g}\right)^2 + k}} + \sqrt[3]{\left(j + \frac{C_{OH}}{2g}\right) - \sqrt{\left(j + \frac{C_{OH}}{2g}\right)^2 + k}} + l$$

The data used to develop these models at 25 °C came from Apps and others (1989) as well as Li and others (2005). The gibbsite solubility equations above are only valid at 25 °C. The equations below are for use at temperatures between 25 °C and 50 °C (CCN 221451).

Equation 1.3-22

$$S_{Al} = e * C_{OH} + f * C_{OH}^2 + g * C_{OH}^3$$

Equation 1.3-23

$$S_{OH} = \sqrt[3]{\left(j+\frac{C_{Al}}{2g}\right)+\sqrt{\left(j+\frac{C_{Al}}{2g}\right)^2+k}} + \sqrt[3]{\left(j+\frac{C_{Al}}{2g}\right)-\sqrt{\left(j+\frac{C_{Al}}{2g}\right)^2+k}} + l$$

Where:

$$e = (7.07864e-6)*T^4 - (9.206808e-4)*T^3 + (4.47814e-2)*T^2 - (9.586194e-1)*T + 7.680834$$

$$f = (-4.823189e-6)*T^4 + (6.268796e-4)*T^3 - (3.044321e-2)*T^2 + (6.521685e-1)*T - 5.197387$$

$$g = (7.259612e-7)*T^4 - (9.410837e-5)*T^3 + (4.5653e-3)*T^2 - (9.764447e-2)*T + 7.787686e-1$$

$$j = \frac{-f^3}{27g^3} + \frac{fe}{6g^2}$$

$$k = \left(\frac{e}{3g} - \frac{f^2}{9g^2}\right)^3$$

$$l = -\frac{f}{3g}$$

C_{OH} = Hydroxide concentration (gmol/kg H_2O)
C_{Al} = Aluminate concentration (gmol/kg H_2O)
S_{Al} = Aluminate solubility (gmol/kg H_2O)
S_{OH} = Hydroxide solubility (gmol/kg H_2O)
T = Vessel temperature (°C)

Aluminum will precipitate/dissolve in accordance with the following reversible reactions

$$Al(OH)_4^- (l) \leftrightarrow Al(OH)_3 (s) + OH^- (l)$$

Details related to the development of the aluminum solubility correlations can be found in CCN 160514 and CCN 221451.

The above solubility equations tend to under-predict the solubility of aluminum in real tank waste (Equation 1.3-20 through Equation 1.3-23). This is because the models only take into account the effect of hydroxide on solubility and do not take into account the effect of other ions. This bounding condition was chosen to conservatively maximize the quantity of free hydroxide required to keep aluminum soluble. The rigorous thermodynamic models account for these other effects and more accurately model gibbsite solubility (24590-WTP-MDD-PO-03-003; CCN 128565), so these models are recommended when less conservative results are desired.

1.3.4.3 Redox Reactions

Redox reactions are driven by the redox potential of the system (Denbigh 1963). The redox potential of a system is a measure of how oxidizing or reducing the system is. The redox potential is described as being the ratio of reduced (electron rich) or oxidized (electron poor) molecules in the system at equilibrium (Denbigh 1963).

Some potential oxidizing species in Hanford waste include oxygen, nitrate, nitrite, ferric iron, manganese (IV), and sulfate. Some potential reducing species are methane, hydrogen gas, and ammonia. The redox potential of the waste in the tanks is not clear, and there are no measurements of waste redox potential available. The composition of the entrained gas bubbles inside tank waste is mostly hydrogen, nitrogen, ammonia, and methane, with little or no oxygen, which would indicate highly reducing conditions (Mahoney and others 1999). The solid and liquid phases contain very oxidized species such as nitrate and manganese (IV) (Agnew and others 1997), which would indicate highly oxidizing conditions. Thus, it is likely that the tank waste is not at redox equilibrium, given that both highly oxidizing and highly reducing conditions exist in the waste. The rate for many electron transfer reactions is extremely slow (Miesler and Tarr 1991). The oxidation state of few waste species has been measured. Rapko and others (1996) have determined that manganese in the waste is predominantly in the +4 oxidation state (a very oxidized manganese species), and that chromium is in both the +6 and +3 oxidation state in the sludges they investigated. In the TWINS database (CHG 2007), the concentration of several species of some redox active elements (Cr and Tc) are reported for the liquid phase. Table 1.3-26 contains the Cr(VI) and total Cr concentrations for several tanks from the AN tank farm. These data were taken from the Means and Confidence Intervals tables in the TWINS database, and are all from core samples taken in 1996. Trivalent chromium would be total Cr – Cr(VI). These results indicate that the ratio of Cr(VI) to Cr(III) is between 0.1 and 0.6, which may be the best indicator of the waste redox conditions.

The redox properties of the waste affect solubility when one oxidation state of an element is more soluble than another. Chromium is a major waste constituent with a solubility that is most dependent on the waste redox environment under conditions relevant to the WTP (24590-101-TSA-W000-0004-168-00002). This is because Cr(III) is relatively insoluble under the high caustic conditions of waste, whereas Cr(VI) is very soluble (24590-101-TSA-W000-0004-168-00002; 24590-PTF-ES-PR-05-001). Cr(III) can be oxidized to soluble Cr(VI) as it comes into contact with a strong oxidant, such as oxygen gas or permanganate (24590-101-TSA-W000-0004-168-00002; 24590-PTF-ES-PR-05-001). This fact is exploited to remove Cr(III) from Envelope D sludge in the oxidative leaching process described in Section 2.3.

1.3.5 Boehmite Dissolution Rate Kinetics

A Boehmite dissolution rate equation for simulants is presented in Section A.4 of 24590-QL-HC9-WA49-00001-03-00032, *WTP-RPT-186, Rev 1, EFRT M-12 Issue Resolution: Caustic-Leach Rate Constants for PEP and Laboratory-Scale Tests*. The differential equation for kinetically controlled dissolution in the simulant is given in Equation 1.3-24. It was derived using Boehmite simulants.

Equation 1.3-24

$$\frac{d}{dt}\left(\frac{n_{bs}}{n_{bs,i}}\right) = -kC_{OHL,i}\left(\frac{n_{bs}}{n_{bs,i}}\right)^{2/3}\left(1-\frac{C_{AlL,i}}{C_{Al^*L,i}}\right)\left(1-\frac{C_{AlL}}{C_{Al^*L,i}}\right)e^{\frac{E_a}{R}\left(\frac{1}{373}-\frac{1}{T}\right)}$$

where:

n_{bs} = mol of solid-phase boehmite at time t

$n_{bs,i}$ = mol of solid-phase boehmite at time $t = t_i$ (start of constant-temperature leaching, after heat-up is complete and assumed to be before any boehmite has been leached; it is not the same as t_0, the time just before caustic is added)

k = rate constant ($hr^{-1}*(mol\ total\ hydroxide/L)^{-1}$)

$C_{OHL,i}$ = mol/L of total hydroxide in the liquid phase at time $t = t_i$
C_{AlL} = mol/L of Al in the liquid phase at time t
$C_{AlL,i}$ = mol/L of Al in the liquid phase at time $t = t_i$
$C_{Al^*L,i}$ = mol/L of Al that would exist at saturation in the liquid for the total OH concentration and temperature present at time $t = t_i$
E_a = activation energy for simulant, 120 kJ/mol (accurate to the nearest 10 kJ/mol)
R = ideal gas constant, 8.314 J/mol K
T = absolute temperature, °K

This kinetic model was developed from leaching studies of pure boehmite at temperatures of 85 °C and 100 °C in a solution of 5 M total hydroxide. At each temperature tests were carried out for a range of different initial dissolved aluminum concentrations, from a minimum of 0 % of the saturated concentration to a maximum of 80 % of saturation. The model was then tested with mixtures using the Pretreatment Engineering Platform (PEP) simulant, 19 M NaOH, and water at temperatures ranging from 80 °C to 100 °C. The model was found to provide reasonable predictions of the leaching reaction in complex liquid compositions.

D. Reynolds, of AEM Consulting, used an early form of Equation 1.3-24 for curve fits. The terminology has changed since PNNL issued the final document as shown in Section A.4 of WTP-RPT-186 but the early equation is of the same form and valid for curve fitting. The form of the equation Reynolds initially used was:

Equation 1.3-25

$$\frac{dM}{dt} = -k \cdot M^{2/3} \cdot [OH]^n \cdot f\left(\frac{C}{C_{Sat}}\right)$$

where:

M = fraction of Boehmite yet to dissolve
k = Coefficient
n = Coefficient
C = total concentration of aluminate in solution
C_{Sat} = Boehmite equilibrium concentration of aluminate in solution

When Equation 1.3-25 was applied to actual waste rather than simulant, the equation results were not sufficiently close to the lab results. Actual waste data reported in CCN 173231 were used to derive a simpler function that fits lab data well. The data from CCN 173231 at 100 °C were used to estimate the activation energy so that an Arrhenius term could be used in place of k in Equation 1.3-25. A general form of the equation will be used for curve-fitting actual waste data. The proposed form of this equation is presented in Equation 1.3-26.

Equation 1.3-26

$$\frac{dM}{dt} = -Ao \cdot e^{\left(\frac{-Ea}{R}\frac{1}{T+273}\right)} \cdot M^{2/3} \cdot [OH]^n \cdot \left(1 - \frac{C}{a \cdot C_{Sat}}\right)$$

where:

M	=	fraction of Boehmite yet to dissolve
Mo	=	not used directly in the equation but is used to adjust some parameters. Mo is the concentration of Al contribution from the dissolved Boehmite.
Ao	=	pre factor and equals 1.5063E+07
Ea	=	activation energy, 60 kJ/mole
n	=	coefficient, 0.21
C	=	total concentration of aluminate in solution
C_{Sat}	=	Boehmite equilibrium concentration of aluminate in solution
a	=	correction factor to C_{Sat} to better represent the equilibrium in Hanford waste, 1.12

1.3.5.1 Comparing the Equation to Data

Several sets of data were utilized as a test of how well Equation 1.3-26 fits the data. The full data set is available in CCN 173231. Memorandum CCN 173231 places PNNL's document WTP-RPT-157, *Characterization and Leach Testing for REDOX Sludge and S-Saltcake Actual Waste Sample Composites*, in the WTP Project library. WTP-RPT-157 was utilized, as well as the data from beaker tests by Shimsky, et al. Earlier leach data for tank 241-S-101 was also used because there were a number of different studies at various temperatures. Each of these studies will be discussed below.

1.3.5.1.1 WTP-RPT-157 Data Fit

The data available in WTP-RPT-157 were used to derive the form of the function of (C/C_{Sat}). The data were used to derive the values for Ea, Ao and n. There were nine sets of data at three temperatures and three caustic concentrations that were utilized to compare the equation. The data set had multiple sets of data at 90 °C and 3 M hydroxide but only the average of the sets are shown.

The solids were estimated to have sufficient aluminum so that the aluminate concentration would be 0.2 M if it all dissolved. The document further estimates that approximately 95 % of the solids are Boehmite and 5 % Gibbsite. These were used to estimate the values for C and Mo. Mo was estimated to be 0.95*0.2 M for 90 °C and 100 °C runs. The data indicated that not as much aluminum was present in the 80 °C runs so Mo was set at 0.975*0.2 M for those runs. C was set as 0.2 minus Mo for all runs.

Even though the calculations do vary somewhat from the data, the range is acceptable. The fact that the curves miss the 1 hour point may be due to estimating Mo, as mentioned above. Note also that the experiments were heated prior to the leaching time; dissolution may start during heat-up and, thus, contribute to the uncertainty of Mo. The curves seem to fit the 100 °C data best so the 100 °C data was used to derive the constants in Equation 1.3-26. The curves have poorer fit at 24 hours. This may be because of a greater extrapolation from initial rate values. Most of the leaching times, for G2, will be less than 16 hours, where the data appears to fit better.

Figure 1.3-4 shows another way to view the fits. Here the data is directly compared to the calculations.

The lower fit could be improved by improving the estimate of Mo for each run.

1.3.5.1.2 WTP-RPT-172 Data Fit

Three different beaker tests were reported by Shimsky, et al. These tests were run at 100 °C and 3, 5, and 7 M hydroxide. A value for Mo is reported as well as the initial aluminate concentration. Figure 1.3-5 shows that the fit is very good initially but degrades at 24 hours. Figure 1.3-6 shows the correlation between data and calculations, and are a reasonable fit.

1.3.5.1.3 241-S-101 Data Fit

Waste in tank 241-S-101 has been used for leaching studies a number of times (Lumetta 1998, Lumetta 1997, Lumetta 2002, Hunt). The main aluminum mineral has been identified as boehmite. The temperatures range from 70 °C to 100 °C and the hydroxide ranges from 1 to 10 M.

Lumetta 1998 had a single temperature of 100 °C. The value for Mo was calculated. This value of 2.2 M is larger by about a factor of 10 than the other Mo values. The hydroxide concentration was only available for after leaching. The value chosen, 2.7 M, was after the second leach. No value was given for C and only one time was given.

Lumetta 1997 had data for 1 and 3 M hydroxide at 70 °C and 95 °C. The document estimated that 90 % of the aluminum was leached after 168 hours at 95 °C and 3 M caustic. This allowed for a calculated Mo, but no information was available for C.

Lumetta 2002 had three data sets for 85 °C and an estimated 1 M caustic. A different Mo was given for each data set. Values for C initial were given for each data set. Samples were taken several times, up to 5 hours.

The data in Hunt was for 1 and 3 M caustic and 70 °C and 95 °C. Values of Mo were calculated, but confidence levels remained low. No values of C initial are given. Data was given at 5 and 24 hours.

Overall, the calculations for the 241-S-101 data comparison (see Figure 1.3-7) tend to predict high for this waste. The value that is farthest from the diagonal is the data point from Lumetta 1997 and has an estimated Mo that is ten times greater than others. The Mo would have to be brought down to about 0.9 M from 2.2 M. The next highest point also has a doubtful Mo.

1.3.5.2 Accuracy of the Boehmite Kinetics Dissolution Curve Fit and Equation

Equation 1.3-26 has been tried on various sets of data. The data sets ranged from 70 °C to 100 °C and from 1 to 7 M hydroxide. Equation 1.3-26 was adequate to estimate the concentration of aluminum in solution. The accuracy decreased as the time approached 24 hours, but the anticipated time range for modeling would be between 4 and 16 hours.

Applying Equation 1.3-26 to the data sets showed that the amount of aluminum in solution initially, C, and the concentration of aluminum if all Boehmite dissolved, Mo, were not well-defined in the data reports. The uncertainty in these two values had a substantial impact on the ability of the equation to accurately estimate the aluminum concentrations. In the G2 model, these two variables are known. When all the data points presented in this report are compared to the calculated results, the coefficient of determination, R^2, is calculated to be 0.75. One interpretation of R^2 would be: "75 % of the variability in aluminum concentration is related to the terms in the rate equation." Considering the uncertainties in $C_{initial}$ and Mo, an R^2 of 0.75 is within the expected range.

Looking at the R^2 for individual data sets, the dataset for WTP-RPT-157 was 0.96. This was the dataset that the Equation 1.3-26 was adjusted to. The RPT-172 data set was not quite as favorable at 0.79, while the S-101 dataset (which had difficulties estimating Mo) had $R^2 = 0.67$. This shows that uncertainty on input parameters degraded the performance of Equation 1.3-26.

Overall, the inclusion of Equation 1.3-26 into the dynamic model will improve the estimates of the aluminum solubility and the amount of sodium needed.

1.3.6 Optimum Caustic Leaching (Caustic Leaching Smart Logic)

Generally, less HLW glass will be produced from tanks UFP-VSL-00001 or UFP-VSL-00002 when the solids are caustic leached to remove aluminum. Under-leaching aluminum will increase the HLW canister count; over-leaching will increase processing time and add unnecessary sodium in the process. The following routine estimates the optimum amount of aluminum to leach and then adjusts the aluminum leach factor accordingly.

1.3.6.1 Estimated HLW Glass for Limiting Species in UFP-01 or -02

The amount of HLW glass expected to be made for most of possible limiting analytes is determined in Equation 1.3-27. A table used to determine the coefficients in Equation 1.3-27 is presented in Section 4.1, Table 4-2. The expected glass amounts for chromium and phosphate are determined separately. The estimated glass for minor constituents in the waste is estimated after the impact by the chromium, which follows in Section 1.3.6.2. The glass estimate in Equation 1.3-27 is coordinated with the HLW glass routine given in Section 4.1 and should estimate a similar amount of glass as that estimated as in Section 4.1, although with less accuracy since not all the glass properties are included in Equation 1.3-27.

Equation 1.3-27

units: kg glass

EG-Majors = MAX
Bi+3 * 232.97 * (1 - LF-Bi+3) / BC-Bi2O3,
Ca+2 * 56.08 * (1 - LF-Ca+2) / BC-CaO,
Cd+2 * 128.41 / BC-CdO,
Cl- * 35.45 / BC-Cl,
F- * 18.99 / BC-F,
Fe+3 * 79.84 * (1 - LF-FE+3) / BC-Fe2O3,
K+ * 47.10 / BC-K2O,
Mg+2 * 40.30 / BC-MgO,
Mn+2 * 70.94 / BC-MnO,
Ni+2 * 74.69 / BC-NiO,
(Pd+2 * 223.20 + Rh+3 * 126.90 + Ru+4 * 133.07) / BC-NobleMetals,
Pb+2 * 223.19 / BC-PbO2,
Si+4 * 60.08 / BC-SiO2,
SO4-2 * 80.06 * (1 - LF-SO4-2) / BC-SO3,
Sr+2 * 103.62 / BC-SrO,

Th+4 * 265.03 / BC-ThO2,
Zr+4 * 123.22 / BC-ZrO2,
U(Total) * 270.03 / BC-UO2,
((Na+ * (1 - LF-Na+) - (2 * C2O4-2(s) * PTWF-C2O4)) * 30.99) / BC-Na2O,
(PO4-3(HARD) + P_{pf} * PO4-3)* 70.97 / BC-P2O5,
((PO4-3(HARD) + P_{pf} * PO4-3) * 70.97 * Ca+2 * 56.08 * (1 - LF-CA+2) / BC-P2O5xCaO) ^ 0.5

where: EG-Majors is the estimated glass amount expected for major glass constituents listed in Equation 1.3-27.

BC-*i* is the HLW glass oxide limiting value set in G2 as wt fraction units, not wt%. BC-*i* coefficients are given in Section 4.1, Table 4-2.

Multiplier values are in kg oxide/kg mol element

LF values are Tank Farm's given leach factor values for corresponding element, units in wt-fraction

PTWF-C2O4 is a wash factor for solid oxalate in Pretreatment

PO4-3(Hard) is the insoluble form of phosphate in the batch, kg mol

PO4-3 is the soluble form of phosphate in the batch, kg mol

P_{pf} is an estimated average of the soluble phosphate that will precipitate and report to HLW for vitrification.

1.3.6.2 Estimated Glass for Chromium

Chromium may be oxidative leached for the batch depending on its concentration in the batch. An estimated oxidative leaching impact needs to be included, as does the effectiveness of washing the dissolved chromium from the batch.

Equation 1.3-28

units: kg glass

EG-Cr = Cr(Total) * 75.99 * (1 - LF-CR+3) * [(1 - OxLF) + (1 - WF-Ox) * OxLF] / BC-Cr2O3

where: OxLF is the oxidative leach factor for chromium

WF-Ox is the estimated wash factor for removing dissolved chromium and other salts from the batch after oxidative leaching. Presently, three vessel washing cycles are performed. Assuming perfect washing, the amount washed away is $e^{X \text{ washes}}$. The oxidative wash factor for three washes would be WF-Ox = $(1 - e^{-3}) = 0.9502$.

Cr(Total) is all forms of solid chromium in the feed, kg

1.3.6.3 Estimated Glass for Minor Waste Constituents

Equation 1.3-29

units: kg glass

EG-Minors =

Ag+ * 115.87 + As+5 * 114.92 +
Ba+2 * 153.33 + Be+2 * 25.01 +
Cl- * 35.45 + Co+2 * 74.93 +
Cs+ * 140.91 + Cu+2 * 79.55 +
Eu+3 * 175.96 + F- * 19.00 +
La+3 * 162.90 + Mo+6 * 111.94 +
Nd+3 168.24 +
Pd+2 * 223.20 + Pr+3 * 164.91 +
Rb+ * 93.47 + Re+7 * 210.21 +
Rh+3 * 126.90 + Ru+4 * 133.07 +
Sb+3 * 145.76 + Se+4 * 110.96 +
Sm+3 * 174.36 + Sn+4 * 150.71 +
Tc+7 * 153.00 + Te+4 * 159.60 +
Tl+4 * 236.38 + V+5 * 90.94 +
W+6 * 231.85 + Y+3 * 112.90 +
Zn+2 * 81.39
/ BC-Minors

1.3.6.4 Estimated Glass for Non-Limiting Aluminum

Aluminum is no longer limiting when enough aluminum is dissolved and washed away in pretreatment processes. Some other analyte then becomes limiting in HLW. This happens when the estimated glass for aluminum equals EG-Majors, EG-Minors, or EG-Cr. Therefore:

Equation 1.3-30

units: kg element

MinAl = MAX (EG-Majors, EG-Minors, EG-Cr) * BC-Al2O3 * 2 * mw(Al) / mw(Al_2O_3)

where: Min-Al defines the goal amount of aluminum (as Al) left as solids when the amount of glass made by aluminum or another analyte is the same.

mw(*i*) means the molecular weight of compound *i*, kg/kgmole

The exception can be if sodium (as sodium hydroxide) were added in an attempt to dissolve aluminum to a degree that it (sodium), becomes limiting. As this is not expected to occur often, it is not included in the logic at this time.

1.3.6.5 Desired Aluminum Leaching

Aluminum shall be leached only until some other constituent in the batch becomes limiting. This should help limit sodium usage and reduce processing time. If kinetic leaching of Boehmite is to be performed, proceed with the logic given in Section 1.3.5 to determine the amount of aluminum to leach and the times required for leaching. If kinetic leaching of Boehmite is not to be performed, then the desired amount of

Gibbsite to leach is calculated as follows. Leachable aluminum is presented as "Al(OH)3" in the feed vector. Consequently, the leaching limit for aluminum is the amount of aluminum in "Al(OH)3". Therefore, leaching this amount or less is allowed in the leaching equations. Caustic addition, processing time, and so forth shall be adjusted in G2 according to the value called GibReact, calculated below.

Equation 1.3-31

units: kg element

AlReact = MIN(Al+3 * mw(Al) + Al(OH)3 * mw(Al) - MinAl , Al(OH)3 * mw(Al))

where: AlReact in the mass of aluminum (in the gibbsite) that reacts and is dissolved, kg

Equation 1.3-32

units: kg compound

$$GibReact = AlReact \frac{mw(Al(OH)_3)}{mw(Al)}$$

where: GibReact is the mass reacted or dissolved gibbsite, kg

Equation 1.3-33

units: kg compound

Al(OH)3u = MAX (Al(OH)3 - GibReact , 0)

where: Al(OH)3u is the mass of undissolved gibbsite (tracked by G2) that proceeds to oxidative leaching or ultrafiltration, kg

A common reasoning is that gibbsite dissolves quickly and the amount of caustic cannot be adjusted accurately enough to dissolve just the amount of gibbsite needed. Therefore, all the gibbsite dissolves and Al(OH)3u = 0.0.

1.3.7 Optimum Oxidative Leaching (Oxidative Leaching Smart Logic)

Oxidative leaching of chromium puts sodium and manganese into the process via the use of sodium permanganate to oxidize insoluble Cr^{+3} to soluble Cr^{+6}. Consequently, oxidative leaching should be performed only if necessary. Also, the logic assumes that oxidative leaching would result in 10 % less HLW glass to be made before oxidative leaching is actually performed.

Washing the leached chromium is an important process step in reducing the amount of chromium sent to the HLW Facility;reduces the available processing time. The provided logic will determine whether two or three washing cycles of the leached solids are necessary.

Equation 1.3-34

units: kg

EGox-Majors = MAX

Bi+3 * 232.97 / BC-Bi2O3,
Ca+2 * 56.08 / BC-CaO,
Cd+2 * 128.41 / BC-CaO,
Cl- * 35.45 / BC-Cl,
F- * 18.99 / BC-F,
Fe+3 * 79.84 / BC-Fe2O3,
K+ * 47.10 / BC-K2O,
Mg+2 * 40.30 / BC-MgO,
Mn+2 * 70.94 / BC-MnO
Ni+2 * 74.69 / BC-NiO,
(Pd+2 * 223.20 + Rh+3 * 126.90 + Ru+4 * 133.07) / BC-NobleMetals,
Pb+2 * 223.19 / BC-PbO2,
Si+4 * 60.08 / BC-SiO2,
SO4-2 * 80.06 / BC-SO3,
Sr+2 * 103.62 / BC-SrO,
Th+4 * 265.03 / BC-ThO2,
Zr+4 * 123.22 / BC-ZrO2,
U(Total) * 270.03 / BC-UO2,
((Na+ - (2 * C2O4-2(s) * PTWF-C2O4)) * 30.99) / BC-Na2O,
(PO4-3(HARD) + PO4-3) * 70.97 / BC-P2O3,
(((PO4-3(HARD) + PO4-3) * 70.97 + Ca+2 * 56.08)/ BC-P2O5+CaO) ^ 0.5,
Al+3(s) * 50.98/ BC-A12O3

where: EGox-Majors is the estimated glass amount expected for major analytes listed in the Equation 1.3-34.

BC-*i* is the HLW glass oxide limiting value set in G2 as wt fraction units, not wt%. BC-*i* coefficients are given in Section 4.1, Table 4-2.

Multiplier values are in kg oxide/kgmole element

LF values are Tank Farm's given leach values for corresponding element, units in wt-fraction.

PTWF-C2O4 is a wash factor for solid oxalate in Pretreatment

PO4-3(HARD) is an un-dissolvable phosphate form used in some feed vectors that should be included with the solids in the batch.

Al+3 is all solid forms of aluminum in the batch (e.g., $Al(OH)_3$, AlOOH, cancrinite, etc.)

Equation 1.3-35

units: kg

EGox-Minors =

Ag+ * 115.87 + As+5 * 114.92 +
Ba+2 * 153.33 + Be+2 * 25.01 +
Cl- * 35.45 + Co+2 * 74.93 +
Cs+ * 140.91 + Cu+2 * 79.55 +

Eu+3 * 175.96 + F- * 19.00 +
La+3 * 162.90 + Mo+6 * 111.94 +
Nd+3 168.24 +
Pd+2 * 223.20 + Pr+3 * 164.91 +
Rb+ * 93.47 + Re+7 * 210.21 +
Rh+3 * 126.90 + Ru+4 * 133.07 +
Sb+3 * 145.76 + Se+4 * 110.96 +
Sm+3 * 174.36 + Sn+4 * 150.71 +
Tc+7 * 153.00 + Te+4 * 159.60 +
Tl+4 * 236.38 + V+5 * 90.94 +
W+6 * 231.85 + Y+3 * 112.90 +
Zn+2 * 81.39
/ BC-Minors

Equation 1.3-36

units: kg

EG-ox = MAX(EGox-Majors, EGox-Minors)

1.3.7.1 Washings after Oxidative Leaching

The following logic should provide logic for deciding whether to oxidative leach a batch, and whether to perform two or three washing cycles of solids after oxidative leaching.

EG-CrNoL = Cr(Total) * 75.99 / BC-Cr2O3 Units: kg
EG-Cr2xW = Cr(Total) * 75.99 * [(1 - OxLF) + (1 - (1 - e^{-2})) * OxLF] / BC-Cr2O3 Units: kg
EG-Cr3xW = Cr(Total) * 75.99 * [(1 - OxLF) + (1 - (1 - e^{-3})) * OxLF] / BC-Cr2O3 Units: kg

where: EG-CrNoL is the estimated glass amount present without oxidative leaching.
EG-Cr2xW is the estimated glass amount based on oxidative leaching and 2 washings.
EG-Cr3xW is the estimated glass amount based on oxidative leaching and 3 washings.
OxLF is the oxidative leach factor for chromium.

IF 1.1 * EG-Ox > EG-CrNoL THEN Unit: kg
OxWash = 0 {integer zero} Unitless
GOTO Line A Unitless
ELSE Unitless
OxWash = 2 {integer two} Unitless
IF 1.1 * EG-Ox > EG-Cr2xW THEN GOTO Line A Unit: kg
ELSE Unitless
OxWash = 3.0 {integer three} Unitless
Line A - Instructions for UFP-2 operation follow.

If *OxWash* = 0, do not perform oxidative leaching on batch. If *OxWash* > 0, the following logic should provide logic for deciding whether to oxidative leach a batch, and whether to perform two or three washing cycles of solids after oxidative leaching.

EG-CrNoL = Cr(Total) * 75.99 / BC-Cr2O3
Units: kg Eq. 4

EG-Cr2xW = Cr(Total) * 75.99 * [(1 - OxLF) + (1 - (1 - e^{-2})) * OxLF] / BC-Cr2O3
Units: kg Eq. 5

EG-Cr3xW = Cr(Total) * 75.99 * [(1 - OxLF) + (1 - (1 - e^{-3})) * OxLF] / BC-Cr2O3
Units: kg Eq. 6

where: EG-CrNoL is the estimated glass amount present without oxidative leaching.
EG-Cr2xW is the estimated glass amount based on oxidative leaching and 2 washings.
EG-Cr3xW is the estimated glass amount based on oxidative leaching and 3 washings.
OxLF is the oxidative leach factor for chromium.

IF 1.1 * EG-Ox > EG-CrNoL THEN	Unit: kg	Eq. 7
OxWash = 0 {integer zero}	Unitless	Eq. 8
GOTO Line A	Unitless	Eq. 9
ELSE	Unitless	Eq. 10
OxWash = 2 {integer two}	Unitless	Eq. 11
IF 1.1 * EG-Ox > EG-Cr2xW THEN GOTO Line A	Unit: kg	Eq. 12
ELSE	Unitless	Eq. 13
OxWash = 3.0 {integer three}	Unitless	Eq. 14
Line A - Instructions for UFP-2 operation follow.		

If *OxWash* = 0, do not perform oxidative leaching on batch. If *OxWash* > 0, then perform oxidative leaching on the batch. The value of *OxWash* dictates the number of oxidative washes to perform, which is 0, 2, or 3.

1.3.8 References

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Table 1.3-1 Envelope D Feed by Waste Group

Limiting Group	Minimum Required wt % in HLW Glass as Oxides	No. of Batches	Percentage of TFCOUP 6's (Kirkbride and others 2007)			Percentage of All HLW Glass Made
			Suspended Solids*	Total Solids**	Total Inventory***	
Aluminum-LL	11	159	30.18	22.86	25.80	39.08
Aluminum-HL	11	94	15.45	12.38	15.30	12.05
Chromium	0.5	79	15.57	11.79	12.81	16.35
Bismuth	2	54	14.70	8.34	8.90	16.35
Fluoride (Halide)	1.7	32	4.45	4.84	5.30	2.84
Iron-Aluminum	21 (Fe+Al+Zr oxides)	7	3.82	3.05	2.12	2.00
Phosphate	3	9	3.60	1.83	1.56	1.90
Iron	12.5 to 14	18	3.59	3.69	3.19	3.25
Zirconium-Aluminum	14 (Al+Zr oxides)	13	3.31	1.41	1.23	1.60
Sodium	15 (Na+K oxides)	8	1.97	3.18	3.24	2.34
Calcium	7	15	1.67	4.53	3.62	1.35
Uranium	8	9	1.12	0.55	1.21	0.39
Sulfate	0.5	8	0.46	4.87	3.38	0.37
Lead (Low Solids)	1	1	0.09	0.96	0.97	0.12
LAW (Low Solids)	--	12	0.00	15.74	11.38	0.00
Totals	--	518	100.00	100.00	100.00	100.00
Mass Totals, kg	--	--	25,481,247	137,514,019	461,557,686	45,913,978

Source: 24590-WTP-RPT-PE-07-001

* The slurry from Tank Farms will contain both dissolved and suspended (undissolved) solids. This column shows the percent by weight of all the suspended solids expected to be delivered with each group.

** This column shows the percent by weight of all solids (both dissolved and suspended) expected to be delivered with each group.

*** The total inventory is the expected mass of all slurry or batches to be delivered to WTP. It includes both the liquid phase and solids phases. It is the equivalent of *Total Solids* plus the water expected to be in the slurry. This column shows the percent by weight of the total inventory (or slurry) expected to be delivered with each group.

Table 1.3-2 System Plan Rev. 6, Species Limiting HLW Waste Loading

	Limiter	Limiting Value wt% in Glass	~No. SP6 Batches	Final Glass by Limiter wt% of Total
1	Al_2O_3	20.00	105	18.16
2	Bi_2O_3	3.20	65	10.18
3	CaO	7.00		
4	CdO	1.50		
5	Cl	0.50		
6	Cr_2O_3	1.20	67	12.58
7	F	2.00		
8	Fe_2O_3	17.40	50	8.33
9	K_2O	6.00		
10	MgO	6.00		
11	MnO	7.00	12	1.39
12	Na_2O	21.40	36	5.36
13	NiO	3.00		
14	Noble metals	0.25		
15	P_2O_5	2.50	4	0.55
16	P_2O_5 x CaO	0.00065*	15	2.42
17	PbO	5.00		
18	SiO_2	53.00		
19	SO_3	0.50	188	32.66
20	SrO	4.50		
21	ThO_2	6.00		
22	UO_3	6.60	18	2.49
23	ZrO_2	13.50	40	5.90
24	Minors	4.50		
			600	100.00

Table 1.3-3 Most Prevalent Organics in TWINS

Species	CAS Number	Number of Tanks Identified in Solid Phase	Number of Tanks Identified in Liquid Phase
Citrate $C_6H_5O_7^{-3}$	126-44-3	6	10
EDTA (Ethylenediaminetetra-acetic acid)$C_{10}H_{16}N_2O_8$	60-00-4	5	7
Glycolate $C_2H_3O_3^{-1}$	666-14-8	14	18

Table 1.3-3 Most Prevalent Organics in TWINS

Species	CAS Number	Number of Tanks Identified in Solid Phase	Number of Tanks Identified in Liquid Phase
Formate CHO_2^{-1}	12311-97-6	35	36
Tributyl phosphate $C_{12}H_{27}O_4P$	126-73-8	3	5
HEDTA(Hydroxyethyl-ethylenediaminetriacetic acid) $C_{10}H_{18}N_2O_7$	150-39-0	4	5
Acetate $CH_3CO_2^{-1}$	71-50-1	29	33
Tridecane $CH_3(CH_2)_{11}CH_3$	629-50-5	2	1
NTA (Nitrilotriacetate) $C_6H_6NO_6^{-3}$	28528-44-1	2	2
Dodecane $C_{12}H_{26}$	112-40-3	2	-
Acetone CH_3COCH_3	67-64-1	6	13
Aroclor 1248 (dry weight)	12672-29-6	5	-
Aroclor 1254	11097-69-1	41	-
Decane $C_{10}H_{22}$	124-18-5	1	-
Nonane $CH_3(CH_2)_7CH_3$	111-84-2	1	-
Pentadecane $CH_3(CH_2)_{13}CH_3$	629-62-9	1	-
Tetradecane $CH_3(CH_2)_{12}CH_3$	629-59-4	2	1
Undecane $C_{11}H_{24}$	1120-21-4	1	-
Xylenes $(CH_3)_2C_6H_4$	1330-20-7 108-38-3M 95-47-6	3	-

Table 1.3-3 Most Prevalent Organics in TWINS

Species	CAS Number	Number of Tanks Identified in Solid Phase	Number of Tanks Identified in Liquid Phase
1-Butanol $CH_3(CH_2)_3OH$	71-36-3	-	5
2-Butanone $CH_3CH_2COCH_3$	78-93-3	-	8
2-Butoxyethanol $CH_3CH_2COCH_3$	111-76-2	-	2
2-Hexanone $C_4H_9COCH_3$	111-76-2	-	1
IDA (Iminodiacetate) $C_4H_5NO_4^{-2}$	28528-43-0	-	2
Methylene chloride CH_2Cl_2	75-09-2	-	1
Nitrosoiminodiacetic/Iminodiacetic Acid	-	-	1
Oxalate $C_2O_4^{-2}$	338-70-5	-	65

Table 1.3-4 Complexants and Carboxylate Ions (Compiled from Meacham 2004)

Tank and Sample	Acetate wt%	Citrate wt%	Glycolate wt%	Formate wt%	Oxalate wt%	EDTA wt%	ED3A wt%	HEDTA wt%	IDA wt%	NTA wt%
Rank	4	2	7	5	1	6	9	8	3	10
A-101	0.0854	0	0	0.0720	1.04	0.0781	0.0000	0	0.440	0
A-102	0.0732	0.0495	0	0.0454	0.382	0	0	0	0	0
AX-102	0	0.194	0.246	0.128	0.491	0.123	0.000	0.0647	0.440	0
B-106	0.00122	0	0	0.00320	0	0	0	0	0	0
BY-102	0.0488	0	0	0.00107	1.86	0	0	0	0	0
BY-104	0	1.143	0	0	1.47	0	0	0	0	0
BY-105	0.0448	0.0800	0	0.0232	0	0	0	0	0	0
BY-107	0.0570	0	0	0.0160	0.710	0	0	0	0	0
BY-110	0.0382	0	0	0.00934	2.59	0	0	0	0	0
BY-110	0.0183	0	0	0	1.01	0	0	0	0	0
BY-110	0.0289	0	0	0.00320	0.0120	0	0	0	0	0
C-104	0.10171	0	0	0.0507	0.0628	0	0	0	0	0
C-105	0.0936	0.149	0	0.0123	0.0139	0	0	0	0	0.0383
C-201	0.0387	0	0	0.00454	1.01	0	0	0	0	0.0421
U-105	0.0289	0.149	0.128	0.192	0.227	0.164	0.000	0.233	0	0
U-106	0.0146	0.225	0.144	0.0720	0.131	0.259	0.000	0.289	0	0
U-108	0.0244	0	0.0512	0.0480	0.136	0.0411	0.0000	0.0112	0.0586	0
AW-101	0.3784	0.0065	0.0150	0.0264	0.3002	0.0000	0.0000	0.0000	0.0000	0.0023
AN-101	0.0000	0.1867	0.3009	0.1201	0.3821	0.0822	0.1205	0.1252	0.0161	0.1264
SY-101	0.0814	0.0316	0.0544	0.1361	0.1774	0.2178	0.3034	0.0000	0.1026	0.0333
SY-101	0.0000	0.0305	0.0000	0.0614	0.5731	0.0781	0.0278	0.0000	0.0806	0.2184
SY-103	0.0610	0.0419	0.0000	0.1201	0.0000	0.0534	0.0249	0.0000	0.2016	0.0142
SY-103	0.0692	0.0572	0.0000	0.0907	0.6004	0.0658	0.1621	0.0000	0.1613	0.1609
Average	0.0560	0.1019	0.0409	0.0537	0.5730	0.0506	0.0278	0.0315	0.0652	0.0276
g compound per g oxalate	0.098	0.178	0.0713	0.094	1	0.088	0.048	0.055	0.114	0.048
g C/g of compound	0.407	0.381	0.320	0.267	0.273	0.411	0.416	0.432	0.367	0.383

Table 1.3-5 Ratio of Alkali Metals to Cesium

Ratio	Maximum	Minimum
Lithium/Cesium	472	0.03
Rubidium/Cesium	11	0.0
Potassium/Cesium	20,263	398
Cesium/radiocesium	7.3	2.9

Source: 24590-WTP-RPT-PE-07-001

Table 1.3-6 Reconciled Compound Based 241-SY-102 Feed Composition

STREAM	FRP14	FRP14
PHASE	Aqueous	Solid
TEMPERATURE, F	77.0	77.0
total lb	1.33E+05	7.72e+04
COMPONENT	lb	lb
Water	9.67E+04	0.00E+00
Oxygen	5.61E-29	0.00E+00
Carbon Dioxide	4.46E-12	0.00E+00
Nitrous Acid	1.09E-08	0.00E+00
Nitric Acid	3.45E-17	0.00E+00
Hydrogen Chloride	4.31E-19	0.00E+00
Hydrogen	2.02E-29	0.00E+00
Mercury[1]	9.45E-04	1.77E+00
Silver	0.00E+00	1.20E+01
Aluminum Hydroxide	1.97E+03	3.13E+04
Arsenic Acid	1.80E-01	0.00E+00
Barium Hydroxide	1.03E-01	0.00E+00
Barium Sulfate	0.00E+00	1.17E+01
Beryllium Hydroxide	5.11E-01	0.00E+00
Bismuth Oxide	6.40E-01	8.17E+02
Calcium Hydroxide	2.33E-02	0.00E+00
Cadmium Hydroxide	0.00E+00	1.56E+02
Cerium (IV) Oxide	0.00E+00	1.69E+01
Chromium (III) Hydroxide	3.18E-08	0.00E+00
Chromium (III) Oxide Hydroxide	0.00E+00	9.17E+03
Copper Oxide	1.39E+00	0.00E+00
Iron(II) Hydroxide	3.05E-03	0.00E+00
Iron (III) Oxide	2.50E-03	1.10E+04

Table 1.3-6 Reconciled Compound Based 241-SY-102 Feed Composition

STREAM	FRP14	FRP14
PHASE	Aqueous	Solid
TEMPERATURE, F	77.0	77.0
total lb	1.33E+05	7.72e+04
COMPONENT	lb	lb
Mercury(II) Hydroxide	1.13E-02	0.00E+00
Potassium Hydroxide	4.49E+02	0.00E+00
Lanthanum Trihydroxide	4.91E-08	2.30E+01
Magnesium Hydroxide	2.44E-06	2.33E+02
Manganese(II) Hydroxide	1.91E-03	0.00E+00
Trimanganese (II,III) Tetraoxide	0.00E+00	1.02E+03
Molybdenum (VI) Oxide	1.20E+01	0.00E+00
Sodium Hydroxide	6.67E+03	0.00E+00
Sodium Nitrite	1.92E+04	0.00E+00
Sodium Nitrate	1.31E+04	0.00E+00
Sodium Carbonate	5.05E+03	0.00E+00
Sodium Sulfate	6.89E+02	0.00E+00
Sodium Chloride	1.03E+03	0.00E+00
Sodium Orthophosphate	1.56E+02	0.00E+00
Sodium Bicarbonate	1.78E-02	0.00E+00
Sodium Chromate	2.04E+02	0.00E+00
Sodium Cyanide	6.62E+00	0.00E+00
Sodium Tellurite	1.69E-08	8.38E-01
Neodymium Hydroxide	0.00E+00	8.59E+01
Nickel (II) Hydroxide	3.44E+00	2.10E+02
Lead(II) Hydroxide	1.84E+01	0.00E+00
Palladium Hydroxide	0.00E+00	9.76E+00
Praseodymium Hydroxide	0.00E+00	2.75E+01
Rhodium Hydroxide	4.49E-01	0.00E+00
Rhodium Oxide	1.92E-08	2.70E-01
Silicon Dioxide[2]	7.31E+01	1.96E+03
Thallium Hydroxide	1.15E-02	0.00E+00
Thorium Dioxide	1.31E-09	1.23E+02
Sodium Orthovanadate	2.67E+01	0.00E+00
Sodium Tungstate	1.24E+02	0.00E+00
Zirconium(IV) Oxide	0.00E+00	9.64E+01
Hydroxyapatite	0.00E+00	1.54E+03

Table 1.3-6 Reconciled Compound Based 241-SY-102 Feed Composition

STREAM	FRP14	FRP14
PHASE	Aqueous	Solid
TEMPERATURE, F	77.0	77.0
total lb	1.33E+05	7.72e+04
COMPONENT	lb	lb
Boric Acid	3.53E+01	0.00E+00
Rutile	0.00E+00	8.84E+00
Titanium Hydroxide	5.06E-15	0.00E+00
Zinc Hydroxide	0.00E+00	1.60E+02
ORGANICS		
Sodium Oxalate	7.33E+01	1.89E+04
RADIONUCLIDES		
Americium (III) Hydroxide	0.00E+00	6.06E+00
Cesium Hydroxide	1.43E+00	0.00E+00
Cobalt Hydroxide	4.81E-01	0.00E+00
Europium Hydroxide	0.00E+00	2.49E-03
Antimony Hydroxide	0.00E+00	2.14E+00
Sodium Selenite	2.20E+00	0.00E+00
Sodium Selenate	4.87E-02	0.00E+00
Strontium Carbonate	4.32E-02	2.16E+01
Sodium Pertechnetate	2.63E+00	0.00E+00
Disodium Diuranate	3.89E-08	3.29E+02
Plutonium(IV) Hydroxide	2.62E-06	3.54E+01
Dioxyplutonium (V) Hydroxide	3.49E-11	0.00E+00
Dioxoplutonium (VI) Hydroxide	6.70E-15	0.00E+00

[1] Elemental mercury is a liquid at ambient temperature. The elemental mercury that is shown in the solids column denotes elemental mercury that is not dissolved in the aqueous phase whereas the liquid column denotes dissolved elemental mercury. To prevent the non-aqueous elemental mercury from passing through the ultrafilter and reporting to the LAW Facility, this mercury may be tracked in the flowsheet as HgO, and 1.77 lb of Hg translates into 1.92 lb of HgO.

[2] Solid SiO_2 is not in all rigorous chemistry models for the Steady-State Flowsheet. The SiO_2 can be added as $Na_2SiO_3.8H_2O$ in these cases. 1960 lb of SiO_2 equates to 8419 lb of $Na_2SiO_3.8H_2O$, which adds a trivial (1.500 lb) amount of sodium to the feed vector.

Table 1.3-7 Comparison of Reconciled 241-SY-102 Liquid Phase to the Specification 7 Limits

Chemical Analyte	mol/mol Na	Env. A Limit (mol/Mol Na)	% Env. A limit	Env. B limit (mol/Mol Na)	% Env. B limit
Al	3.46E-02	2.50E-01	1.38E+01	2.50E-01	1.38E+01
Ba	8.21E-07	1.00E-04	8.21E-01	1.00E-04	8.21E-01
Ca	4.32E-07	4.00E-02	1.08E-03	4.00E-02	1.08E-03
Cd	0.00E+00	4.00E-03	0.00E+00	4.00E-03	0.00E+00
Cl	2.41E-02	3.70E-02	6.50E+01	8.90E-02	2.70E+01
Cr	1.73E-03	6.90E-03	2.51E+01	2.00E-01	8.64E-01
F	0.00E+00	9.10E-02	0.00E+00	9.10E-02	0.00E+00
Fe	8.96E-08	1.00E-02	8.96E-04	1.00E-02	8.96E-04
Hg	7.25E-08	1.40E-05	5.18E-01	1.40E-05	5.18E-01
K	1.10E-02	1.80E-01	6.10E+00	1.80E-01	6.10E+00
La	3.55E-13	8.30E-05	4.27E-07	8.30E-05	4.27E-07
Ni	5.10E-05	3.00E-03	1.70E+00	3.00E-03	1.70E+00
NO2	3.82E-01	3.80E-01	1.00E+02	3.80E-01	1.00E+02
NO3	2.11E-01	8.00E-01	2.63E+01	8.00E-01	2.63E+01
Pb	1.05E-04	6.80E-04	1.54E+01	6.80E-04	1.54E+01
PO4	1.30E-03	3.80E-02	3.43E+00	1.30E-01	1.00E+00
SO4	6.66E-03	1.00E-02	6.66E+01	7.00E-02	9.51E+00
TIC	6.53E-02	3.00E-01	2.18E+01	3.00E-01	2.18E+01
TOC	1.50E-03	5.00E-01	3.00E-01	5.00E-01	3.00E-01
U	1.68E-13	1.20E-03	1.40E-08	1.20E-03	1.40E-08
Radionuclides	**µCi/mol Na**	**Env. A Limit (µCi/mol Na)**	**% Env. A limit**	**Env. B limit (µCi/mol Na)**	**% Env. B limit**
TRU	2.40E-04	13	1.85E-03	13	1.85E-03
Cs137	5.21E+04	1.16E+05	4.49E+01	5.41E+05	9.62E+00
Sr90	5.83E+01	1.19E+03	4.90E+00	1.19E+03	4.90E+00
Tc99	3.26E+01	192	1.70E+01	192	1.70E+01
Co60	0.00E+00	1.65	0.00E+00	1.65	0.00E+00
Eu154	0.00E+00	16.2	0.00E+00	16.2	0.00E+00

Table 1.3-8 Comparison of 241-SY-102 Reconciled Sludge to the Specification 8 Limit

Non-Volatiles	g/100 g oxide	limit (g/100 g oxide)	% of maximum
As	0.00E+00	0.16	0.00E+00
B	0.00E+00	1.3	0.00E+00
Be	0.00E+00	0.065	0.00E+00
Ce	1.40E-12	0.81	1.73E-10
Co	0.00E+00	0.45	0.00E+00
Cs	0.00E+00	0.58	0.00E+00
Cu	0.00E+00	0.48	0.00E+00
Hg	8.83E-14	0.1	8.83E-11
La	1.74E-12	2.6	6.70E-11
Li	0.00E+00	0.14	0.00E+00
Mn	4.89E-10	6.5	7.52E-09
Mo	0.00E+00	0.65	0.00E+00
Nd	6.11E-12	1.7	3.59E-10
Pr	2.04E-12	0.35	5.82E-10
Pu	9.67E-13	0.054	1.79E-09
Rb	0.00E+00	0.19	0.00E+00
Sb	2.04E-13	0.84	2.43E-11
Se	0.00E+00	0.52	0.00E+00
Sr	3.34E-12	0.52	6.42E-10
Ta	0.00E+00	0.03	0.00E+00
Tc	0.00E+00	0.26	0.00E+00
Te	0.00E+00	0.13	0.00E+00
Tl	0.00E+00	0.45	0.00E+00
V	0.00E+00	0.032	0.00E+00
W	0.00E+00	0.24	0.00E+00
Y	0.00E+00	0.16	0.00E+00
Zn	4.92E-11	0.42	1.17E-08
Volatiles	**g/100 g oxide**	**limit (g/100 g oxide)**	**% of maximum**
Cl	0.00E+00	0.33	0.00E+00
CO3	2.35E-08	30	7.83E-08
NO2	0.00E+00	36	0.00E+00
TOC	1.02E-15	11	9.30E-15
CN	0.00E+00	1.6	0.00E+00

Table 1.3-8 Comparison of 241-SY-102 Reconciled Sludge to the Specification 8 Limit

Non-Volatiles	g/100 g oxide	limit (g/100 g oxide)	% of maximum
NH3	0.00E+00	1.6	0.00E+00
Radionuclides	**Ci/100 g oxide**	**Ci/100 g oxide**	**% of maximum**
3H	0.00E+00	6.50E-05	0.00E+00
14C	4.28E-09	6.50E-06	6.59E-02
60Co	0.00E+00	1.00E-02	0.00E+00
90Sr	4.14E-02	1.00E+01	4.14E-01
99Tc	0.00E+00	1.50E-02	0.00E+00
125Sb	0.00E+00	3.20E-02	0.00E+00
126Sn	0.00E+00	1.50E-04	0.00E+00
129I	0.00E+00	2.90E-07	0.00E+00
137Cs	0.00E+00	1.50E+00	0.00E+00
152Eu	0.00E+00	4.80E-04	0.00E+00
154Eu	8.21E-04	5.20E-02	1.58E+00
233U	1.14E-06	4.50E-06	2.53E+01
235U	7.26E-10	2.50E-07	2.90E-01
237Np	0.00E+00	7.40E-05	0.00E+00
238Pu	8.14E-04	3.50E-04	2.33E+02
239Pu	3.24E-03	3.10E-03	1.05E+02
241Pu	0.00E+00	2.20E-02	0.00E+00
241Am	3.44E-02	9.00E-02	3.82E+01
243+244Cm	0.00E+00	3.00E-03	0.00E+00

Table 1.3-9 Reconciled Compound Based 241-AZ-101 Feed Composition

Compound	Chemical Formula	Aqueous, lb	Solid, lb
Water	H_2O	7.2911E+06	0.00E+00
Aluminum Hydroxide	$Al(OH)_3$	9.56E+04	1.58e+05
Boehmite	AlOOH	0.00E+00	6.14E+04
Arsenic Acid	As_2O_5	8.05E+02	0.00E+00
Barium Sulfate	$BaSO_4$	4.18E+00	4.38E+02
Calcium Carbonate	$CaCO_3$	0.00E+00	3.16E+03
Calcium Hydroxide	$Ca(OH)_2$	1.71E+01	0.00E+00
Cadmium Hydroxide	$Cd(OH)_2$	8.19E+01	3.18E+03
Cerium Oxide	Ce_2O_3	0.00E+00	1.81E+02
Chromium Hydroxide	$Cr(OH)_3$	1.00E-02	0.00E+00
Copper Oxide	CuO	3.92E+02	4.40E+02
Iron (III) Oxide	Fe_2O_3	3.30E-01	4.98E+04
Dichromium Iron Tetraoxide	$FeCr_2O_4$	0.00E+00	9.04E+02
Mercury(II) Hydroxide	$Hg(OH)_2$	0.00E+00	1.91
Potassium Arsenate	K_3AsO_4	6.64E+00	0.00E+00
Potassium Hydroxide	KOH	4.66E+04	0.00E+00
Lanthanum Trihydroxide	$La(OH)_3$	5.43E-05	1.29E+03
Manganese Hydroxide	$Mn(OH)_2$	2.17E+01	1.33E+03
Molybdenum (VI) Oxide	MoO_3	9.70E+02	0.00E+00
Sodium Hydroxide	NaOH	1.90E+05	0.00E+00
Sodium Nitrite	$NaNO_2$	6.91E+05	0.00E+00
Sodium Nitrate	$NaNO_3$	5.42E+05	0.00E+00
Sodium Carbonate	Na_2CO_3	6.66E+05	0.00E+00
Sodium Sulfate	Na_2SO_4	1.93E+05	0.00E+00
Sodium Chloride	NaCl	2.98E+03	0.00E+00
Sodium Fluoride	NaF	3.71E+04	0.00E+00
Sodium Orthophosphate	Na_3PO_4	2.44E+04	0.00E+00
Sodium Bicarbonate	$NaHCO_3$	6.93E+01	0.00E+00
Sodium Bichromate	$Na_2Cr_2O_7$	1.26E+04	0.00E+00
Sodium Tellurite	Na_2TeO_3	3.36E-05	1.79E+02
Neodymium Hydroxide	$Nd(OH)_3$	0.00E+00	8.89E+02
Nickel Hydroxide	$Ni(OH)_2$	1.63E+00	2.30E+03
Palladium Hydroxide	$Pd(OH)_2$	6.98E+02	0.00E+00
Praseodymium Hydroxide	$Pr(OH)_3$	2.99E+02	0.00E+00
Rubidium Hydroxide	RbOH	8.03E+01	0.00E+00
Rhodium Oxide	Rh_2O_3	3.24E-05	5.88E+01
Ruthenium Hydroxide	$Ru(OH)_3$	0.00E+00	9.02E+02

Table 1.3-9 Reconciled Compound Based 241-AZ-101 Feed Composition

Compound	Chemical Formula	Aqueous, lb	Solid, lb
Thorium Dioxide	ThO_2	1.64E-07	6.51E+01
Zirconium(IV) Oxide	ZrO_2	1.66E+01	1.39E+04
Formic Acid	HCOOH	2.89E+03	0.00E+00
Sodium Acetate	NaAcetate	1.06E+03	0.00E+00
Sodium Oxalate	$Na_2C_2O_4$	1.64E+04	0.00E+00
Sodium Glycolate	NaGlycolate	1.99E+03	0.00E+00
Citric Acid	Citric Acid	3.10E+03	0.00E+00
Succinic Acid	Succinic Acid	3.88E+02	0.00E+00
Americium Hydroxide	$Am(OH)_3$	1.65E-04	8.31E+00
Cesium Hydroxide	CsOH	4.45E+02	0.00E+00
Cobalt Hydroxide	$Co(OH)_2$	9.48E+01	5.22E+01
Europium Hydroxide	$Eu(OH)_3$	0.00E+00	9.91
Antimony Hydroxide	$Sb(OH)_3$	1.17E+01	0.00E+00
Sodium Selenite	Na_2SeO_3	1.87E+00	0.00E+00
Sodium Selenate	Na_2SeO_4	2.05E+00	0.00E+00
Strontium Carbonate	$SrCO_3$	8.22E-01	3.15E+02
Sodium Pertechnetate	$NaTcO_4$	5.76E+02	0.00E+00
Disodium Diuranate	Na_2U2O_7	1.94E-01	2.60E+03
Neptunium Oxide	Np_2O_5	3.58E+01	0.00E+00
Plutonium(IV) Hydroxide	$Pu(OH)_4$	1.20E-03	1.36E+01
Total, lb		9.87E+06	3.00E+05
Volume, gal		9.89E+05	1.20E+04
Enthalpy, Btu		-5.84E+10	-1.78E+09
E-Con, cm2/ohm-mol		2.78E+01	N/A
Abs Visc, cP		1.40E+00	N/A
Ionic Strength		5.68E+00	N/A
Total Sodium, molar		4.63E+00	N/A
Free Hydroxide, molar		4.99E-01	N/A
Free Hydroxide, ug/L		8.48E+03	N/A

Table 1.3-10 Comparison of 241-AZ-101 Liquids to Specification 7 Envelope B Limits

Analyte	mol/mol Na	Limit (mol/mol Na)	% of limit
Al	3.24E-02	2.50E-01	1.30E+01
Ba	4.74E-07	1.00E-04	4.74E-01
Ca	6.11E-06	4.00E-02	1.53E-02
Cd	1.48E-05	4.00E-03	3.70E-01
Cr	2.54E-03	2.00E-02	1.27E+01
Fe	1.09E-07	1.00E-02	1.09E-03
Hg	0.00E+00	1.45E-05	0.00E+00
K	2.20E-02	1.80E-01	1.22E+01
La	7.57E-12	8.30E-05	9.12E-06
Ni	4.61E-07	3.00E-03	1.54E-02
U	8.11E-09	1.23E-03	6.59E-04
sulfate	3.59E-02	7.00E-02	5.13E+01
nitrite	2.90E-01	3.80E-01	7.64E+01
nitrate	1.54E-01	8.00E-01	1.93E+01
carbonate	1.66E-01	3.00E-01	5.54E+01
Cl	1.35E-03	8.90E-02	1.52E+00
F	2.34E-02	2.00E-01	1.17E+01
PO4	3.94E-03	1.30E-01	3.03E+00
Radionuclides	**uCi/mol Na**	**Limit (uCi/mol Na)**	**% of limit**
TRU	3.00E-01	1.30E+01	2.31E+00
Cs137	2.88E+05	5.41E+05	5.33E+01
Sr90	7.53E+02	1.19E+03	6.33E+01
Tc99	1.38E+02	7.10E+06	1.94E-03
Co60	8.58E+01	3.70E+05	2.32E-02
Eu154	0.00E+00	4.30E+06	0.00E+00

Note: Some constituents in the feed specification are not in the feed vector because they were below detection limits.

Table 1.3-11 Comparison of 241-AZ-101 Solids to Specification 8 Limits for Unwashed Solids

Constituent	g/100 g oxide	Limit (g/100 g oxide)	% of limit
Al	3.53E+01	1.40E+01	2.52E+02
Ba	1.10E-01	4.50E+00	2.45E+00
Ca	5.43E-01	7.10E+00	7.64E+00
Cd	1.05E+00	4.50E+00	2.32E+01
Ce	3.31E-02	8.10E-01	4.09E+00
Cr	1.80E-01	6.80E-01	2.65E+01
Cu	1.51E-01	4.80E-01	3.14E+01
Fe	1.50E+01	2.90E+01	5.18E+01
Hg	7.00E-04	1.00E-01	7.00E-01
La	4.03E-01	2.60E+00	1.55E+01
Mn	3.52E-01	6.50E+00	5.41E+00
Nd	2.81E-01	1.70E+00	1.66E+01
Te	4.41E-02	1.30E-01	3.39E+01
Ni	6.19E-01	2.40E+00	2.58E+01
Rh	2.04E-02	1.30E-01	1.57E+01
Ru	2.59E-01	3.50E-01	7.39E+01
Zr	4.41E+00	1.50E+01	2.94E+01
Sr	8.01E-02	5.20E-01	1.54E+01
U	4.18E-01	1.40E+01	2.99E+00
Pu	4.53E-03	5.40E-02	8.39E+00
Na	8.09E-02	1.90E+01	4.26E-01
TIC	8.67E-01	3.00E+01	2.89E+00
Radionuclides	**Ci/100 G oxide**	**Limit (Ci/100 g Oxide)**	**% of limit**
C-14	3.39E-08	6.50E-06	5.22E-01
Co-60	7.50E-04	1.00E-02	7.50E+00
Sr-90	4.54E+00	1.00E+01	4.54E+01
Eu-154	6.54E-02	5.20E-02	1.26E+02
U-233	1.80E-07	4.50E-06	4.01E+00
U-235	8.08E-09	2.50E-07	3.23E+00
Pu-238	6.99E-05	3.50E-04	2.00E+01
Pu-239	2.61E-04	3.10E-03	8.41E+00
Pu-241	2.66E-03	2.20E-02	1.21E+01

Table 1.3-11 Comparison of 241-AZ-101 Solids to Specification 8 Limits for Unwashed Solids

Constituent	g/100 g oxide	Limit (g/100 g oxide)	% of limit
Am-241	1.01E-02	9.00E-02	1.12E+01

Note: Some constituents in the feed specification are not in the feed vector because they were below detection limits or were only present in the liquid phase.

Table 1.3-12 Reconciled Compound Based 241-AP-101 Feed Composition

Constituent	Chemical Formula	Aqueous (lb)	Solid (lb)
Water	H_2O	7.88E+06	0.00E+00
Nitrogen	N_2	3.64E+01	0.00E+00
Oxygen	O_2	2.17E+01	0.00E+00
Silver Carbonate	Ag_2CO_3	0.00E+00	0.00E+00
Aluminum Hydroxide	$Al(OH)_3$	1.84E+05	0.00E+00
Arsenic Acid	As_2O_5	2.02E+00	0.00E+00
Berrylium Hydroxide	$Be(OH)_2$	5.87E+01	0.00E+00
Potassium Hydroxide	KOH	4.15E+05	0.00E+00
Molybdenum (VI) Oxide	MoO_3	2.03E+02	0.00E+00
Sodium Hydroxide	NaOH	5.95E+05	0.00E+00
Sodium Nitrite	$NaNO_2$	5.85E+05	0.00E+00
Sodium Nitrate	$NaNO_3$	1.69E+06	0.00E+00
Sodium Carbonate	Na_2CO_3	5.61E+05	0.00E+00
Sodium Sulfate	Na_2SO_4	5.55E+04	0.00E+00
Sodium Chloride	NaCl	3.04E+04	0.00E+00
Sodium Fluoride	NaF	4.99E+04	9.84E+03
Sodium Orthophosphate	Na_3PO_4	1.64E+04	0.00E+00
Sodium Bicarbonate	$NaHCO_3$	6.54E-01	0.00E+00
Sodium Bichromate	$Na_2Cr_2O_7$	3.36E+03	0.00E+00
Sodium Iodide	NaI	2.81E+01	0.00E+00
Kalsilite	$KAlSiO_4$	0.00E+00	6.13E+03
Nickel Hydroxide	Ni(OH)2	8.35E+01	3.28E+01
Rubidium Hydroxide	RbOH	4.43E+01	0.00E+00
Silicon Oxide	SiO_2	4.03E+02	0.00E+00
Thallium Hydroxide	TlOH	1.82E+00	0.00E+00
Sodium Tungstate	Na_2WO_4	4.30E+02	0.00E+00
Boric Acid	H_3BO_3	8.52E+02	0.00E+00

Table 1.3-12 Reconciled Compound Based 241-AP-101 Feed Composition

Constituent	Chemical Formula	Aqueous (lb)	Solid (lb)
ORGANICS			
Formic Acid	HCOOH	1.14E+04	0.00E+00
Sodium Acetate	NaAcetate	2.12E+04	0.00E+00
Sodium Oxalate	$Na_2C_2O_4$	4.26E+03	2.13E+04
RADIONUCLUDES	**Chemical Formula**	**Aqueous (lb)**	**Solid (lb)**
Americium Hydroxide	$Am(OH)_3$	5.55E-04	0.00E+00
Cesium Hydroxide	CsOH	5.36E+01	0.00E+00
Cobalt Hydroxide	$Co(OH)_2$	5.17E+00	0.00E+00
Antimony Hydroxide	$Sb(OH)_3$	5.52E-01	0.00E+00
Sodium Selenite	Na_2SeO_3	2.88E-01	0.00E+00
Strontium Carbonate	$SrCO_3$	1.00E-02	0.00E+00
Sodium Pertechnetate	$NaTcO_4$	4.87E+01	0.00E+00
Disodium Diuranate	$Na_2U_2O_7$	4.00E-07	6.89E+02
RADIONUCLUIDES	**Chemical Formula**	**Aqueous (lb)**	**Solid (lb)**
Plutonium(IV) Hydroxide	$Pu(OH)_4$	1.18E-04	2.41E-02
Total, lb		1.21E+07	3.80E+04
Volume, gallons		1.12E+06	7.19E+02
Enthalpy, BTU		-6.81E+10	-1.86E+08
Ionic Strength		8.05E+00	
Total Sodium, molar		6.11E+00	
Free Hydroxide, molar		2.11E+00	
Free Hydroxide, µg/L		8.82E+06	0.00E+00

Table 1.3-13 Comparison of 241-AP-101 Liquids to Specification 7 Limits

Analyte	mol/mol Na	Envelope A limit (mol/mol Na)	% of limit
Al	3.93E-02	2.50E-01	1.57E+01
Cr	4.28E-04	6.90E-03	6.20E+00
K	1.23E-01	1.80E-01	6.85E+01
Ni	1.49E-05	3.00E-03	4.95E-01
U	1.05E-14	1.20E-03	8.77E-10
SO_4^{-2}	6.51E-03	1.00E-02	6.51E+01
NO_2^{-1}	1.55E-01	3.80E-01	4.07E+01

Table 1.3-13 Comparison of 241-AP-101 Liquids to Specification 7 Limits

Analyte	mol/mol Na	Envelope A limit (mol/mol Na)	% of limit
NO_3^{-1}	3.03E-01	8.00E-01	3.79E+01
CO_3^{-2}	8.82E-02	3.00E-01	2.94E+01
Cl	8.68E-03	3.72E-02	2.33E+01
F	1.98E-02	9.10E-02	2.18E+01
PO_4^{-3}	1.67E-03	3.80E-02	4.39E+00
RADIONUCLIDES	**uCi/mol Na**	**Limit (uCi/mol Na)**	**% of limit**
TRU	2.74E-02	1.30E+01	2.11E-01
Cs-137	6.88E+04	1.16E+05	5.93E+01
Sr-90	1.37E+01	1.19E+03	1.15E+00
Tc-99	7.35E+00	1.92E+02	3.83E+00
Co-60	5.19E-01	1.65E+00	3.15E+01

Note: Some analytes in the specification are not in the reconciled waste feed because they were below the detection limits.

Table 1.3-14 Reconciled Feed Composition for 241-AY-102/C-106

PHASE	**Aqueous**	**Solid**
TEMPERATURE, F	120	120
PRESSURE, psia	14.7	1.4.71
pH	12.5	N/A
COMPONENT	**lb**	**lb**
Water	6.61E+06	0.00E+00
Nitrogen	4.13E+01	0.00E+00
Oxygen	1.80E+01	0.00E+00
Carbon Dioxide	1.44E-05	0.00E+00
Nitrous Acid	2.11E-05	0.00E+00
Nitric Acid	8.07E-15	0.00E+00
Hydrogen Chloride	2.84E-16	0.00E+00
Hydrogen Fluoride	2.05E-07	0.00E+00
Silver Carbonate	1.77E-01	3.34E+03
Aluminum Hydroxide	2.02E+04	1.79E+05
Barium Hydroxide	3.30E+00	0.00E+00

Table 1.3-14 Reconciled Feed Composition for 241-AY-102/C-106

PHASE	Aqueous	Solid
TEMPERATURE, F	120	120
PRESSURE, psia	14.7	1.4.71
pH	12.5	N/A
COMPONENT	lb	lb
Barium Carbonate	0.00E+00	1.46E+03
Bismuth Oxide	3.52E+01	2.10E+01
Calcium Hydroxide	1.96E+00	0.00E+00
Cadmium Hydroxide	7.20E+00	2.55E+02
Cerium (III) Oxide	0.00E+00	2.30E+03
Chromium Hydroxide	1.73E+00	5.15E+03
Copper Oxide	5.16E+00	3.48E+02
Iron (III) Oxide	6.29E-02	2.10E+05
Mercury(II) Hydroxide	0.00E+00	0.00E+00
Potassium Hydroxide	3.51E+03	0.00E+00
Lanthanum Trihydroxide	6.58E-06	1.27E+03
Magnesium Hydroxide	4.97E-02	3.24E+03
Manganese(II) Hydroxide	1.88E+00	4.83E+04
Sodium Hydroxide	6.23E+04	0.00E+00
Sodium Nitrite	3.19E+05	0.00E+00
Sodium Nitrate	2.22E+03	0.00E+00
Sodium Carbonate	6.56E+05	0.00E+00
Sodium Sulfate	1.48E+04	0.00E+00
Sodium Chloride	1.37E+03	0.00E+00
Sodium Fluoride	2.59E+03	0.00E+00
Sodium Orthophosphate	5.05E+04	0.00E+00
Sodium Bicarbonate	2.42E+02	0.00E+00
Sodium Bichromate	8.16E+02	0.00E+00
Low Albite ($NaAlSi_3O_8$)	0.00E+00	1.30E+05
Neodymium Hydroxide	0.00E+00	3.02E+03
Nickel Hydroxide	5.31E-01	7.68E+03
Lead(II) Hydroxide	0.00E+00	1.16E+04
Praseodymium Hydroxide	1.71E+02	5.98E+02

Table 1.3-14 Reconciled Feed Composition for 241-AY-102/C-106

PHASE	Aqueous	Solid
TEMPERATURE, F	120	120
PRESSURE, psia	14.7	1.4.71
pH	12.5	N/A
COMPONENT	**lb**	**lb**
Rhodium Oxide	9.11E-05	5.22E+01
Ruthenium Hydroxide	0.00E+00	6.29E+02
Silicon Oxide	5.72E+01	0.00E+00
Tin Hydroxide	4.33E+00	0.00E+00
Thallium Hydroxide	4.37E+00	0.00E+00
Thorium Dioxide	2.03E-07	1.12E+03
Sodium Orthovanadate (Na_3VO_4)	7.25E+01	0.00E+00
Zirconium(IV) Oxide	7.67E+00	6.99E+03
Hydroxyapatite ($Ca_5OH(PO_4)_3$)	0.00E+00	1.27E+04
Boric Acid (H_3BO_3)	1.58E+03	0.00E+00
Rutile	0.00E+00	4.81E+02
Titanium Hydroxide	4.81E-11	0.00E+00
Zinc Oxide	0.00E+00	6.58E+02
Mercury(II) Oxide	0.00E+00	5.19E+02
ORGANICS		
Formic Acid	8.49E+02	0.00E+00
Sodium Acetate	2.82E+03	0.00E+00
Sodium Oxalate	2.75E+04	0.00E+00
Citric Acid	2.38E+02	0.00E+00
RADIONUCLUDES		
Americium Hydroxide	3.53E-04	2.93E+00
Cesium Hydroxide	2.71E+01	0.00E+00
Cobalt Hydroxide	1.25E+01	4.15E+01
Europium Hydroxide	0.00E+00	6.71E-02
Strontium Carbonate	3.49E-01	2.04E+03
Sodium Pertechnetate	1.14E+01	0.00E+00
Disodium Diuranate	1.53E+01	4.08E+03
Neptunium Oxide	1.91E+01	0.00E+00

Table 1.3-14 Reconciled Feed Composition for 241-AY-102/C-106

PHASE	Aqueous	Solid
TEMPERATURE, F	120	120
PRESSURE, psia	14.7	1.4.71
pH	12.5	N/A
COMPONENT	**lb**	**lb**
Plutonium(IV) Hydroxide	2.25E+00	5.70E+01
Total Mass, lb	7.79E+06	6.18E+05
Total Volume, gal	8.32E+05	2.28E+04
Enthalpy, Btu	-4.96E+10	-2.93E+09
Density, lb/gal	9.34E+00	2.71E+01
Osmotic Pres, atm	4.94E+01	0.00E+00
Ionic Strength	3.86E+00	0.00E+00
Aqueous Sodium, molar	2.92E+00	0.00E+00
Total Sodium, molar	2.91E+00	0.00E+00
Free Hydroxide, molar	1.80E-01	0.00E+00
Free Hydroxide, ug/L	3.05E+03	0.00E+00
Soluble Aluminum, molar	3.73E-02	0.00E+00
Total Aluminum, molar	4.27E-01	0.00E+00

Table 1.3-15 Comparison of Liquids from 241-AY-102 to Specification 7 Envelope A Limits

Analyte	mol/mol Na	Limit (mol/mol Na)	% of limit
Al	1.34E-02	2.50E-01	5.35E+00
Ba	9.95E-07	1.00E-04	9.95E-01
Ca	1.36E-06	4.00E-02	3.41E-03
Cd	2.54E-06	4.00E-03	6.34E-02
Cr	3.21E-04	2.00E-02	1.61E+00
Fe	4.07E-08	1.00E-02	4.07E-04
Hg	0.00E+00	1.45E-05	0.00E+00
K	3.23E-03	1.80E-01	1.79E+00
La	1.79E-12	8.30E-05	2.15E-06
Ni	2.92E-07	3.00E-03	9.74E-03

Table 1.3-15 Comparison of Liquids from 241-AY-102 to Specification 7 Envelope A Limits

Analyte	mol/mol Na	Limit (mol/mol Na)	% of limit
U	1.24E-06	1.23E-03	1.01E-01
sulfate	8.00E-03	7.00E-02	1.14E+01
nitrite	2.61E-01	3.80E-01	6.88E+01
nitrate	1.23E-03	8.00E-01	1.54E-01
carbonate	3.19E-01	3.00E-01	**1.06E+02**
Cl	1.21E-03	8.90E-02	1.36E+00
F	3.18E-03	2.00E-01	1.59E+00
PO_4	1.59E-02	1.30E-01	1.22E+01
Radionuclides	**µCi/mol Na**	**Limit (µCi/mol Na)**	**% of limit**
TRU	8.46E+00	1.30E+01	6.51E+01
Cs-137	2.66E+04	5.41E+05	4.91E+00
Sr-90	3.14E+00	1.19E+03	2.64E-01
Tc-99	3.21E-01	7.10E+06	4.52E-06
Co-60	3.75E+04	3.70E+05	1.01E+01
Eu-154	0.00E+00	4.30E+06	0.00E+00

Note: Some constituents in the feed specification are not in the feed vector because they were below detection limits.

Table 1.3-16 Comparison of Solids From 241-AY-102 Reconciled Feed to Specification 8 Limits for Unwashed Solids

Analyte[a]	g/100 g oxide	Limit (g/100 g oxide)	% of limit
Ag	4.75E-01	5.50E-01	8.63E+01
Al	1.36E+01	1.40E+01	9.74E+01
Ba	1.85E-01	4.50E+00	4.11E+00
Bi	3.41E-03	2.80E+00	1.22E-01
Ca	9.15E-01	7.10E+00	1.29E+01
Ce	3.56E-01	8.10E-01	4.39E+01
Cd	3.56E-02	4.50E+00	7.90E-01
Co	4.78E-03	4.50E-01	1.06E+00
Cr	4.72E-01	6.80E-01	6.94E+01
Cu	5.05E-02	4.80E-01	1.05E+01
Fe	2.67E+01	2.90E+01	9.19E+01
Hg	8.72E-02	1.00E-01	8.72E+01
La	1.68E-01	2.60E+00	6.47E+00

Table 1.3-16 Comparison of Solids From 241-AY-102 Reconciled Feed to Specification 8 Limits for Unwashed Solids

Analyte[a]	g/100 g oxide	Limit (g/100 g oxide)	% of limit
Mg	2.45E-01	2.10E+00	1.17E+01
Mn	5.41E+00	6.50E+00	8.33E+01
Nd	4.04E-01	1.70E+00	2.38E+01
Ni	8.72E-01	2.40E+00	3.63E+01
P	4.24E-01	1.70E+00	2.50E+01
Pb	1.81E+00	1.10E+00	**1.65E+02**
Pr	7.96E-02	3.50E-01	2.27E+01
Rh	7.68E-03	1.30E-01	5.91E+00
Ru	7.63E-02	3.50E-01	2.18E+01
Si	7.57E+00	1.90E+01	3.99E+01
Th	1.79E-01	5.00E+00	3.58E+00
Ti	5.23E-02	1.30E+00	4.02E+00
Zr	9.39E-01	1.50E+01	6.26E+00
Zn	7.85E-02	4.20E-01	1.87E+01
Sr	2.19E-01	5.20E-01	4.22E+01
U	2.78E-01	1.40E+01	1.98E+00
Pu	8.05E-03	5.40E-02	1.49E+01
Na	2.12E+00	1.90E+01	1.12E+01
TIC	3.63E-01	3.00E+01	1.21E+00
Radionuclides	**Ci/100 G oxide**	**Limit (Ci/100 g Oxide)**	**% of limit**
C-14	3.89E-09	6.50E-06	5.99E-02
Co-60	3.22E-05	1.00E-02	3.22E-01
Sr-90	1.37E+00	1.00E+01	1.37E+01
U-235	4.89E-09	2.50E-07	1.96E+00
Pu-238	9.51E-05	3.50E-04	2.72E+01
Pu-239	4.50E-04	3.10E-03	1.45E+01
Pu-241	9.03E-04	2.20E-02	4.11E+00
Am-241	1.50E-03	9.00E-02	1.67E+00

Note: Some constituents in the feed specification are not in the feed vector because they were below detection limits or were only present in the liquid phase.

Table 1.3-17 Particle Size and Density of Solids in Waste Feed

Solid-Phase Compound	Mass Percent of Total	Volume Percent of Total	Crystal Density (g/mL)	Maximum Observed Particle Size (μm)	Particle Size Distribution (μm): sonicated					Particle Size Distribution (μm): minimal disturbance				
					0.05	0.25	0.5	0.75	0.95	0.05	0.25	0.5	0.75	0.95
$Al(OH)_3$, Gibbsite	44.9	51.5	2.42	20	0.6	1.3	4	7.7	22	0.77	2.2	6	13	46
$(NaAlSiO_4)_6 \cdot (NaNO_3)1.6 \cdot 2H_2O$	16.6	16.6	2.365	8	0.6	1.7	5	10	774	0.77	2.8	6	13	129
AlOOH, Boehmite	10.6	10.6	3.01	0.05	0.6	1.7	4	10	46	0.77	2.8	6	13	60
$NaAlCO_3(OH)_2$	9.5	9.5	2.42	4.2	0.6	1.3	4	7.7	22	1	2.8	6	13	36
Fe_2O_3	4.1	4.1	5.24	1.6	0.6	1.3	5	10	46	1	2.2	4.6	10	36
$Ca_5OH(PO_4)_3$	2	2.0	3.14	0.1	0.6	1.3	4	7.7	46	1	2.8	6	13	46
$Na_2U_2O_7$	1.6	1.6	5.617	15	0.6	1.7	5	10	774	1	2.8	6	17	1000
ZrO_2	1.1	1.1	5.68	50	0.6	1.3	4	10	28	1	2.8	6	13	129
Bi_2O_3	0.81	0.81	8.9	10	0.6	1.7	4	10	28	1	2.8	6	13	77
SiO_2	0.69	0.69	2.6	100	0.6	1.3	4	7.7	22	1	2.2	6	13	46
$Ni(OH)_2$	0.55	0.55	4.1	0.5	0.6	1.3	4	10	60	0.77	2.2	6	13	46
MnO_2	0.54	0.54	5.026	10	0.6	1.3	4	10	46	0.77	2.8	6	13	129
CaF_2	0.23	0.23	3.18	15	0.6	1.3	4	7.7	28	1	2.8	6	13	77
$LaPO_4 \cdot 2H_2O$	0.13	0.13	6.51	3	0.6	1.3	4	10	60	0.77	2.2	6	13	129
Ag_2CO_3	.00094	0.00940	6.077	4	0.6	1.3	4	7.7	17	1	2.8	6	13	36
PuO_2	0.0013	0.0013	11.43	40	0.6	1.3	4	10	46	0.77	2.2	6	13	129

Table 1.3-18 Particle Size Distribution of Hanford Tank Waste (μm)

Quantile	1 %	5 %	25 %	50 %	75 %	95 %	99 %	100 %
Sonicated [a]	0.39	0.70	1.63	4.39	10.1	33.4	112	774
Minimal Disturbance [b]	0.65	1.00	2.80	6.31	14.0	58.6	256	1000

a Combined data from 18 sludge tanks

b Combined data from 19 sludge tanks

Table 1.3-19 Model Fits to Shear Strength and Consistency as a Function of Solids Content for Many Waste Sludge Samples

Waste Type	Waste Tank	Waste Status	Temp, C	Consistency Parameter, a (cP)	Consistency Parameter, b	Consistency Model Correlation Coefficient, r^2	Predicted Solids Loading at 30 cP Consistency (vol %)	Yield Stress parameter, c (Pa)	Yield Stress Parameter, d	Yield Stress Model Correlation Coefficient, r^2	Predicted Solids Loading at 30 Pa yield Stress (vol %)
224	B-202	Washed	20-35	1.51	36	0.91	8.3	72100	2.94	0.95	7.1
224	B-203	Washed	20-35	1.3	72	1	44	13100000	3.8	1	3.3
224	T-111	Washed	20-35	2.64	37	0.82	6.5	n/r	n/r	n/r	n/r
224	T-203	Washed	20-35	1.08	79	1	4.2	250000	2.6	1	3.1
224	B-202	Washed	80-95	1.01	40	0.71	8.5	23400	2.62	0.92	7.9
224	T-111	Washed	80-95	1.16	43	0.9	7.6	n/r	n/r	n/r	n/r
1C	BX-107	Washed	20-35	1.64	37	0.98	7.9	n/r	n/r	n/r	n/r
1C	BX-107	Washed	80-95	0.97	54	0.92	6.3	1.28E+15	9.53	1	3.7
2C	T-110	Washed	20-35	1.16	46	1	7	12100	2.68	1	10.7
A2SltSlr	AN-105	Salt Cake	20-35	1.38	34	0.95	9	n/r	n/r	n/r	n/r
A2SltSlr	AN-105	Salt Cake	35-50	3.37	17	0.93	13	n/r	n/r	n/r	n/r
A2SltSlr	AN-105	Salt Cake	50-65	1.83	18	0.95	15.3	n/r	n/r	n/r	n/r
A2SltSlr	AN-104	Washed	20-35	11.35	35	0.87	2.8	n/r	n/r	n/r	n/r
A2SltSlr	AN-104	Washed	35-50	7.53	26	0.91	5.3	n/r	n/r	n/r	n/r

Table 1.3-19 Model Fits to Shear Strength and Consistency as a Function of Solids Content for Many Waste Sludge Samples

Waste Type	Waste Tank	Waste Status	Temp, C	Consistency Parameter, a (cP)	Consistency Parameter, b	Consistency Model Correlation Coefficient, r^2	Predicted Solids Loading at 30 cP Consistency (vol %)	Yield Stress parameter, c (Pa)	Yield Stress Parameter, d	Yield Stress Model Correlation Coefficient, r^2	Predicted Solids Loading at 30 Pa yield Stress (vol %)
A2SltSlr	AN-104	Washed	50-65	4.83	24	0.92	7.7	n/r	n/r	n/r	n/r
CWP	C-104	Salt Cake	20-35	1.25	12	1	26.5	279	2.4	1	39.4
CWP	C-104	Washed	20-35	0.78	28	1	13.2	4130	3.11	1	20.5
CWP	C-104	Washed	35-50	0.45	32	0.99	13.3	15900	3.6	1	17.5
CWP	C-104	Washed	50-65	0.36	32	0.99	13.9	49000	4.03	1	15.9
S2SltSlr	SY-101	Salt Cake	20-35	43.05	3.7	0.91	0	n/r	n/r	n/r	n/r
S2SltSlr	SY-101	Salt Cake	35-50	16.47	6.4	0.95	9.4	71.4	1.98	0.99	64.6
S2SltSlr	SY-101	Salt Cake	65-80	8.32	14	0.76	9	119	1.58	0.65	41.9
S2SltSlr	SY-101	Salt Cake	80-95	16.18	13	1	4.7	n/r	n/r	n/r	n/r
Unclassified	AY-102	Salt Cake	50-65	0.8	6.8	0.46	52.9	#N/A	#N/A	#N/A	#N/A

n/r - not reported due to poor correlation results

Table 1.3-20 Electrolyte Coefficients Used in Density Equation 1.3-5

Electrolyte*	c_0	c_1	c_2	c_3	c_4
$NaAl(OH)_4$	-258.681	851.308	48.50073	-0.15934	-2266.55
$Na_2C_2O_4$	12.694	218.218	0.304984	0.004552	1508.402
NaCl	-0.00433	0.06471	1.0166	0.014624	3315.6
Na_2CO_3	0.012755	0.014217	-0.091456	0.002134	3342.4
NaF	2.82E-06	2.18E-07	-0.041483	0.000218	4586.9
$NaNO_2$	78.365	298	0.96246	0.0022	1500
$NaNO_3$	49.209	94.737	0.77927	0.007545	1819.2
NaOH	385.55	753.47	-0.10938	0.000695	542.88
Na_3PO_4	1015.6	1533.7	-0.1518	0.000137	173.71
Na_2SO_4	-1.21E-07	4.35E-07	0.15364	0.007251	4731.5

* All coefficients are from Laliberte and Cooper (2004) except for $NaAl(OH)_4$ (from Reynolds and Carter 2007) and $Na_2C_2O_4$ (from Reynolds and others 2007).

Table 1.3-21 Coefficients for Equation 1.3-15 and Equation 1.3-16

Coefficient	Value
a	-0.0220206
b	-0.1028143
c	-1.016929
d	17.1877483
e	-0.0008179
f	-0.0134259
g	0.92062137
h	-9.7239226
Ln(Q)	-4.21128

Table 1.3-22 Coefficients for Equation 1.3-17 (24590-WTP-M4C-V37T-00009)

Coefficient	Value
A	-5,298.7
B	15.1368
C	-1.0050
D	-0.1280
E	-0.4030

Table 1.3-23 Relevant Ranges for Equation 1.3-17 Parameters (24590-WTP-M4C-V37T-00009)

Parameter	Range
Temperature, °C	15 - 50
C_{Na} (m)	1.3 - 10.0
C_{OH} (m)	0.01 - 7.0
C_F (m)	0.01 - 0.65

Table 1.3-24 Coefficients for Equation 1.3-20; the 25 °C Gibbsite Model

Coefficients	Value (log Q units)	P value	Lower 95 % Confidence Interval	Upper 95 % Confidence Interval
e	12.298114	1.97E-23	11.66054	12.93568
f	-7.502178277	6.52E-15	-8.41062	-6.59374
g	1.50964729	4.92E-11	1.23207	1.787225

Table 1.3-25 Coefficients for Equation 1.3-21

Coefficients	Values (Log Q units)
g	1.50964729
j	-2.20180336
k	-2.3228E-05
l	1.656496924

Table 1.3-26 Total and Hexavalent Chromium Concentration of Selected Hanford Waste Tanks, in Units of ug/g (Solids) or ug/mL (Liquids)

Tank	AN-103 (saltcake)	AN-103 (liquids)	AN-104 (saltcake)	AN-104 (liquids)	AN-105 (liquids)
Cr(6)	99.7	112	200	213	154
Total Cr	438	560	2000	361	937

Figure 1.3-1 WTP-RPT-157 80 °C Comparison

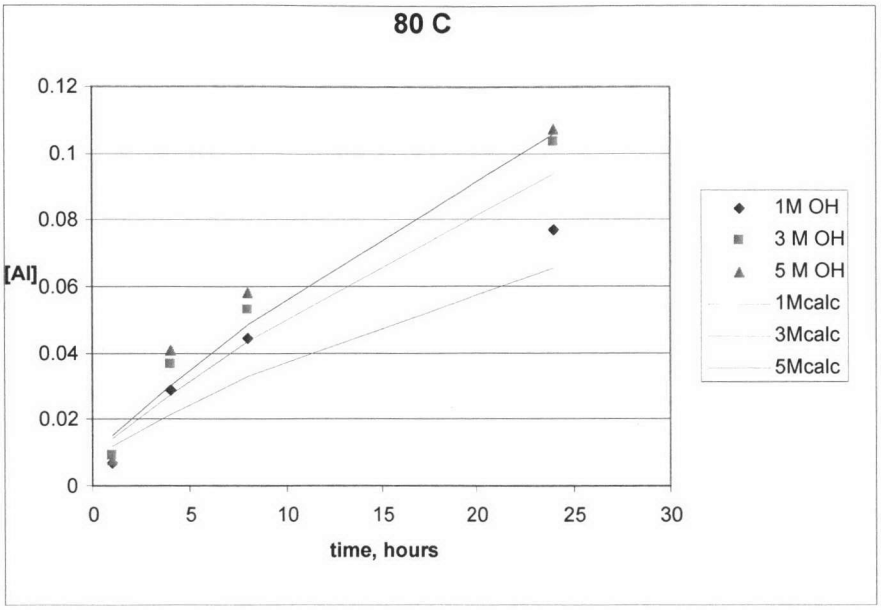


Figure 1.3-2 WTP-RPT-157 90 °C Comparison

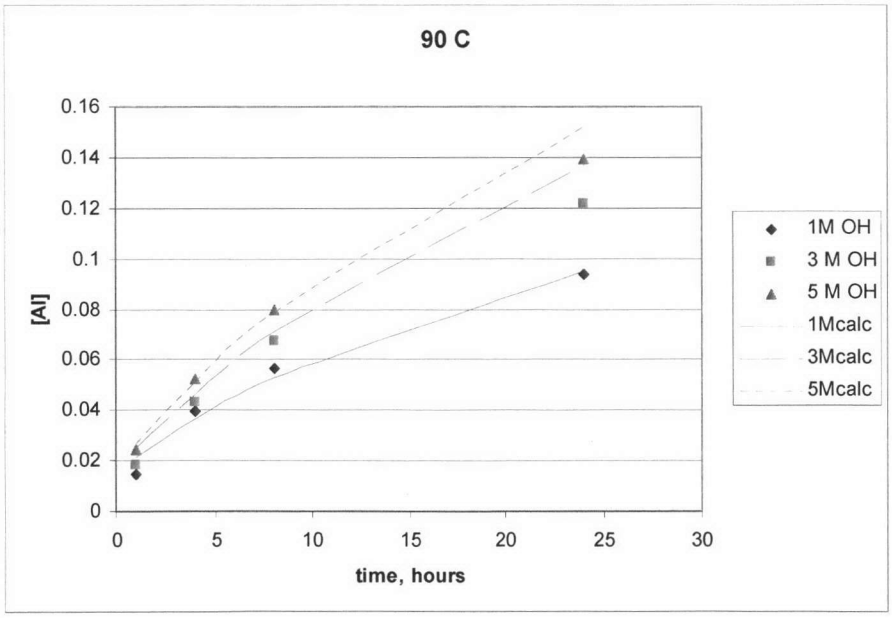


Figure 1.3-3 WTP-RPT-157 100 °C Comparison

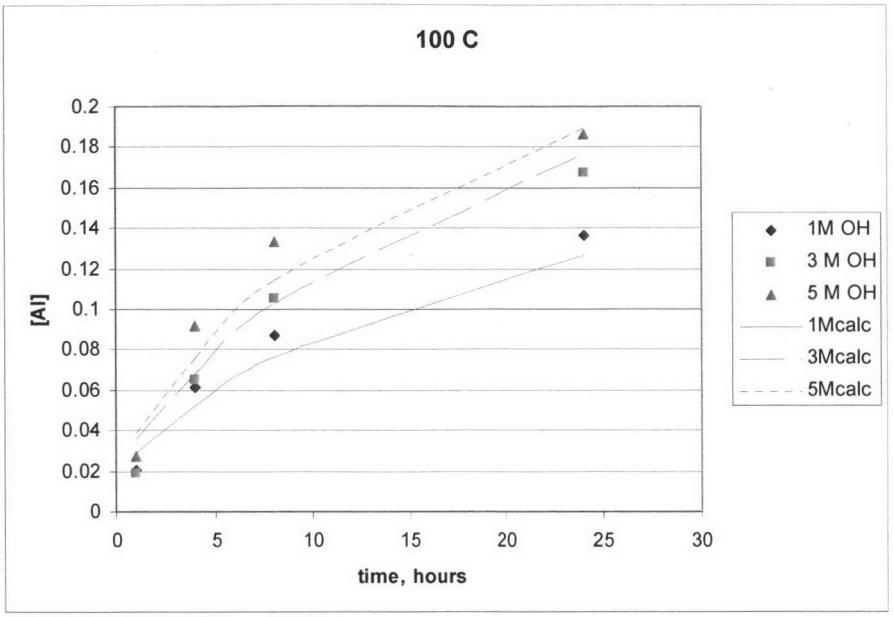


Figure 1.3-4 WTP-RPT-157 Data Comparison

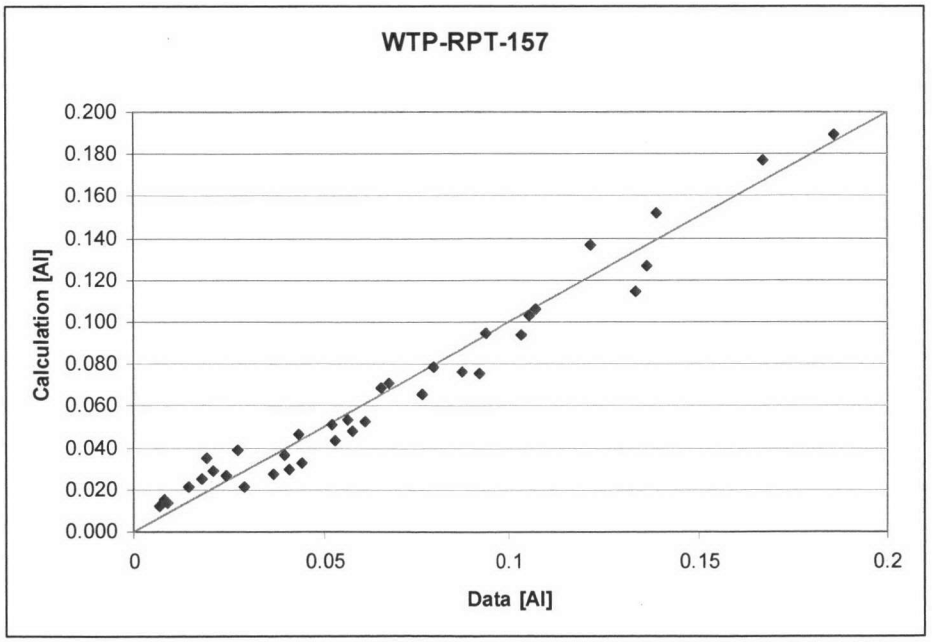


Figure 1.3-5 WTP-RPT-172 Data Fit

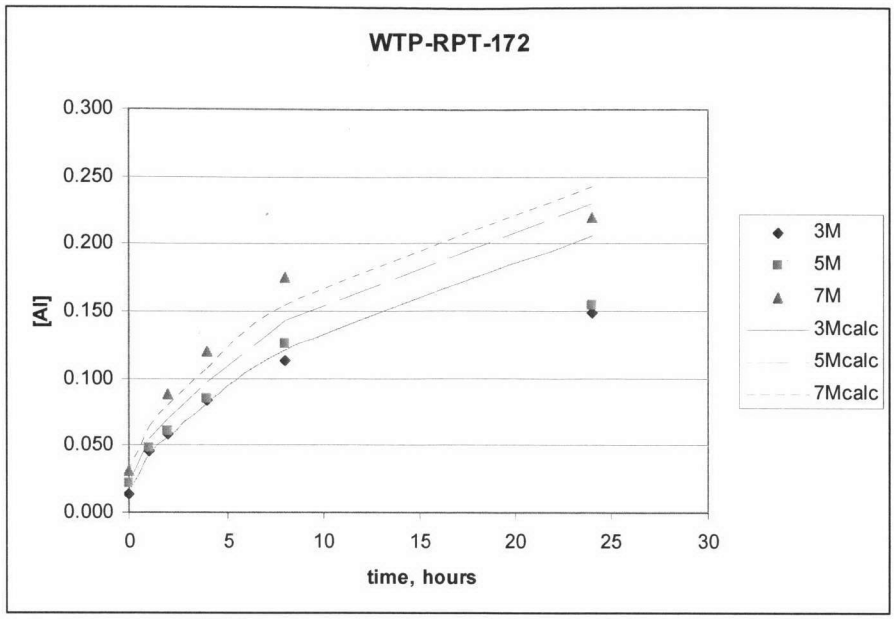


Figure 1.3-6 WTP-RPT-172 Data Comparison

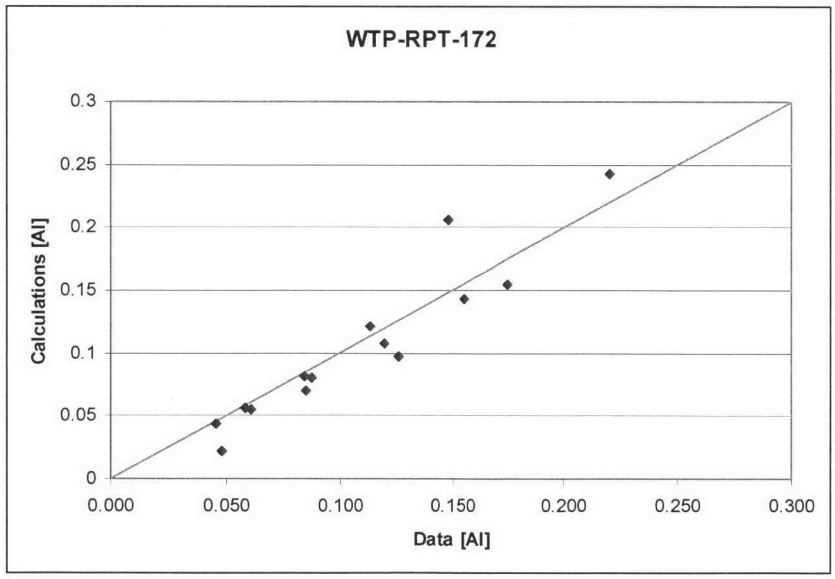


Figure 1.3-7 241-S-101 Data Comparison

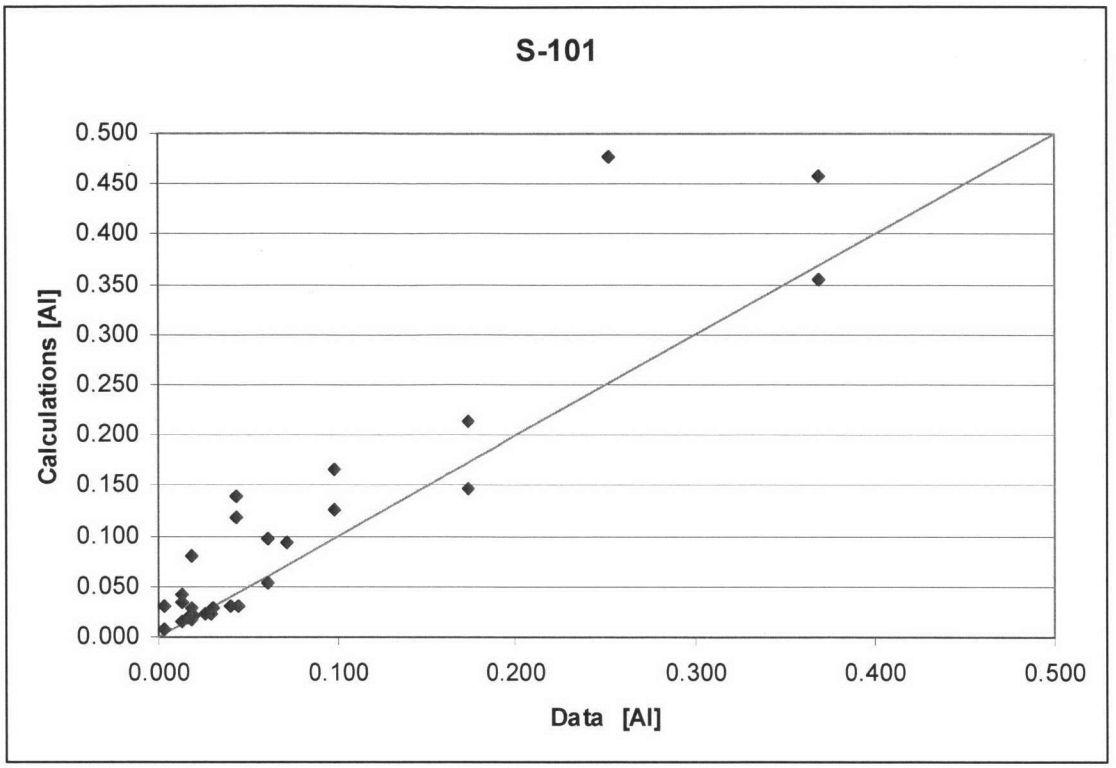
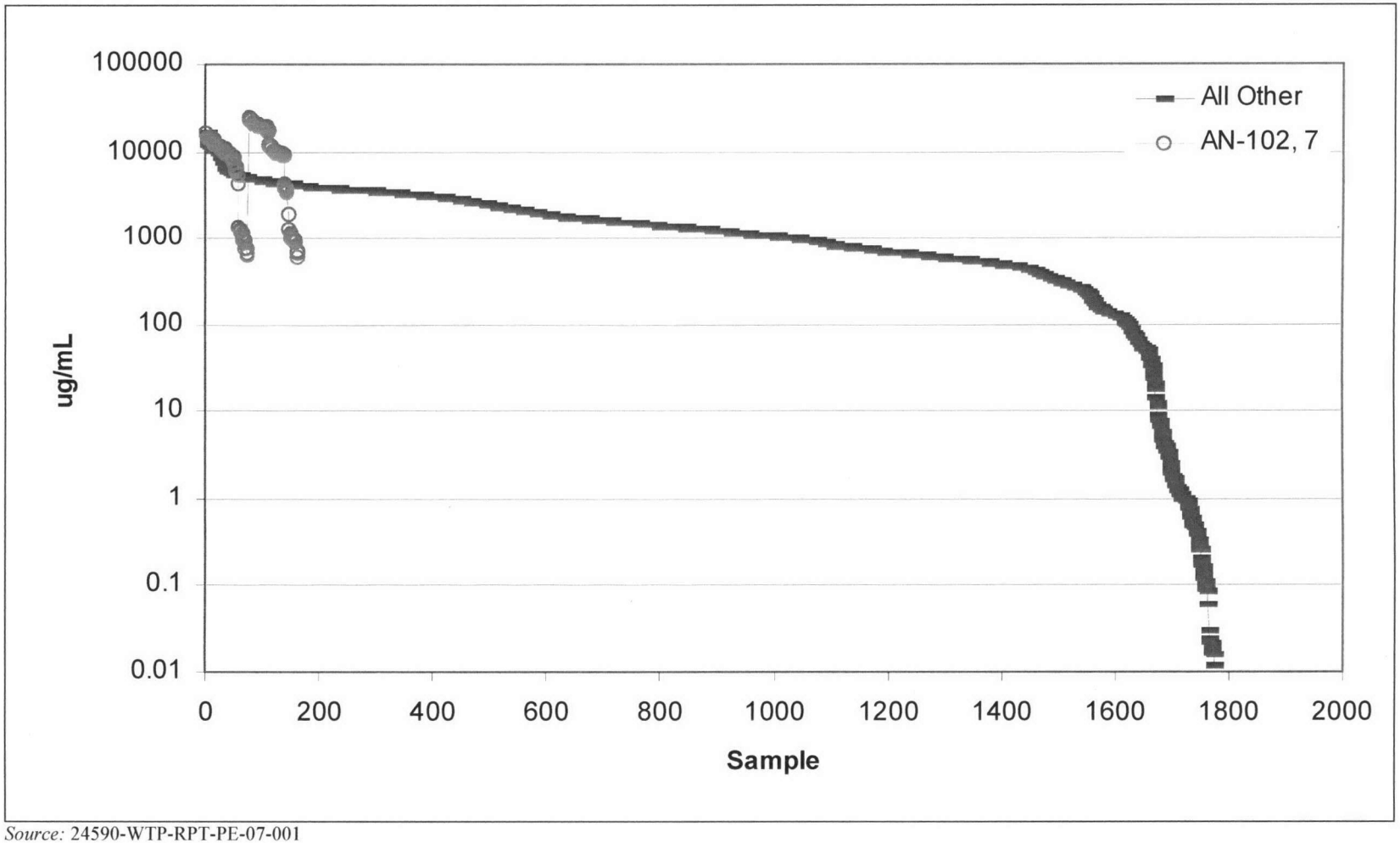
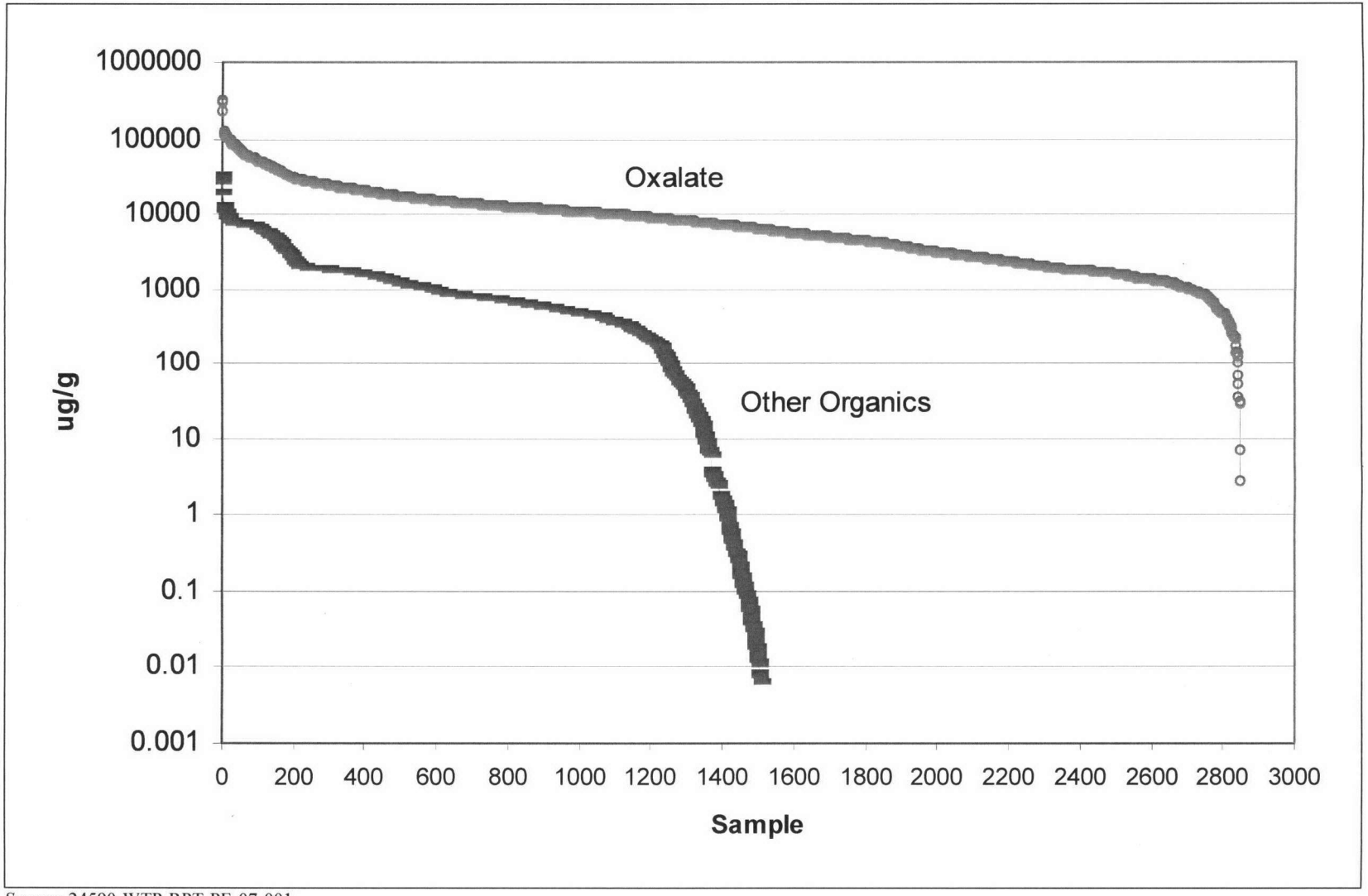


Figure 1.3-8 Organic Species Concentrations in Liquid Phase Waste; Sample Numbers are Arranged from Highest to Lowest



Source: 24590-WTP-RPT-PE-07-001

Figure 1.3-9 Organics in Tank Waste Solids; Sample Numbers are Arranged from Highest to Lowest



Source: 24590-WTP-RPT-PE-07-001

Figure 1.3-10 Oxalate Solubility in Tank Waste as Predicted by the Oxalate Solubility Model (Temperature 303 Kelvin)

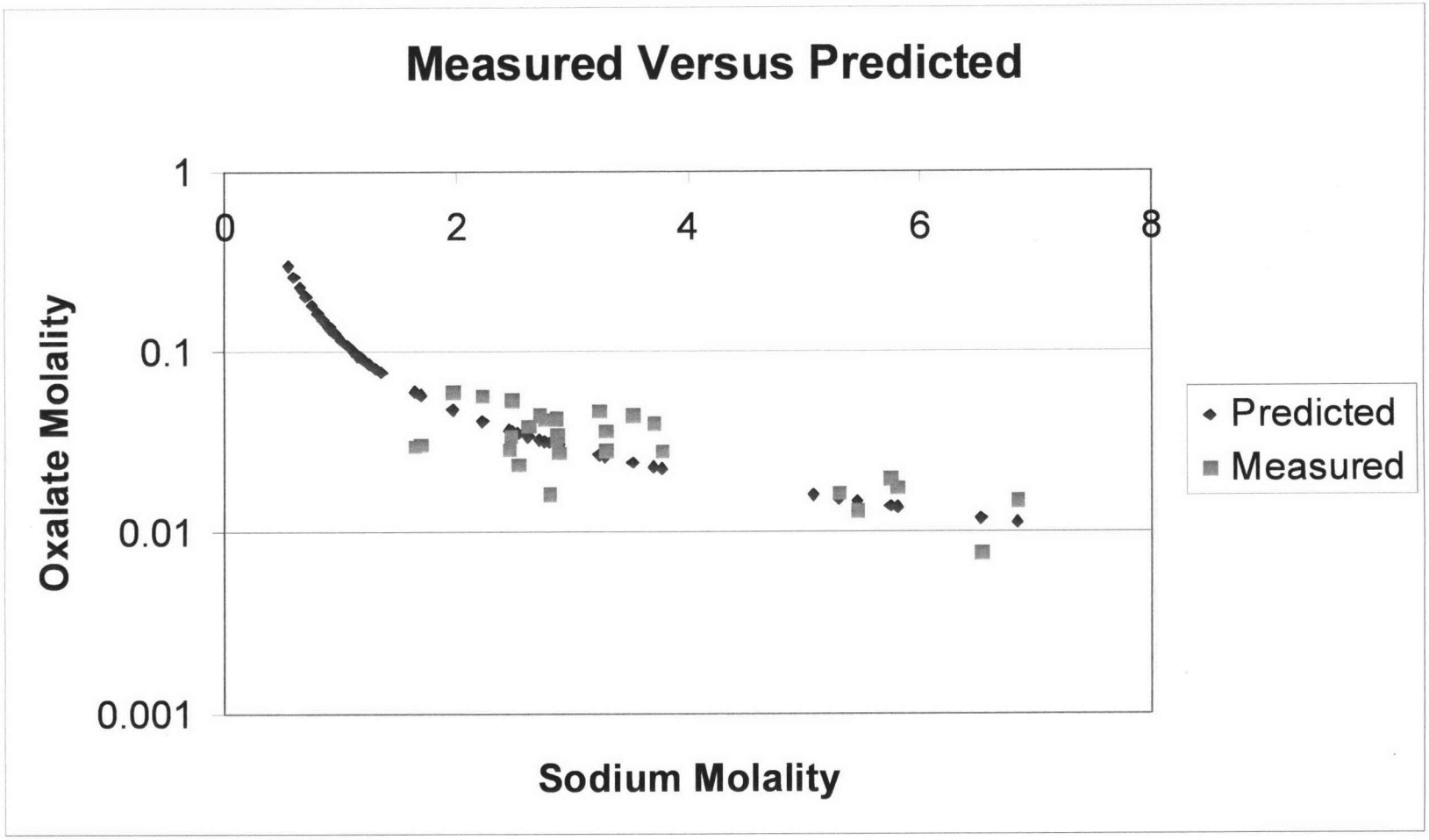


Figure 1.3-11 Comparison of Sodium Effect on Phosphate Correlations

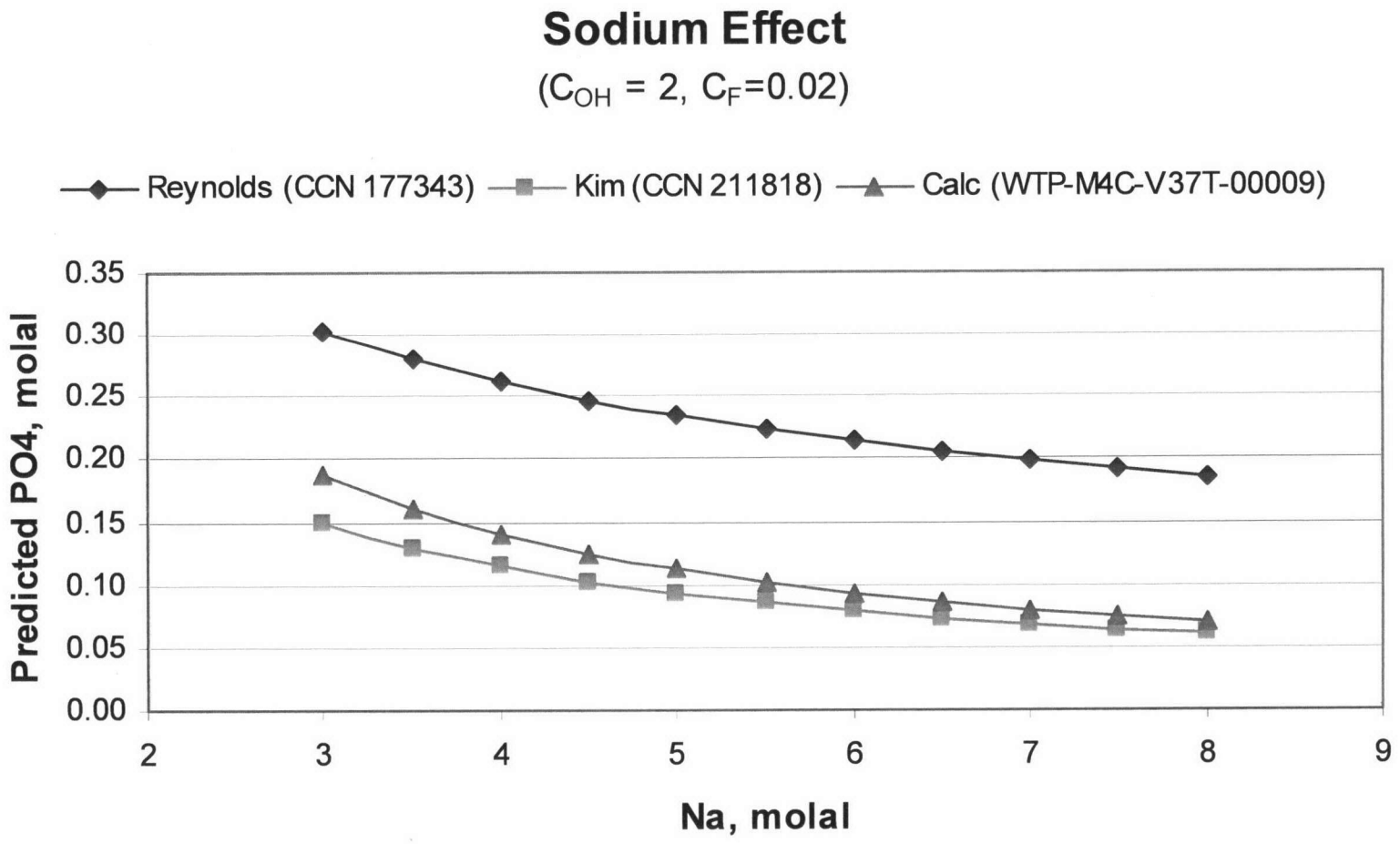


Figure 1.3-12 Comparison of Hydroxide Effect on Phosphate Correlations

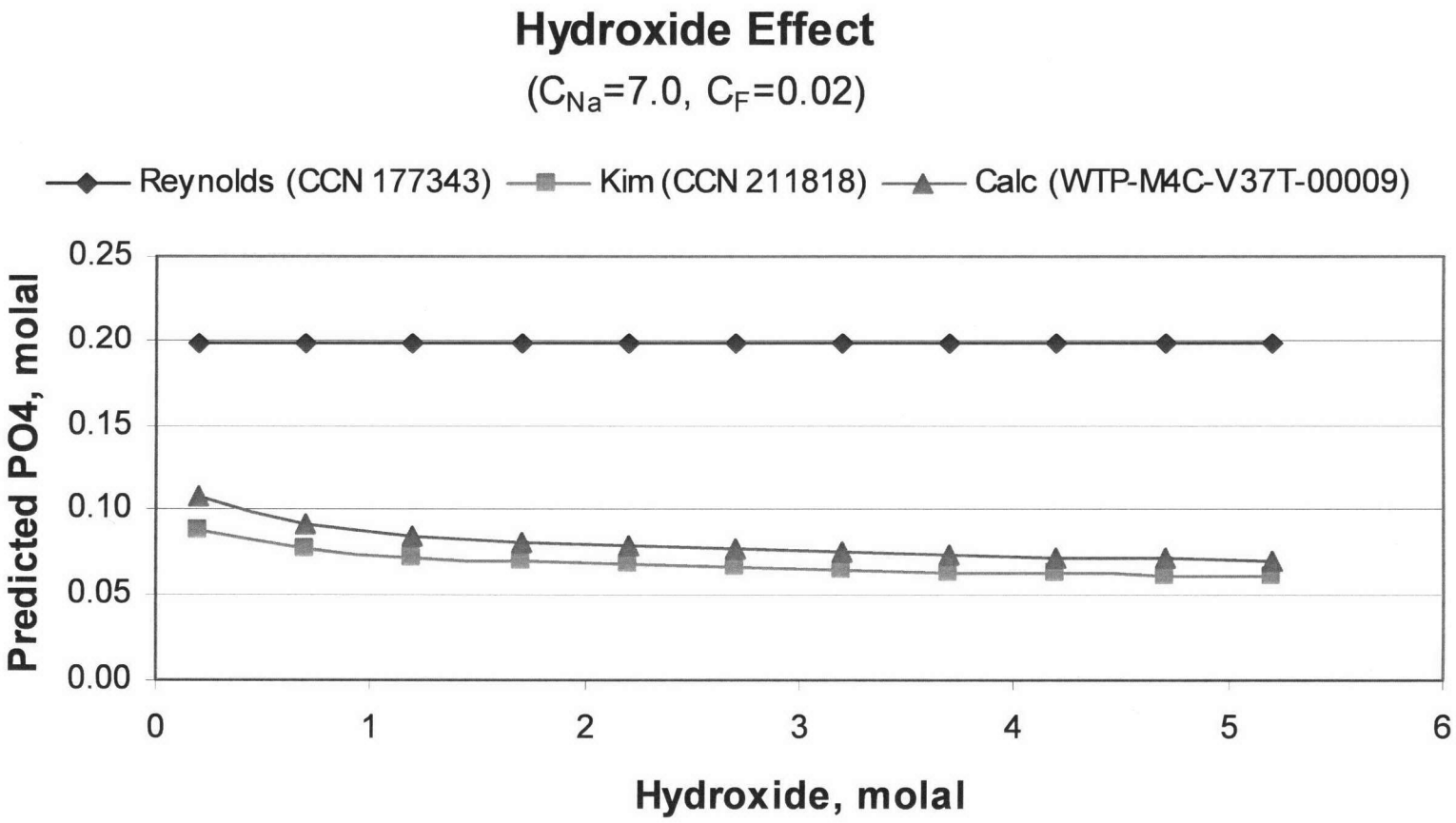
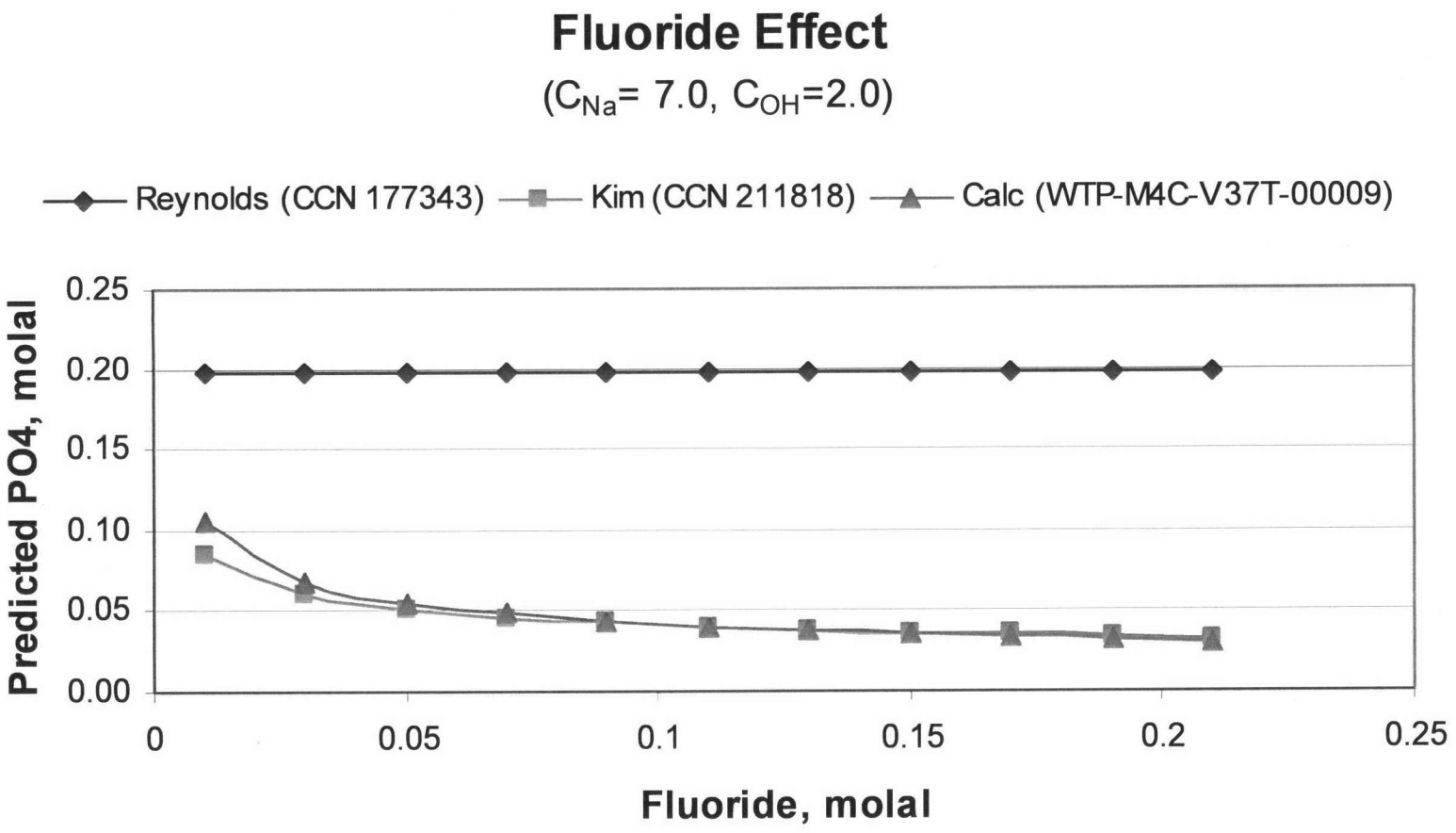


Figure 1.3-13 Comparison of Fluoride Effect on Phosphate Correlations



2 Pretreatment

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2.1 System FRP: Waste Feed Receipt Process

2.1.1 Function and Requirements

The Waste Feed Receipt Process System (FRP) consists primarily of four waste receipt vessels (FRP-VSL-00002A/B/C/D). The main function of this system is to receive low-activity waste (LAW) from Hanford Tank Farms and to supply this feed to downstream WTP processes.

High-level waste (HLW) from Hanford Tank Farms is normally transferred to the HLW waste feed receipt vessel HLP-VSL-00022. This vessel is in the HLW Lag Storage and Feed Blending Process System (HLP) (see Section 2.4).

The FRP system can also provide lag storage capacity for intermediate pretreated LAW melter feed and process recycles, and transfer waste back to Hanford Tank Farms. The FRP system also provides tie-in points for waste transfer pipelines to a possible future processing facility.

Requirements

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136) defines the LAW feed in terms of Envelopes A, B, or C and specifies the compositional limits for chemical and radiological constituents for each envelope. The concentration limits for the LAW envelopes are in Table 2.1-1 and Table 2.1-2. The LAW feed may contain up to 3.8 wt % solids. The settling rate of entrained solids in LAW feed is limited to 0.03 ft/min. Sodium and ^{137}Cs are limited by SOW Section C.8, Specifications 7.2.2.1 and 7.2.2.2, to the following:

Waste Feed	Sodium (mol/liter)	Cs-137 (Ci/liter)
Envelopes A, B, C	4-10	1.2
AZ-101 and AZ-102 supernatant	2-5	3.0

The WTP SOW specifies the following for LAW feed receipt capacity in the Facility Specification, Section C.7 (b)(1):

> *...capability to receive and store 1.5 Mgal of LAW feed. The design shall include the capability to receive without interruption 1.125 Mgal of LAW feed while processing from the remaining capacity of 0.375 Mgal of LAW feed. The tanks shall be connected to allow blending.*

2.1.2 Process Description

The FRP system is depicted in the diagram 24590-PTF-M5-V17T-00003, *Process Flow Diagram Waste Feed Receipt System FRP*. Vessels FRP-VSL-00002A/B/C/D are the primary LAW waste feed receipt vessels. HLW is received in the HLW waste feed receipt vessel, HLP-VSL-00022, which is part of the HLP system (see Section 2.4).

The Tank Farm Contractor (TFC) will provide samples of the staged waste feed batch to the WTP Contractor not less than 180 calendar days prior to the agreed-upon waste transfer date (24590-WTP-ICD-MG-01-019, *ICD 19 - Interface Control Document for Waste Feed*). A dedicated LAW transfer header is specified in CCN 220452, *Technology Steering Group-Issue Closure Record - Partial*

Closure EFRT Issue M-3 (Closure Package Volume 6, FRP-VSL-00002A/B/C/D) Inadequate Mixing System Design. Prior to a LAW transfer from the Tank Farms, a pre-transfer warming flush may be performed with heated water to mitigate the precipitation of salts. After the waste transfer is complete, the TFC will send a post-transfer pipeline flush of inhibited water (process water containing at least 0.01 M NaOH and 0.011 M $NaNO_2$). Combined, the pre- and post-transfer flushes will not exceed three times the transfer pipeline volume and will not exceed 7500 gal (see Section 2.1.3.2 for details).

Each FRP vessel has a working volume of 375,000 gal (1.5 Mgal total), as documented in 24590-PTF-M5-V17T-00003 (see Appendix B for a definition of *working volume*), when only two PJMs are operating. When all twelve PJMs are operating, the working volume of each vessel is approximately 363,700 gallons (24590-PTF-MTE-FRP-00004, *Clarification to PJMs Mixing at Upper Operating Level and Account for Flush in Overflow Sizing*). Each vessel is equipped with pulse jet mixers to agitate the waste, and the tanks are connected for limited blending. Each vessel vapor space is purged to prevent hydrogen accumulation. Vessel contents are sampled to ensure compliance with acceptance criteria. This is a process hold point of 37.8 hr (see CCN 254099, *Laboratory Sample Turnaround Time*). Appendix B contains the volumes and other information for the FRP system.

Figure 2.1-1, located at the end of this section, depicts normal FRP system operations. Under normal operations, feed is transferred from the FRP system through transfer pump (FRP-PMP-00002A) to the ultrafiltration feed preparation (UFP) vessels (UFP-VSL-00001A/B). The feed can also be transferred via pump FRP-PMP-00002A to the Waste Feed Evaporation System (FEP) for concentration by evaporation, if needed. Following a transfer from the FRP system, the transfer pipeline is flushed with an amount of plant wash equivalent to 1.2 to 1.7 line volumes (CCN 141492, *Transmittal of Flush Requirements Following Transfers*).

The FRP process flow diagram, 24590-PTF-M5-V17T-00003, also depicts the following non-routine transfers. Although the following transfer options are available, they are not considered part of normal operations and are not in the flowsheet.

Non-routine transfers into the FRP system include:

- Treated LAW concentrate from the treated LAW concentrate storage vessel TCP-VSL-00001
- Excess recycles from the waste feed evaporator feed vessels FEP-VSL-00017A/B

Non-routine transfers from the FRP system include:

- Treated LAW concentrate to the treated LAW concentrate storage vessel TCP-VSL-00001
- Waste return to Hanford Tank Farms via transfer pump FRP-PMP-00001
- Waste to HLW feed receipt vessel HLP-VSL-00022

System Description for Waste Feed Receipt Process (FRP) (24590-PTF-3YD-FRP-00001) provides detailed information on the FRP system.

2.1.3 Basis

2.1.3.1 Vessel Capacity

SOW requirements form the basis for the size and configuration of the LAW waste feed receipt vessels. Four vessels, each with a working volume of 375,000 gal, compose the FRP system.

2.1.3.2 Line Flushes

The initial bases for the line flushes are found in two documents: ICD 19 and 24590-PTF-3YD-FRP-00001. However, additional flush requirements were established to prevent the formation of flammable concentrations of hydrogen in piping and ancillary vessels and to decrease the likelihood of plugging in the process lines. The bases for these additional requirements can be found in *External Flowsheet Review Team Issue P2 Dynamic Flowsheet Modeling Results* (24590-WTP-RPT-PO-07-001).

ICD 19 specifies the following flush requirements for waste feed transfers from Hanford Tank Farms:

- The pipeline will be flushed before the transfer with heated water, if necessary, to mitigate the precipitation of salts.
- Inhibited water (defined as process water containing 0.01 M NaOH and 0.011 M $NaNO_2$) will be used to flush the Hanford Tank Farm transfer lines after the waste transfer is complete.
- Immediately following (in less than 120 min) the transfer of feed to the FRP system, the TFC will commence flushing the transfer pipeline.
- The pre-transfer and post-transfer combined flush volumes will not exceed three times the transfer pipeline volume and will not exceed 7500 gal total.
- Following an FRP return transfer of waste to Hanford Tank Farms, the TFC will provide a post-transfer pipeline flush of inhibited water.

24590-PTF-3YD-FRP-00001 specifies the following flush requirements for waste feed transfers from Hanford Tank Farms:

- A pre-transfer warming flush will be sent from Hanford Tank Farms to WTP to ensure proper valve alignment and to prevent salt precipitation.
- After the waste is transferred from Hanford Tank Farms to WTP, flush water will be sent from the Tank Farms to clean the transfer pipeline.
- Liquid remaining in the transfer pipeline following the post-transfer flush will gravity drain to PWD-VSL-00043.

24590-PTF-3YD-FRP-00001 specifies the following flush requirements for transfers from the FRP system to downstream systems (i.e., UFP or FEP):

- A post-transfer flush will be performed with plant wash to flush the transfer pump and pipes.
- The volume of flush water will be controlled via a timer.
- After the flush is complete, liquid remaining in the transfer pipeline will be gravity drained to PWD-VSL-00033.

The required frequency and volume for specific FRP system flushes is provided in 24590-WTP-RPT-PO-07-001, Appendix A.

2.1.4 Ongoing Work and Potential Changes

In March 2006 an External Flowsheet Review Team (EFRT), consisting of experts from industry, national laboratories, and universities, completed a comprehensive review of the WTP flowsheet and throughput (CCN 132846).

The EFRT identified 17 major issues and 11 potential issues that could negatively affect the WTP throughput. EFRT M3, Inadequate Design of Mixing Systems, was applicable to the FRP-VSL-00002A/B/C/D vessels.

EFRT M3 was partially closed for the FRP-VSL-00002A/B/C/D vessels following an assessment of test results and analyses (CCN 220452). However, several residual risks were cited within the assessment, these risks are:

1 The actual full-scale vessel may under- or over-perform when compared with the results in the M3 vessel assessment. This is due to a combination of conditions in the testing that challenge the design condition (e.g., the selection of solids in the simulants used in testing that are more difficult to suspend compared to nominal tank wastes) and simplifications in the calculation methods (e.g., movement of solids on the vessel bottom and suspension and settling rates as projected by the Low Order Accumulation Model). Testing at a large scale has not been performed. In addition, the testing program and design assessment methods have not comprehensively accounted for fluid flow distribution interferences from seismic supports and internal structures. Actual waste fluid viscosities, localized concentrations, and temperatures could impact estimated design margins presented in the assessment. Extrapolation of effective PJM clearing radius results to solids depths that have not been tested are uncertain.

2 The following operational conditions were not completely evaluated in the M3 testing program:
   a The suction line transfer system has not been prototypically tested at full scale. The frequency of flushing the transfer line could have an unacceptable impact on plant throughput.
   b The normal PJM air supply and venting control strategy is not complete to support the identification of PJM operating parameters for pulse length, duty cycle, pulse volume fraction, and air pressures. The impact of off-normal conditions, (e.g., blockage of level detection probes on effective and safe operation of the PJMs) has not been completely evaluated.

3 The recommended changes from the vessel assessment and the mixing requirements have led to a condition in which the WTP technical baseline is not entirely consistent. This is required to support the design confirmation process for PJM mixing and WTP capacity assessments. The following issues have been identified:
   a The WTP Integrated Process Strategy Description (WIPSD), Integrated Sampling and Analysis Requirements Document (ISARD), and Contract Run (G2) Model Run Results are based on the assumption that the solids in the vessels are uniformly distributed (homogeneously mixed). Homogeneous mixing is not possible for all particle sizes and densities using PJMs. As a consequence, solids are stratified in most PJM-mixed vessels.

As such, there is a risk that the stratified solids distribution may: 1) impact the current process strategy and 2) impact waste throughput projections.

b The process stream properties used to provide input information to support the vessels assessments originated from several source documents, including: WTP Process Stream Properties, Unit Dose Factors for Use in Updated MAR Accident Analysis, and testing information. WTP is also evaluating the WTP process limits as part of future studies which may impact the process stream properties.

c The M3 program has provided analysis and results that have not been incorporated in the Preliminary Criticality Safety Evaluation Report (CSER) update.

4 Vessel off normal operating conditions may result in the formation of solids (by agglomeration or precipitation) that have a settling velocity greater than 0.03 ft/min.

The M3 resolution Technology Steering Group (TSG) agreed to the following recommendations to mitigate the risks:

1 The TSG concurs with the recommended changes provided in the FRP-2A/B/C/D Vessel Assessment, 24590-WTP-RPT-ENG-08-021-06, EFRT Issue M3 PJM Vessel Mixing Assessment, Volume 6 - FRP-VSL-00002A/B/C/D, as summarized in Table 2.1-3.

2 The TSG recommends the following risk mitigation actions.

a To mitigate the risk identified in Risk #1 above, a validated and verified (V&V) computational fluid dynamics (CFD) assessment must be used to support the design confirmation process to assess vessel performance with an accurate physical geometry of the vessel and spatially dependent fluid properties.

b To mitigate the risk identified in Risk #1 and #2 above, testing at a large scale should be completed prior to commissioning, 24590-WTP-RPT-ENG-10-001, Rev. 0, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy,* to increase confidence in the projected full scale vessel mixing performance and operations. This testing should evaluate:

- The capability of the PJMs to operate under the expected range of fill conditions.
- The PJM gravity re-fill mode for the anticipated temperatures during operations. [Not applicable to *FRP-2A1B/C/D* but included for consistency with other Closure Packages.]
- The suction line transfer system at full scale.
- Process control sampling strategies.
- The PJM control strategies with prototypic operating conditions and controls (e.g., the use of bubblers for vessel level monitoring).

c To mitigate the risk identified in Risk #3 above, the WTP must update the integrated technical baseline to: 1) support design confirmation of the PJM vessel designs for mixing and 2) assess WTP design capacity performance. In particular,

- The WIPSD, ISARD, and Contract Run (G2) Model Run Results should be updated to account for stratified solids in the vessel to determine if the WTP Contract waste treatment capacity requirements as defined in Table C. 7 -1.1 of the WTP Contract are achieved.
- This technical baseline including (but not limited to) the WTP Process Stream Properties and Unit Dose Factors for Use in Updated MAR Accident Analysis must be consistent with the safety authorization basis and represent the current design. The fluid properties must include: solids concentration, rheological properties (e.g.

viscosity, yield strength, cohesive properties), particle sizes/distributions and densities, and chemical species.

- The Preliminary Criticality Safety Evaluation Report must be updated based on the results and evaluations provided in the M3 analyses. This update should also include an evaluation of impacts that could be associated with the removal rate of poisons as compared to the removal rate of PuO2 and evaluation of differential settling rates.

3 The previous recommendation that the erosion sensitivity analysis presented in 24590-WTP-RPT-PET-08-008, *EFRT Issue M2 Closure Report*, should continue to be evaluated. The action item (ATS#08-1884) should be completed to determine if the results demonstrate sufficient erosion wear allowances with stratified solids concentrations.

4 Conduct a formal analysis to provide a technical basis to establish the functional and operating requirements for the proposed large scale PJM mixed vessel testing. This analysis should address issues identified in Residual Risks 1 and 2 above, the Engineering Strategy Document, 24590-WTP-RPT-ENG-10-001, and the technical uncertainties in the vessel assessment closure packages.

5 WTP and DOE should jointly prepare and approve a technical issues summary sheet in accordance with 24590-WTP-GPG-ENG-0125, Rev 2, *Engineering Technical Issues Identification Management,* to address the proposed large scale PJM mixed vessel testing. The initial technical issues summary sheet should be prepared by August 4, 2010. The technical issue summary sheet shall be provided with a preliminary Level 2 schedule for major work activities.

6 Perform parametric (e.g., fluid density and viscosity; particle size and density; vessel upper and lower operating levels) sensitivity analyses to determine the maximum allowable settling rate (beyond design basis). The sensitivity analysis should include the 10 micron spherical Pu particle. These analyses will be used to support: 1) understanding of the vessel mixing capability to suspend solids, and the 2) development of vessel operating procedures.

2.1.5 References

24590-PTF-3YD-FRP-00001, Rev 1, *System Description for Waste Feed Receipt Process (FRP).*

24590-PTF-M5-V17T-00003, Rev 2, *Process Flow Diagram Waste Feed Receipt System (FRP).*

24590-PTF-MTE-FRP-00004, *Clarification to PJMs Mixing at Upper Operating Level and Account for Flush in Overflow Sizing*

24590-WTP-GPG-ENG-0125, Rev 2, *Engineering Technical Issues Identification Management,* June 2010.

24590-WTP-ICD-MG-01-019, Rev 4, *ICD 19 - Interface Control Document for Waste Feed.*

24590-WTP-ICF-OP-04-0002, Interface Change Form, *Emergency Returns Flush Responsibility.*

24590-WTP-PL-PR-04-0001, Rev 2, *Integrated Sampling and Analysis Requirements Document (ISARD).*

24590-WTP-RPT-ENG-08-021-06, *EFRT Issue M3 PJM Vessel Mixing Assessment, Volume* 6 - *FRP-VSL-00002A/B/C/D*, June 2010.

24590-WTP-RPT-ENG-10-001, Rev. 0, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy,* February 2010

24590-WTP-RPT-PO-07-001, Rev 0, *External Flowsheet Review Team Issue P2 Dynamic Flowsheet Modeling Results.*

CCN 132846, *Report of External Flowsheet Review Team for the Hanford Tank Waste Treatment and Immobilization Plant - Final Report Titled: "Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput."* 17 March 2006.

CCN 141492, *Transmittal of Flush Requirements Following Transfers.* 1 August 2006.

CCN 220452, *Technology Steering Group-Issue Closure Record - Partial Closure EFRT Issue M-3 (Closure Package Volume 6, FRP-VSL-00002A/B/C/D) Inadequate Mixing System Design.* 30 June 2010

CCN 254099, *Laboratory Sample Turnaround Times (WTP OR Model V7.0).* 05 April 2013.

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136, Modification M196. US Department of Energy, Office of River Protection, Richland.

Table 2.1-1 Low-Activity Waste Chemical Composition, Soluble Fraction Only

Maximum Ratio, Analyte (mole) to Sodium (mole) and Analyte (kg) to Sodium (kg)						
Chemical Analyte	Envelope A		Envelope B		Envelope C	
	mol/mol Na	kg/kg Na	mol/mol Na	kg/kg Na	mol/mol Na	kg/kg Na
Al	2.5E-01	2.9E-01	2.5E-01	2.9E-01	2.5E-01	2.9E-01
Ba	1.0E-04	6.0E-04	1.0E-04	6.0E-04	1.0E-04	6.0E-04
Ca	4.0E-02	7.0E-02	4.0E-02	7.0E-02	4.0E-02	7.0E-02
Cd	4.0E-03	2.0E-02	4.0E-03	2.0E-02	4.0E-03	2.0E-02
Cl	3.7E-02	5.7E-02	8.9E-02	1.4E-01	3.7E-02	5.7E-02
Cr	6.9E-03	1.6E-02	2.0E-02	4.5E-02	6.9E-03	1.6E-02
F	9.1E-02	7.5E-02	2.0E-01	1.7E-01	9.1E-02	7.5E-02
Fe	1.0E-02	2.4E-02	1.0E-02	2.4E-02	1.0E-02	2.4E-02
Hg	1.4E-05	1.2E-04	1.4E-05	1.2E-04	1.4E-05	1.2E-04
K	1.8E-01	3.1E-01	1.8E-01	3.1E-01	1.8E-01	3.1E-01
La	8.3E-05	5.0E-04	8.3E-05	5.0E-04	8.3E-05	5.0E-04
Ni	3.0E-03	7.7E-03	3.0E-03	7.7E-03	3.0E-03	7.7E-03
NO2	3.8E-01	7.6E-01	3.8E-01	7.6E-01	3.8E-01	7.6E-01
NO3	8.0E-01	2.2E+00	8.0E-01	2.2E+00	8.0E-01	2.2E+00
Pb	6.8E-04	6.1E-03	6.8E-04	6.1E-03	6.8E-04	6.1E-03
PO4	3.8E-02	1.6E-01	1.3E-01	5.4E-01	3.8E-02	1.6E-01
SO4	1.0E-02	4.2E-02	7.0E-02	2.9E-01	2.0E-02	8.4E-02
TIC[a]	3.0E-01	1.6E-01	3.0E-01	1.6E-01	3.0E-01	1.6E-01
TOC[b]	5.0E-01	2.6E-01	5.0E-01	2.6E-01	5.0E-01	2.6E-01
U	1.2E-03	1.2E-02	1.2E-03	1.2E-02	1.2E-03	1.2E-02

Source: WTP *Statement of Work*. Specification 7; Table TS-7.1.

[a] TIC: Mole of inorganic carbon atoms/mole sodium.

[b] TOC: Mole of organic carbon atoms/mole sodium.

Table 2.1-2 Low-Activity Waste Radionuclide Composition, Soluble Fraction Only

Maximum Ratio, Radionuclide (Bq) to Sodium (mole) and Radionuclide (Ci) to Sodium (kg)						
	Envelope A		Envelope B		Envelope C	
Radionuclide	Bq/mol Na	µCi/mol Na	Bq/mol Na	µCi/mol Na	Bq/mol Na	µCi/mol Na
TRU[b]	4.80E+05	1.3E+01	4.80E+05	1.3E+01	3.00E+06	8.11E+01
^{137}Cs	4.30E+09	1.16E+05	2.00E+10	5.41E+05	4.30E+09	1.16E+05
^{90}Sr	4.40E+07	1.19E+03	4.40E+07	1.19E+03	8.00E+08	2.16E+04
^{99}Tc	7.10E+06	1.92E+02	7.10E+06	1.92E+02	7.10E+06	1.92E+02
^{60}Co	6.10E+04	1.65E+00	6.10E+04	1.65E+00	3.70E+05	1.00E+01
^{154}Eu	6.00E+05	1.62E+01	6.00E+05	1.62E+01	4.30E+06	1.16E+02

Source: WTP *Statement of Work*, Specification 7; Table TS-7.2.

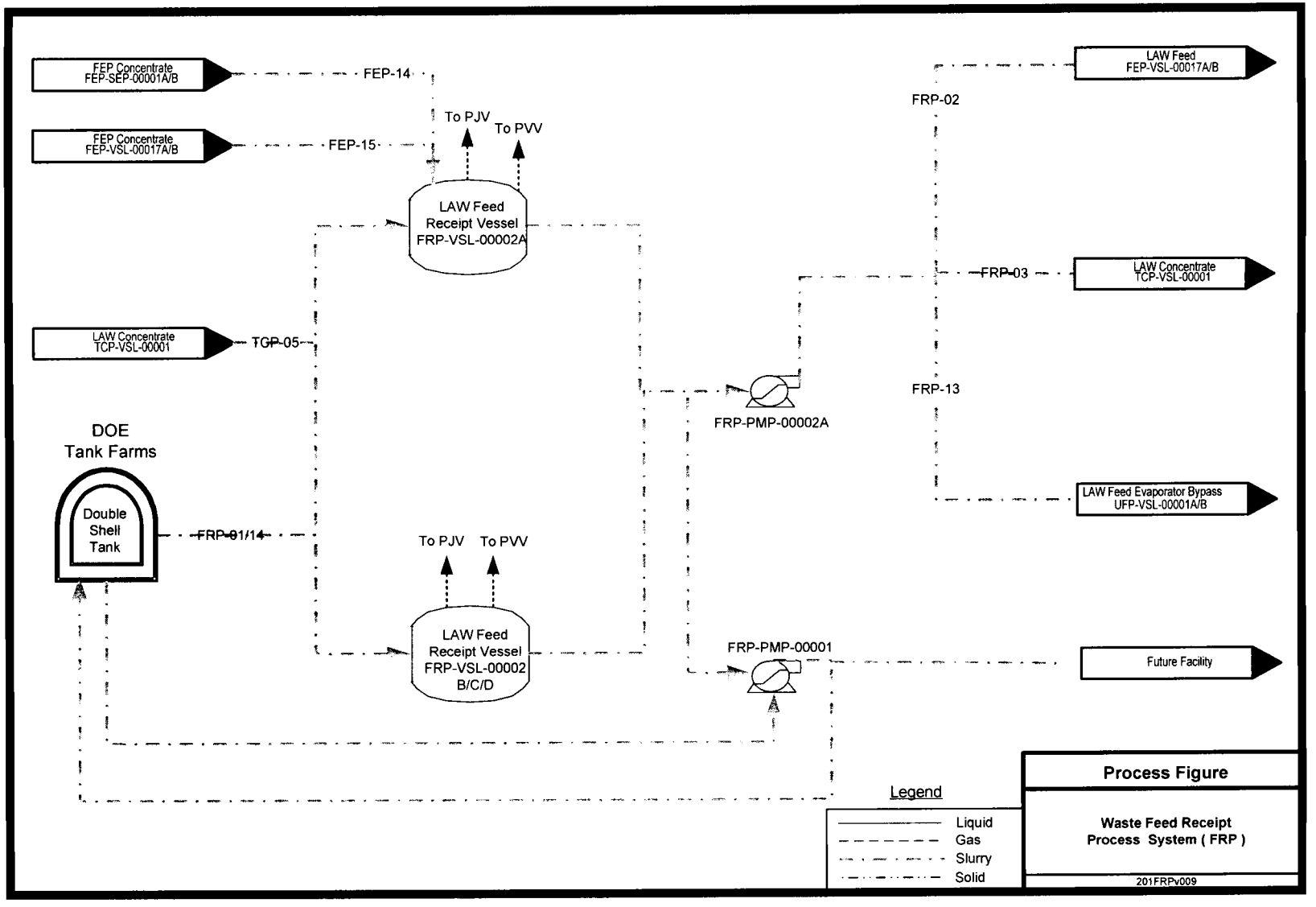
[a] The activity limit shall apply to the feed certification date.

[b] TRU is defined as alpha-emitting radionuclides with an atomic number greater than 92 with half-life greater than 10 years.

Table 2.1-3 FRP-VSL-00002A/B/C/D Recommended Changes (CCN 220452)

FRP-2 Recommendations	Equipment Changes
FRP-1	Change the Jet Pump Pair (JPP) model from L50M to H80SX which increases the drive velocity from 8 m/s to 12 m/s for FRP-VSL-2/B/C/D
FRP-2	Angle the 8 outer PJM nozzles so they are perpendicular to the vessel bottom
FRP-3	Shifts in pipe routings including adding a dedicated LA W header to FRP and a dedicated LAW transfer line from tank farms.
	Document Changes
FRP-4	P&ID needs to be modified to show shifted pipe routings and dedicated LAW header to the FRP vessels involved with dedicated LAW transfer line from Tank Farms. Piping and valves also need to be added to P&ID to account for LAW feed filter.
FRP-5	JPP datasheet needs to be modified for increased velocity for PJMs in FRP-VSL-2B/C/D
FRP-6	System Description, Calculations, & P&IDs need to be updated to align with changes from tests, studies, and assessments from M3.
FRP-7	Process Stream Properties (PSP) and Process Inputs Basis of Design (PIBOD) documents need to be evaluated for possible changes to wt% solids, slurry density, and viscosity.
FRP-8	Issue calculation which provides a basis for using 10 microns as the bounding PuO_2 particle size (calculation will include data from CCN 211814).
	Contract Changes
FRP-9	Settling rate of entrained solids in LAW feed is limited to 0.03 ft/min.

Figure 2.1-1 Feed Receipt Process System



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2.2 System FEP: Feed Evaporator Process

2.2.1 Function and Requirements

The function of the Waste Feed Evaporation Process System (FEP) is to reduce the volumetric throughput of the ultrafiltration process (UFP) and other downstream unit operations, and also separate water for reuse and disposal. The FEP system receives recycle streams from throughout the plant (may also receive low-activity waste [LAW] from the feed receipt vessels) and concentrates them until either the 5 M Na concentration or the 8.9 wt % undissolved solids bounding constraint for the evaporator bottoms is achieved.

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7, Paragraphs C.7(d)(1)(v) and (vi), specifies the following for the FEP system, as applicable to evaporation:

> *Radionuclide Concentration: This operation concentrates and recycles process streams that contain the recovered radionuclides and entrained solids recovered from the Envelope A, B, and C supernatants.*
>
> *Liquid Effluent Treatment: This operation concentrates and recycles waste processing streams resulting from the treatment of HLW and LAW Vitrification system off-gas condensates. Treated condensates will be transferred to the Effluent Treatment Facility on the Hanford Site.*

2.2.2 Process Description

The FEP system consists of two parallel, continuous, forced-circulation, vacuum evaporation systems. The feed to the evaporators is pumped from two evaporator feed vessels (FEP-VSL-00017A/B). Each evaporator system consists of a separation vessel, recirculation pump and pipe loop, reboiler, slurry product pump, vacuum eductor system, primary condenser, intercondenser, and aftercondenser. The condensate from the condensers is collected in the condensate collection vessel (FEP-VSL-00005).

The process flow diagrams (24590-PTF-M5-V17T-00004001, *Process Flow Diagram Waste Feed Evaporation Sheet 1 of 2 System [FEP]* and 24590-PTF-M5-V17T-00004002, *Process Flow Diagram Waste Feed Evaporation Sheet 2 of 2 System [FEP]*) and the FEP system description (24590-PTF-3YD-FEP-00001, *System Description for Waste Feed Evaporation Process [FEP]*) provide details.

2.2.2.1 Material Transfer to FEP System

The evaporator feed receipt vessels (FEP-VSL-00017A/B) receive recycle streams from throughout the plant and may also receive LAW feed from the feed receipt vessels. The following streams may be transferred to the FEP feed receipt vessels (FEP-VSL-00017A/B):

1 Neutralized high-activity effluent from acidic/alkaline effluent vessel PWD-VSL-00015.
2 Neutralized high-activity effluent from acidic/alkaline effluent vessel PWD-VSL-00016.
3 Spent resin flush from RDP-VSL-00002A/B/C.
4 Neutralized high-activity effluents from plant wash vessel PWD-VSL-00044.
5 LAW feed from the LAW feed receipt vessels FRP-VSL-00002A/B/C/D.
6 19M NaOH caustic addition for solubility adjustments.

7 Evaporator concentrate recycled from UFP-VSL-00001A/B. During normal conditions, evaporator overheads product will not be reworked.

8 Contaminated process condensate from FEP-VSL-00005. During normal conditions, process condensate will not be contaminated.

The FEP feed vessels (FEP-VSL-00017A/B) will receive batch transfers from a combination of the above sources. However, the combination of transfers from all sources into FEP-VSL-00017A/B must result in a net solids concentration of ≤ 2 wt % solids and sodium concentration < 5 M sodium (24590-WTP-RPT-ENG-08-021-09, *EFRT Issue M3 PJM Vessel Mixing Assessment, Volume 9 - FEP-VSL-00017A/B*). Dissolved solids, containing oxalate and phosphorous, may precipitate when feed streams are blended together or when heating/cooling of the process stream occurs throughout the FEP system.

Envelope C waste, will be routed directly to vessels FEP-VSL-00017A/B, where the downstream precipitation reaction requires a heated solution of 122 °F (24590-PTF-3YD-UFP-00001, *System Description for Ultrafiltration Process System [UFP]*).

For recycles coming from vessels PWD-VSL-00015, PWD-VSL-00016, and PWD-VSL-00044, these three vessels are mixed in a ratio so that the evaporator inlet (FEP-VSL-00017A/B vessels) will have a sodium concentration of less than 5 M and a solid weight percent of less than 2.0. The evaporator outlet will have a sodium concentration of greater than 5 M and weight percent solids of less than 8.9. The 8.9 wt % solid bounding conditions are based on hydrogen generation calculations (CCN 074569). The upper limit on sodium concentration will be controlled as discussed in Section 2.2.3.5.

In case LAW feeds and recycled wastes need to go through the evaporator at the same time, one vessel, FEP-VSL-00017A or B, may be dedicated for recycles and the other one for LAW feeds. The LAW feeds always have a lower priority than recycle batches. Typically the feed vessels will be filled with one or more of the recycled streams and operate with one vessel feeding the evaporator system while the other vessel is filling. One possible operating scenario is that one will receive and blend for the period, while the other vessel feeds one or both evaporators. The two vessels alternate receiving and sending functions.

2.2.2.2 Evaporator Feed Properties

Batch transfers are made from FEP-VSL-00017A/B to FEP-SEP-00001A/B via stream FEP01, with the following stream characteristics (as referenced above and including 24590-WTP-RPT-ENG-07-007, *Process Stream Properties)*:

- Maximum Temperature = 122 °F
- Maximum Specific Gravity = 1.5
- Maximum Viscosity = 10 cP
- Maximum Vapor Pressure = 1.8 psia
- Weight Percent Solids ≤ 2 wt %
- Sodium Molarity < 5 M
- Maximum Pump Flow = 50 gpm

2.2.2.3 Evaporator Operations

The feed from the feed tanks enters the evaporator recirculation loop. The liquor is recirculated by way of the evaporator reboiler, which increases the temperature of the liquor, and discharges back into the separator vessel. The pump and reboiler are located such that sufficient hydraulic head is provided by the liquid-level in the separator so that cavitation will not occur in the pump and boiling will not occur in the reboiler tubes. When the recirculating liquor enters the separator vessel, flash evaporation occurs due to the reduced pressure in the vessel. The vacuum in the separator vessel is maintained by the vacuum eductor system and by controlling the in-bleed of air to the suction side of the vacuum eductor. This reduced pressure lowers the boiling point of the liquor. The vapors exiting the evaporator separator must pass through a disengagement zone, three bubble-cap trays, and two de-entrainment pads (see Figure 2.2-1). Process condensate is delivered as a spray underneath the de-entrainment pad section to aid decontamination factor (DF) performance and de-entrainment. Antifoam is added to the disengaging zone below the bubble-cap trays.

Overheads from the evaporator are routed to the primary condenser, where most of the vapor is condensed at the saturation pressure. A two-stage steam eductor system maintains a vacuum in the evaporator. Vapor from the steam eductors is condensed in an intercondenser and aftercondenser. Non-condensable gases from the aftercondenser enter the Pretreatment vessel vent process system (PVP).

The condensate from all three condensers is routed to the process condensate vessel, FEP-VSL-00005. Most of the condensate is then transferred to the radioactive liquid waste disposal system (RLD), where the solution is recycled for use in the WTP process or excess condensate transferred to Liquid Effluent Retention Facility/Effluent Treatment Facility. Some of the FEP process condensate is filtered and routed to the de-entrainment section of the evaporator separator. If activity of the condensate is above specifications, the contaminated condensate is recycled to the evaporator feed vessel (FEP-VSL-00017A/B). Capability is also provided to divert high-activity condensate from the condensers to the second FEP separator vessel for double-effect evaporation.

The evaporators are capable of handling the range of facility recycle streams and, as necessary, LAW feeds, at the required throughput rates. The evaporator load is variable and dependent on factors such as waste feed density, recycle volumes, and production rates. The two parallel evaporators each have a boil-off capacity of 30 gpm (24590-QL-POA-MEVV-00001-04-04, *Calculation- 60% Design -Hanford Evaporator Project #1 - Evaporator Mass and Energy Balance*). The varying loads are accommodated by operating only one evaporator, with the other in standby, or by turning down one or both evaporators. The evaporators are turned down by adjusting the steam flow rate to the reboiler and separator pressure. It is estimated that during normal operation it will be necessary to operate only one evaporator at a time (CCN 021805).

2.2.2.4 FEP-VSL-00017A/B Heel Dilution

As recommended in *EFRT Issue M3 PJM Vessel Mixing Assessment, Volume 9 - FEP-VSL-00017A/B,* the capability for heel dilution has been provided for FEP-VSL-00017A/B . The steps for heel dilution are provided below (24590-WTP-RPT-PET-10-013, *Pretreatment Vessel Heel Dilution/Cleanout feasibility Study*):

- Pump the vessel slurry level down to an initial low heel level (about 1,800 gallons).
- Add dilution liquid from one of the following sources (in order or preference) LAW feeds, process condensate, or DI water until the PJM operation liquid level (about 5,700 gallons).

- Fluidize solids heel by briefly mixing dilution liquid and solids heel using PJMs (1 hour).
- Transfer fluidized solids heel to FEP-SEP-00001A/B and continue transfer until vessel liquid level is at an ending heel level (about 1,800 gallons).

2.2.3 Basis

2.2.3.1 Evaporator Type

A continuous, forced-circulation, vacuum-type evaporator was chosen for the waste feed evaporators based on engineering assessment and the performance of the existing 242-A evaporator. The 242-A evaporator is a continuous, forced-circulation, vacuum evaporator that concentrates Tank Farm waste to increase tank storage space (WHC 1984). This evaporator also processes the same wastes that the WTP will process.

2.2.3.2 Evaporator Capacity

The two parallel evaporators are each capable of continuous operation while achieving a feed evaporation rate ranging from 10 to 30 gpm. The design feed evaporator rate excludes all water and fluid additions to demister pads' spray, separation trays, and antifoam injection (24590-PTF-3PS-MEVV-T0001, *Engineering Specification for Forced Circulation Vacuum Evaporator System*). The varying load is accommodated by operating only one evaporator, with the other in standby, or by turning down one or both evaporators.

2.2.3.3 Rates for Feed Delivery, Recirculation, and Concentrate Removal

The evaporator feed streams mix with the evaporator bottoms in the forced-circulation piping loop. The forced-circulation pump recirculates the evaporator contents at approximately 11,000 gpm (24590-QL-POA-MEVV-00001-08-01, *System Description - 60% Design - Hanford Evaporator Project #1 System Description*). The contents of the evaporator are turned over in less than a minute and the velocity through the reboiler tubes reduces the build-up of scale. The mixing and pumping of the feed and recirculated concentrate determines the composition and enthalpy of the material that is delivered to the reboiler.

Concentrate is removed from the evaporator at a continuous flow rate and composition determined to meet the requirements of the downstream processes. Concentrate may also be removed on a semi-batch basis to achieve a target velocity in the transfer pipe that may be necessary to keep solids from settling in the concentrate transfer line. This velocity is determined by detail design calculations and is approximately 4 ft/sec or higher. Feed may be delivered to the evaporator to achieve the concentrate flow velocity and minimize the frequency of the concentrate line post-transfer flush. Operation with dilute feed may require variation of the separator liquid level within control requirements to periodically achieve the concentrate flow velocity.

The semi-integrated pilot plant (SIPP) average boil-off rate for evaporator, reported in SCT-M0SRLE60-00-208-00003, met or exceeded the plant boil-off rate. The tests also show that additions of different recycle streams to the evaporator feed have no impact on average boil-off rate of the SIPP evaporator.

2.2.3.4 Recycle Streams to the Waste Feed Evaporation Process

Streams recycled to the FEP system are collected before being received into the FEP feed receipt vessels.

- Neutralized effluents from vessel PWD-VSL-00015, consisting primarily of low sodium content solutions (~ 0.1 M Na, or lower):
  - Ultrafilter caustic cleaning effluent
  - Cesium (Cs)/nitric acid recovery evaporator condensate
  - Dilute effluents from Cs ion exchange
- Neutralized effluents from vessel PWD-VSL-00016, consisting primarily of:
  - Ultrafiltration wash solution
  - Ultrafilter acid cleaning effluent

  Note: The operating functions of PWD-VSL-00015 and 00016 are interchangeable. The effluent sources identified may also be routed to one vessel with the vessels operating in alternating cycles of filling and emptying (SCT-M0SRLE60-00-33-03).
- Neutralized HLW and pretreatment (PT) waste from vessel PWD-VSL-00044, consisting primarily of low sodium content solutions (~ 0.1 M Na, or lower):
  - Purge solution from the HLW submerged bed scrubber (SBS), wet electrostatic precipitator, and high-efficiency mist eliminator (HEME) condensate
  - Canister decontamination waste solution from HLW vitrification
  - PT caustic scrubber condensate and purge solution
  - PT vessel ventilation HEME condensate collection
  - Various line flushes and drainage
  - Ultrafilter piping-loop flushing and draining of washed solids (during leaching and prior to cleaning of the ultrafilters)
- The spent resin liquor stream recycle effluent from vessel RDP-VSL-00002B.
- Out-of-specification FEP process condensate is included in the FEP evaporator energy balance evaluation in order to obtain the maximum boil-off rate and utility loads for operation of one evaporator.

These streams are recycled upstream of the waste feed evaporator system, except for the out-of-specification process condensate. The sodium content, the solids content, and the potential for solids formation during concentration affect the concentration factor that can be achieved for the recycled streams (or blended recycled streams) to the evaporator.

2.2.3.5 Antifoam Addition

The antifoaming agent (AFA) DOW Q2-3183A is added to the evaporator to minimize foaming. The antifoam constituents and composition from the material safety data sheet (No. 01603183) are listed below:

40 - 70 wt %	Polypropylene glycol
40 - 70 wt %	Polydimethylsiloxane
3 - 7 wt %	Octylphenoxy polyethoxy ethanol

3 - 7 wt %	Treated silica (trade secret)
3 - 7 wt %	Polyether polyol
SpG @ 25 °C	= 1.0

The primary compounds of the AFA (CCN 182189) are:

- Polypropylene glycol (PPG) = $(C_3H_6O)_{60}*H_2O$
- Polydimethylsiloxane (PDMS) = $(H_3C)_3*SiO[Si(CH_3)_2O]_{470}Si(CH_3)_3$
- Molecular weight of PPG = 3,503 g/mol
- Molecular weight of PDMS = 35,015 g/mol

Heating and irradiation will cause the PPG and PDMS to decompose at a rate of 20 wt % every 24 hours (SCT-M0SRLE60-00-99-00009). The AFA is delivered to the evaporator at a rate necessary to achieve, and maintain, a concentration of 500 ppm in the concentrate (not including any dilution of the antifoam for delivery). Thus, the antifoam delivery rate to the evaporator varies with the concentrate flow rate, which depends on the operating methodology. For additional AFA information see Section 2.16.

2.2.3.6 Waste Feed Evaporator End Product Concentration

Five molar sodium concentration is currently regarded as the optimum feed condition for unit operations downstream of the FEP evaporation process. This information is detailed in Section 2.3, System UFP: Ultrafiltration Process. The product from the FEP system for Envelopes A and B is concentrated to approximately 5 M Na or a specific gravity to achieve that molarity (SpG of 1.27). The feed blending strategy and solids content of the feed, if routed through the evaporator, must also be considered in the determination of the evaporator product concentration (24590-PTF-3YD-FEP-00001). The specific gravity required of the evaporator concentrate (at the operating temperature) is an operating setpoint of the evaporator and determines the volume reduction of the feed delivered to the evaporator. In addition, the maximum bounding condition for the evaporator bottoms (concentrate) is 8.9 wt % solids (CCN 074569). Dissolved solids, containing oxalate and phosphorous, may precipitate when FEP feeds solutions are blended, undergo solubility adjustments, or are evaporated. The bounding wt % solids constraint includes any solids that may precipitate during the evaporation process.

A higher sodium concentration (6 M or equivalent specific gravity) for Envelope C feed provides the operating conditions for precipitation of transuranic elements and ^{90}Sr in the ultrafiltration preparation vessels, as detailed in Section 2.3. Envelope C will be diluted to approximately 5 M Na before ion exchange.

2.2.3.7 Fate of Mercury in the Evaporator

Mercury is generally categorized as elemental, inorganic, or organic. Based on experience, small mercury concentrations, and the caustic nature of the Hanford Tank Farm waste, the mercury delivered to the WTP is predicted to be predominantly HgO. Mercury is predicted to be volatilized in the LAW and HLW melters and sent to the LAW and HLW offgas systems (24590-WTP-RPT-PR-01-011, *Mercury Pathway and Treatment Assessment for the WTP*).

The gaseous mercury is converted to soluble Hg^{+2} gas ($HgCl_2$) or remains as elemental mercury gas (Hg^{+0}) in the offgas systems. The fraction of mercury converted to $HgCl_2$ can be determined by the molar

ratio of Hg:Cl in the melter offgas streams (24590-101-TSA-W000-0004-125-00004, *WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant*).

If the ratio of Hg:Cl ≤ 0.1, Hg = 100 % $HgCl_2$
= 0.1 to 0.5, Hg = mixture of $HgCl_2 + Hg^{+0}$
≥ 0.5, Hg = 100 % Hg^{+0}

For when the ratio results in a mixture of mercury species, the following relationship can be applied for partitioning the stream:

$$\% Hg^{+0} = \left[\frac{(ratio - 0.1)}{(0.5 - 0.1)}\right] * 100\%$$

2.2.3.7.1 Stream pH Impacts on Mercury Speciation

The recycle streams identified in Section 2.2.3.4 are neutralized to pH = 12 with 19 M NaOH in PWD before being delivered to FEP-VSL-00017A/B. An Environmental Simulation Program (ESP) model run predicts that all of the aqueous mercury will be converted to hydrated mercuric oxide $HgO{\bullet}H2O_{(s)}$ when the stream is neutralized (CCN 028630, *Mercury Speciation in Pretreatment*).

The expected reaction is (24590-WTP-RPT-PR-01-011):

$$Hg^{+2}{}_{(l)} + 2OH^{-}{}_{(l)} = HgO{\bullet}H2O_{(s)}$$

A study was performed that examined the fate of mercury in evaporator bench scale testing for solutions, excessively injected with $Hg(NO3)_2$, with pH = 13 (24590-101-TSA-W000-0004-125-00004). These studies concluded that at experimental conditions, an evaporator DF = 22 (compared to CCN 022422, *Estimates of Evaporator Decontamination Factors – Corrected Definition* which estimates DF = 1010) was more applicable.

However, by injecting the stream with mercury nitrate, the composition of the stream was made to contain a higher concentration of nitrate/nitrite species than what is predicted to be in the feeds to the WTP. Based on the *White Paper for Evaluation of Mercury Impacts on Pretreatment Evaporators* (24590-WTP-RPT-PT-02-011), mercury species become more soluble in higher pH solutions. In the presence of high nitrites and high pH, mercury will be reduced to Hg^0.

It was determined (CCN 156324, *Mercury and Mercury Compounds*) that pH does impact the speciation of mercury in the presence of other compounds, but the overall chemistry (e.g. organic types/concentration, mercury species, and chloride concentration) of the high pH stream is the driving force for determining the reactions and end products of mercury in the evaporator (Hg^0, HgO, $HgCl_2$, or DMHg). All other studies have concluded that the split fraction from the evaporator to the offgas would be negligible (*Treated LAW Feed Evaporation: Physical Properties and Solubility Determination*, SCT-M0SRLE60-00-184-01). Therefore, at this time the DF for mercury in the evaporator will remain as 1010.

2.2.3.7.2 Dimethyl Mercury in the Evaporators

The two constituents, mercury and organics (AFA), that are necessary for the formation of dimethyl mercury (DMHg) are present in the WTP evaporators. Formation of DMHg at the WTP is dependent on several conditions such as temperature, catalyst, time, quantity and speciation of mercury, and amount of methylating agent present (CCN 074276, *Risk Response Report for Formation of Hazardous Mercury Compounds (Dimethyl Mercury) in Evaporator Overheads*). Testing at the Savannah River Site (SRS) showed no DMHg formation at the maximum operating temperature for the FEP evaporator of 50 °C (CCN 163052, *Studies of Mercury in High-Level Waste Systems*). This testing was conducted to simulate the SRS tank waste, which contains ~forty times more mercury than that found in the Hanford Tank Farms waste. Because of these two findings, DMHg formation is not modeled for the FEP evaporator at this time. Sampling evaporator feeds for mercury species and organic compositions, and monitoring dimethyl mercury may be necessary as part of normal WTP plant commissioning and operations.

2.2.3.8 Evaporator and Condenser Decontamination Factors

The evaporation and condenser DFs are presented in Table 2.2-1 for radionuclides and Table 2.2-2 for chemical components. The DF is defined as "the mass flow rate in the feed to be evaporated or condensed, divided by the mass flow rate in the vapor discharged from the evaporator separator or condenser":

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

The DFs are documented in 24590-PTF-MEC-FEP-00004, *Waste Feed and Treated LAW Evaporator System DF Estimates*. The 242-A stream information to calculate the DFs is provided in *242-A Evaporator Safety Analysis Report* (242-A SAR) (Campbell 1999). The exceptions to this are the DFs for Cs-134, Cs-137, and Cs+, which are documented in 24590-WTP-RPT-PR-06-002, *Resolution of EFRT Issue P1 - Cesium Decontamination Factor in FEP and TLP Evaporators*. The iodine DFs were provided in *Iodine Decontamination Factors for WTP Evaporators* (CCN 023478). The 242-A de-entrainment section does not include bubble-cap trays; the de-entrainment mesh and thickness are different and the de-entrainment spray is configured differently. The condenser DF values include the contribution of the condensate vessel to the vent system as defined in 242-A SAR.

Assumption 2.2.1. Assumptions made in the reference calculation define some of the DF values for radionuclides and chemical components as having similar values to calculated values for which constituent information is available. Assumptions used to establish DF values are provided in the referenced calculation and summarized in Table 2.2-1 and Table 2.2-2. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data.

2.2.3.9 Organic Decontamination Factors in Evaporators

Organic constituent behavior in the evaporators has been defined by the use of DFs (Section 2.2.3.8). For emissions estimates used to support permitting, organic behavior is defined by the use of Henry's Law (see Section 7). The DFs used for antifoam were provided in *Ultrafiltration Process (UFP) Caustic Leaching Antifoam Performance* (SCT-M0SRLE60-00-99-00009). Organic constituents have been historically considered in terms of total organic carbon (TOC) in the non-emissions flowsheets to reflect

the form from which organic data was received from the Tank Farm Contractor. DF values have been previously based solely on oxalate to define the TOC values in previous flowsheet versions. These DF values for TOC (oxalate) are 1000 for the evaporator DF and 17.2 for the condenser DF; based on literature reviews, the behavior of oxalate in feeds of high sodium concentration will more closely follow that of calcium in the evaporators. The evaporator and condenser DFs for organics are presented in Table 2.2-3.

Assumption 2.2.2. Assumptions are made in defining the DF values for organic components as having similar values to calculated values for formate, and other test compounds as detailed in CCN 027646. Assumptions used to establish values are summarized in Table 2.2-3. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data.

2.2.3.10 Evaporator De-entrainment Section

The vapors and any entrainment generated in the evaporator bottoms of the evaporator separator must pass through a disengagement zone, three bubble-cap trays, and two de-entrainment pads before exiting the separator to the primary condenser (see Figure 2.2-1). The FEP system process condensate is filtered and delivered as a spray underneath the de-entrainment pad section. The spray is an aid to DF and de-entrainment performance. The flow rate for this spray defined by the detail design is 3 gpm (24590-QL-POA-MEVV-00001-08-01).

2.2.3.11 Evaporator and Condenser Operating Pressures

The evaporator is operated at a vacuum to reduce the boiling point of the solution. The two-stage vacuum eductor system is designed to control the separator vessel pressure between 1.0 and 1.3 psia. Vacuum evaporation lowers the boiling temperature of the liquor to approximately 122 °F, which reduces potential corrosion of the evaporator by chlorides (24590-PTF-3PS-MEVV-T0001).

The operating vacuum for the evaporator and each condenser affects the vapor-liquid equilibrium that is calculated for the constituents and volatile components. A vacuum correction is also made in the Henry's Law coefficients for organics that are used in the emissions run (discussed in Section 7).

2.2.3.12 Evaporator Vacuum Eductor Steam Usage

The evaporator separator vessel pressure is maintained by a two-stage vacuum eductor system. The primary vacuum eductor maintains vacuum on the evaporator separator and primary condenser, and discharges to the intercondenser. The secondary vacuum eductor maintains vacuum on the intercondenser and discharges to the aftercondenser.

- The high-pressure steam (HPS) supply conditions:
  - Minimum operating condition: 110 psig at 344 °F
  - Normal operating condition: 118 psig at 349 °F
  - Maximum operating condition: 135 psig at 358 °F
  - Design condition: 163 psig at 372 °F

The HPS flows to the vacuum eductors will be updated by the vendor as part of the design analysis to ensure performance of the vacuum eductors (24590-PTF-3PS-MEVV-T0001).

2.2.3.13 Condenser Offgas Rates

The non-condensable offgas leaving the evaporator separator vessel passes through three condensers before exiting to the PVP system. The primary condenser is significantly larger than the intercondenser and aftercondenser. The condenser offgas system and vacuum eductors are sized for a nominal non-condensable air flow from the separator of 42.7 lb/hr.

- Air is added upstream of the primary vacuum eductor to maintain the nominal 1.0 to 1.3 psia operating pressure. The control air is varied to obtain a relatively constant non-condensable air flow to the vacuum eductor. An initial value of 7.6 lb/hr is set in the flowsheet and will be updated as part of detail design evaluation.
- Soluble gases and volatile components are released from the feed stream as it enters the separator due to the vacuum applied.
- Air in-leakage into the evaporator system is minimized by the low number of flanges present. No value is assigned in the flowsheet.
- The shell side of the reboiler (to reduce the temperature differential across the reboiler tube) and the steam condensate collection tank are also vented to the upstream side of the secondary vacuum eductor. No value is assigned in the flowsheet.

2.2.3.14 Cooling Water to the Condensers

The process cooling water delivered to the condensers is supplied at approximately 45 psig and 75 °F, with a peak summer maximum of 83 °F. The cooling duty required of each condenser is determined from the enthalpy change of the process stream.

2.2.3.15 Condenser Outlet Temperatures

The condenser outlet temperature is set at 30 °C (86 °F) for use in the flowsheet. This setpoint definition provides a maximum cooling load for the evaporator condensers. The vent streams leaving each condenser are set at this temperature and saturated with water vapor for use in the flowsheet. The condenser outlet stream temperatures will be updated by the vendor as part of the design analysis for the evaporator performance specification (24590-PTF-3PS-MEVV-T0001).

2.2.3.16 Steam to the Reboiler

HPS is delivered to the reboiler at approximately 135 psig (CCN 135608) and 358 °F (at PT Facility boundary) and routed first through a pressure reducing valve and then through a de-superheater. This results in a pressure of approximately 0 psig at a temperature of 211 °F (24590-QL-POA-MEVV-00001-04-04). The resulting temperature is based on the reboiler fouled tube condition.

2.2.3.17 Concentrate Physical Properties

Testing was conducted on simulants of the waste feed, evaporator feed, and post-evaporation blends and reported in SCT-M0SRLE60-00-154-06. Testing was conducted on recycle without waste feed and on blends of recycle with the waste feed. The physical properties (density, vapor pressure, heat capacity, thermal conductivity, and viscosity) of the feed to the evaporator and the evaporator bottoms were measured as a function of temperature and sodium concentration.

2.2.3.17.1 Density

Correlations of specific gravity as a function of sodium molarity were developed for recycle and for combined sets of waste feeds, recycles, and waste/recycle blends (SCT-M0SRLE60-00-154-06). The temperature impact on density was found to be similar to the temperature impacts on water. The specific gravity at 25 °C was correlated for the recycle, slurry, and supernate streams. The specific gravity was found to increase with increasing sodium molarity. The increase in specific gravity per mole of sodium ranged from 0.046 to 0.06, depending on the stream and waste envelope. At 5 M Na this range corresponds to a specific gravity value between 1.23 and 1.30 at 25 °C. Additional information is found in the referenced report and in evaporation reports for specific waste feeds reported in the list of references.

2.2.3.17.2 Vapor Pressure and Boiling Point Elevation

A correlation between vapor pressure as a function of sodium concentration and temperature for the combined data sets of waste feeds, recycles, and blended streams was developed. This correlation was developed for all envelopes since the correlation fit was acceptable with all envelopes combined. The results indicated that the vapor pressure was primarily dependent on temperature with a secondary impact from bulk salt concentration as represented by sodium concentration. The correlation for vapor pressure was determined as follows (SCT-M0SRLE60-00-154-06):

$$VP(mmHg) = 19.3235 + 2.398815(M_{NA}) - 1.38003T - 0.02894(M_{NA})^2 + 0.059138T^2 - 0.12527(M_{NA})*T$$

The correlation was valid over a temperature range of 15 to 65 °C and 0 to 7.5 M Na.

This equation was used to solve for the evaporator operating temperature as function of sodium concentration. The operating temperature of the evaporator at low sodium concentrations and 1.3 psia was determined to be 42 °C, while the temperature at 5 M Na and 1.42 psia was determined to be 49 °C. The operating pressure of the evaporator can change the operating temperature significantly compared to the changes due to sodium concentration. Comparing the boiling point determined by the correlation to that of water at the same temperature and pressure gives a boiling point elevation of 4 to 5 °C at 5 M Na. Additional information is found in the referenced report and in evaporation reports for specific waste feeds reported in the list of references.

2.2.3.17.3 Heat Capacity

Heat capacity was found to be independent of temperature over the range tested and to decrease with sodium molarity. At 5 M Na the heat capacity of the various streams tested ranged from 0.77 to 0.81 calories/gram- °C. Additional information is found in the referenced report and in evaporation reports for specific waste feeds reported in the list of references.

2.2.3.17.4 Viscosity

Viscosity was found to decrease with temperature and increase with sodium concentration. At 25 °C and 5 M Na the viscosity of the various streams tested ranged from 2 to 3.5 mPascal-seconds. Additional information is found in the referenced report and in evaporation reports for specific waste feeds reported in the list of references.

2.2.3.17.5 Concentrate Solids

The formation of solids in the evaporator concentrate is dependent on many factors pertaining to how the WTP process is operated and the operating setpoint of the evaporator. Solids characterization was performed for the waste envelopes and recycles that were tested in the referenced report (SCT-M0SRLE60-00-154-06). The list of solids that may be present is not all-inclusive. Recycle of washed solids is also generated during drainage and cleaning of the ultrafilter and associated piping loop, which may add solids that are present with any waste feed. Insoluble solids will also be present in the recycled streams of the HLW SBS condensate and canister decontamination solutions. In addition, insoluble solids that are present with any waste feed that is routed through the FEP evaporator will be present. Additional information is found in the referenced report and in evaporation reports for specific waste feeds reported in the list of references.

From the referenced report (SCT-M0SRLE60-00-154-06) a brief summary is provided of the solids that were analyzed to be present in most of the concentrated recycle streams for each waste envelope.

- Envelope A concentrate:
  aluminum hydroxides (gibbsite and bayerite), sodium carbonate (Na2CO3.H2O), sodium fluoro-phosphate (Na7F[PO4]2.19H2O), and sodium oxalate (Na2C2O4). Lithium-aluminum-carbonate-hydroxide-hydrate ([Al2Li{OH}6]2CO3.H2O) was present in most samples that contained melter offgas condensate. The presence of corundum (Al2O3), quartz (SiO2) and reevesite (Ni6Fe2[CO3][OH].4H2O) may have been masked.
- Envelope B concentrate:
  sodium oxalate (Na2C2O4), sodium nitrate (NaNO3), corundum (Al2O3), and sodium carbonate (Na2CO3.H2O).
- Envelope C concentrate:
  sodium fluoro-phosphate (Na7F[PO4]2.19H2O), and sodium-strontium phosphate hydrate.

The addition of recycle to the waste feed impacts the permeate flux rate in ultrafiltration because of the increase in the insoluble solids. Comparisons of the ultrafilter flux curves with and without the recycle concentrate from SCT-M0SRLE60-00-154-06, pages 28 and 29, show that the primary impact on the filtration process is the increase in solids loading rather than the recycle streams being more difficult to filter than the waste feed solids.

The formation of sodium aluminosilicate (NAS) was also evaluated. The presence of NAS was not noted in any evaporator feed or concentrate sample except for one Envelope A sample in the previously referenced report. Similar trends were noted in comparison to Savannah River Site evaporator experience during testing: that high aluminum and/or high hydroxide concentration was found to suppress NAS formation. The experimental results from SCT-M0SRLE60-00-154-06 indicate that significant NAS formation in the waste feed evaporator is unlikely, but that other aluminate species (gibbsite and bayerite) will be present. In a test of the pilot-scale evaporator documented in SCT-M0SRLE60-00-54-00002, the formation of NAS solids was reported.

SIPP evaporator tests reported in SCT-M0SRLE60-00-208-00003 showed that the precipitation of oxalate occurred in all tests. The tests were performed by evaporating mixtures of different recycle streams only. Ultrafiltration Process System (UFP) recycle streams were generated while dewatering simulated AY-102/C-106 waste only or a blend of different recycles with simulated AY-102/C-106 and AP-101 wastes. Cesium Ion Exchange Process System (CXP) recycle streams were generated while processing a mix of different recycles with simulated AY-102/C-106 and AP-101 wastes. The additional recycle

streams included were synthetic HLW canister decontamination and PVP, LAW, and HLW SBS from pilot melter testing at the Vitreous State Laboratory of The Catholic University of America. The differences in mass of precipitated oxalate as a result of different recycles present in the evaporator feed could not be evaluated due to discrepancies in anion analysis. However, this indicates that there will be an increase in solids loading to the ultrafiltration process.

2.2.4 Ongoing Work and Potential Changes

None has been identified at this time.

2.2.5 References

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Table 2.2-1 Evaporation and Condenser Radionuclide DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
3H(s)+	NA	Follows H2O	NA	Follows H2O
3H+	NA	Follows H2O	NA	Follows H2O
14C(s)+4	1.01E+03	242-A FSAR 3E, ^{14}C	6.50E+02	242-A FSAR 3E, ^{14}C
14C+4	1.01E+03	242-A FSAR 3E, ^{14}C	6.50E+02	242-A FSAR 3E, ^{14}C
60Co(s)+3	1.01E+03	242-A FSAR 3E, ^{60}Co	6.50E+02	242-A FSAR 3E, ^{60}Co
60Co+3	1.01E+03	242-A FSAR 3E, ^{60}Co	6.50E+02	242-A FSAR 3E, ^{60}Co
63Ni(s)+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
63Ni+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
90Sr(s)+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
90Sr+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
99Tc(s)+7	1.01E+03	242-A FSAR 3E, ^{99}Tc	6.50E+02	242-A FSAR 3E, ^{99}Tc
99Tc+7	1.01E+03	242-A FSAR 3E, ^{99}Tc	6.50E+02	242-A FSAR 3E, ^{99}Tc
125Sb(s)+3	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb
125Sb+3	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb
126Sn(s)+2	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb
126Sn+2	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb
129I-	4.33E+02	CCN 023478	9.10E+02	242-A FSAR 3E, ^{129}I
129I(s)-	4.33E+02	CCN 023478	9.10E+02	242-A FSAR 3E, ^{129}I
134Cs(s)+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
134Cs+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
137Cs(s)+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
137Cs+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
151Sm(s)+3	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu
151Sm+3	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu
152Eu(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
152Eu+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
154Eu(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
154Eu+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
155Eu(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
155Eu+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
232Th(s)+4	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
232Th+4	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
233U(s)+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
233U+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
234U(s)+6	1.01E+03	242-A FSAR 3E, ^{234}U	6.50E+02	242-A FSAR 3E, ^{234}U

Table 2.2-1 Evaporation and Condenser Radionuclide DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
234U+6	1.01E+03	242-A FSAR 3E, ^{234}U	6.50E+02	242-A FSAR 3E, ^{234}U
235U(s)+6	1.01E+03	242-A FSAR 3E, ^{235}U	6.50E+02	242-A FSAR 3E, ^{235}U
235U+6	1.01E+03	242-A FSAR 3E, ^{235}U	6.50E+02	242-A FSAR 3E, ^{235}U
236U(s)+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
236U+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
237Np(s)+4	1.01E+03	242-A FSAR 3E, ^{237}Np	6.50E+02	242-A FSAR 3E, ^{237}Np
237Np+4	1.01E+03	242-A FSAR 3E, ^{237}Np	6.50E+02	242-A FSAR 3E, ^{237}Np
238Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu
238Pu+4	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu
238U(s)+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
238U+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
239Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
239Pu+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
240Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
240Pu+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
241Am(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
241Am+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
241Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
241Pu+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
243Cm(s)+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm
243Cm+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm
244Cm(s)+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm
244Cm+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm

(S) = solids

Source: 24590-PTF-MEC-FEP-00004.

Table 2.2-2 Evaporation and Condenser Chemical Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
Ag(s)+	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu
Ag+	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu
Al(s)+3	1.52E+03	242-A FSAR 3E, AlO_2^{-1}	6.50E+02	242-A FSAR 3E, AlO_2^{-1}
Al+3	1.52E+03	242-A FSAR 3E, AlO_2^{-1}	6.50E+02	242-A FSAR 3E, AlO_2^{-1}
As(s)+3	1.01E+03	242-A FSAR 3E, ^{79}Se	6.50E+02	242-A FSAR 3E, ^{79}Se
As+3	1.01E+03	242-A FSAR 3E, ^{79}Se	6.50E+02	242-A FSAR 3E, ^{79}Se
B(s)+3	1.01E+03	242-A FSAR 3E, B	5.65E+02	242-A FSAR 3E, B
B+3	1.01E+03	242-A FSAR 3E, B	5.65E+02	242-A FSAR 3E, B
Ba(s)+2	1.01E+03	242-A FSAR 3E, Ba	4.96E+02	242-A FSAR 3E, Ba
Ba+2	1.01E+03	242-A FSAR 3E, Ba	4.96E+02	242-A FSAR 3E, Ba
Bi(s)+3	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
Bi+3	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
C2O4(s)-2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
C2O4-2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Ca(s)+2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Ca+2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
CCl4	1.00E+00	no new data	1.00E+00	no new data
Cd(s)+2	2.21E+04	SRTC Lab Data for Cd	6.50E+02	242-A FSAR 3E, Cd
Cd+2	2.21E+04	SRTC Lab Data for Cd	6.50E+02	242-A FSAR 3E, Cd
Ce(s)+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
Ce+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
Cl-	5.26E+02	242-A FSAR 3E, Cl^-	7.70E+03	242-A FSAR 3E, Cl^-
Cl(s)-	5.26E+02	242-A FSAR 3E, Cl^-	7.70E+03	242-A FSAR 3E, Cl^-
CO	1.00E+00	no new data	1.00E+00	no new data
CO_2	1.00E+00	no new data	1.00E+00	no new data
CO3(s)-2	1.01E+03	242-A FSAR 3E, CO_3^{-2}	6.50E+02	242-A FSAR 3E, CO_3^{-2}
CO3-2	1.01E+03	242-A FSAR 3E, CO_3^{-2}	6.50E+02	242-A FSAR 3E, CO_3^{-2}
Cr(s)+3	3.54E+04	242-A FSAR 3E, Cr	5.32E+03	242-A FSAR 3E, Cr
Cr+3	3.54E+04	242-A FSAR 3E, Cr	5.32E+03	242-A FSAR 3E, Cr
Cs(s)+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
Cs+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
Cu(s)+2	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu
Cu+2	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu

Table 2.2-2 Evaporation and Condenser Chemical Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
F-	2.43E+04	242-A FSAR 3E, F^-	1.89E+03	242-A FSAR 3E, F^-
F(s)-	2.43E+04	242-A FSAR 3E, F^-	1.89E+03	242-A FSAR 3E, F^-
Fe(s)+3	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
Fe+3	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
H+	1.00E+01	no new data	1.00E+02	no new data
H_20	N/A	Defined by concentration setpoint	N/A	Defined by concentration setpoint
HCl	1.00E+00	no new data	1.00E+00	no new data
HF	1.00E+00	no new data	1.00E+00	no new data
Hg(s)+2	1.01E+03	242-A FSAR 3E, Hg	6.49E+02	242-A FSAR 3E, Hg
Hg+2	1.01E+03	242-A FSAR 3E, Hg	6.49E+02	242-A FSAR 3E, Hg
HNO3	N/A	no new data	N/A	no new data
K(s)+	3.54E+03	242-A FSAR 3E, K	6.37E+02	242-A FSAR 3E, K
K+	3.54E+03	242-A FSAR 3E, K	6.37E+02	242-A FSAR 3E, K
La(s)+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
La+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
Li(s)+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
Li+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
Mg(s)+2	1.01E+03	242-A FSAR 3E, Mg	2.86E+01	242-A FSAR 3E, Mg
Mg+2	1.01E+03	242-A FSAR 3E, Mg	2.86E+01	242-A FSAR 3E, Mg
Mn(s)+3	1.01E+03	242-A FSAR 3E, Mn	6.09E+02	242-A FSAR 3E, Mn
Mn+3	1.01E+03	242-A FSAR 3E, Mn	6.09E+02	242-A FSAR 3E, Mn
MnO4-	1.01E+03	242-A FSAR 3E, Mn	6.09E+02	242-A FSAR 3E, Mn
N_2	1.00E+00	no new data	1.00E+00	no new data
Na(s)+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
Na+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
NH3	1.11E+00	242-A FSAR 3E, NH_4^+	1.24E+01	242-A FSAR 3E, NH_4^+
NH4+	1.11E+00	242-A FSAR 3E, NH_4^+	1.24E+01	242-A FSAR 3E, NH_4^+
Ni(s)+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
Ni+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
NO	1.00E+00	no new data	1.00E+00	no new data
NO2	1.00E+00	no new data	1.00E+00	no new data
NO2-	2.43E+03	242-A FSAR 3E, NO_2^-	1.04E+04	242-A FSAR 3E, NO_2^-
NO2(s)-	2.43E+03	242-A FSAR 3E, NO_2^-	1.04E+04	242-A FSAR 3E, NO_2^-
NO3-	5.77E+02	242-A FSAR 3E, NO_3^-	1.04E+04	242-A FSAR 3E, NO_3^-

Table 2.2-2 Evaporation and Condenser Chemical Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
NO3(s)-	5.77E+02	242-A FSAR 3E, NO_3^-	1.04E+04	242-A FSAR 3E, NO_3^-
O(s)--	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
O_2	1.00E+00	no new data	1.00E+00	no new data
OH-	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
OH(b)-	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
OH(s)-	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
P(s)+5	1.01E+03	242-A FSAR 3E, Si	2.30E+02	242-A FSAR 3E, Si
Pb(s)+2	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
Pb+2	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
Pd(s)+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
Pd+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
PO4(s)-3	1.01E+03	242-A FSAR 3E, PO_4^{-3}	6.50E+02	242-A FSAR 3E, PO_4^{-3}
PO4-3	1.01E+03	242-A FSAR 3E, PO_4^{-3}	6.50E+02	242-A FSAR 3E, PO_4^{-3}
S(s)+6	1.01E+03	242-A FSAR 3E, ^{79}Se	6.50E+02	242-A FSAR 3E, ^{79}Se
Si(s)+4	1.01E+03	242-A FSAR 3E, Si	2.30E+02	242-A FSAR 3E, Si
SiO4-4	1.01E+03	242-A FSAR 3E, Si	2.30E+02	242-A FSAR 3E, Si
SO4(s)-2	1.42E+03	242-A FSAR 3E, SO_4^{-2}	4.21E+03	242-A FSAR 3E, SO_4^{-2}
SO4-2	1.42E+03	242-A FSAR 3E, SO_4^{-2}	4.21E+03	242-A FSAR 3E, SO_4^{-2}
Sr(s)+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
Sr+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
Ti(s)+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
Ti+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
TOC	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Zn(s)+2	1.01E+03	242-A FSAR 3E, Zn	6.17E+02	242-A FSAR 3E, Zn
Zn+2	1.01E+03	242-A FSAR 3E, Zn	6.17E+02	242-A FSAR 3E, Zn
Zr(s)+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
Zr+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe

Source: 24590-PTF-MEC-FEP-00004.

Table 2.2-3 Evaporation and Condenser Organic Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Chemical Formula	Molecular Weight	Separator DF	Separator Assumption	Condenser DF	Condenser Assumption
Oxalate	$C2O4^{-2}$	88.02	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Formate	$CHO2^{-1}$	45.02	10.7	CCN 027646	652,000	242-A FSAR 3E, TOC
Acetate	$C2H3O2^{-1}$	59.05	10.7	Same as formate	652,000	242-A FSAR 3E, TOC
Glycolate	$C2H3O3^{-1}$	75.05	10.7	Same as formate	652,000	242-A FSAR 3E, TOC
IDA	$C4H5NO4^{-2}$	131.10	1.00E+03	Similar to TOC	1.72E+01	242-A FSAR 3E, Ca
Citrate	$C6H5O7^{-3}$	189.11	10.7	Same as formate	652,000	242-A FSAR 3E, TOC
HEDTA	$C10H15N2O7^{-3}$	275.27	1.00E+03	Similar to TOC	1.72E+01	242-A FSAR 3E, Ca
EDTA	$C10H12N2O8^{-4}$	288.24	1.00E+03	Similar to TOC	1.72E+01	242-A FSAR 3E, Ca
Toluene	C7H8	92.13	1.01	CCN 027646	1.01	CCN 027646
Phenol	C6H6O	94.11	1.01	Same as benzene	1.01	Same as benzene
Tributyl phosphate	C12H27O4P	266.30	1.00E+03	Similar to TOC	1.72E+01	242-A FSAR 3E, Ca
Perchloro-ethylene	CCN 027646	165.84	1.1929	Same as 1,2,3-Trichloro-propane from CCN 027646	1.07	Same as 1,2,3-Trichloro-propane from CCN 027646
Polychlorinated biphenyls (PCBs)	C12H4Cl6	326.43	2332	Same as pentachloro phenol, from CCN 027646	1.00	Same as pentachloro phenol, from CCN 027646
Ace-naphthylene	C12H8	152.18	1.02	Same as MIBK, from CCN 027646	1.02	Same as MIBK, from CCN 027646
Carbon Tetrachloride	CCl4	153.83	1.15	Based on 1,2,3-Trichloro-propane from CCN 027646	1.07	Based on 1,2,3-Trichloro-propane from CCN 027646

Table 2.2-3 Evaporation and Condenser Organic Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Chemical Formula	Molecular Weight	Separator DF	Separator Assumption	Condenser DF	Condenser Assumption
1,1-Dimethyl-hydrazine	C2H8N2	60.10	1.01	similar to toluene from CCN 027646	1.01	similar to toluene from CCN 027646
Tridecane	C13H28	184.35	1.9999	assumed similar to sucrose. DFs from MRQ 04-0063	2.0	assumed similar to sucrose. DFs from MRQ 04-0063
Benzene	C6H6	78.11	1.00	from CCN 027646	1.01	from CCN 027646
Acetonitrile	C2H3N	41.05	1.03	similar to naphthalene from CCN 027646	1.21	similar to naphthalene from CCN 027646
Trichloro-ethylene	C2HCl3	262.79	1.19	Based on 1,2,3-Trichloropropane from CCN 027646	1.07	Based on 1,2,3-Trichloropropane from CCN 027646
Naphthalene	C10H8	128.16	1.03	from CCN 027646	1.21	from CCN 027646
Antifoam-PPG/dPPG	H2O*(C3H6O)60	3,503.00	1.0E+08	SCT-M0SRLE60-00-99-00009	N/A	N/A
Antifoam-PDMS/dPDMS	(CH3)3 SiO[Si(CH3)2O]47 0(Si(CH3)3)	35,015.00	1.0E+08	SCT-M0SRLE60-00-99-00009	N/A	N/A
Acetophenone	C8H8O	120.14	1.03	similar to naphthalene from CCN 027646	1.21	similar to naphthalene from CCN 027646

Figure 2.2-1 Evaporator Separator Sketch for FEP and Treated LAW Evaporation Process Systems (TLP)

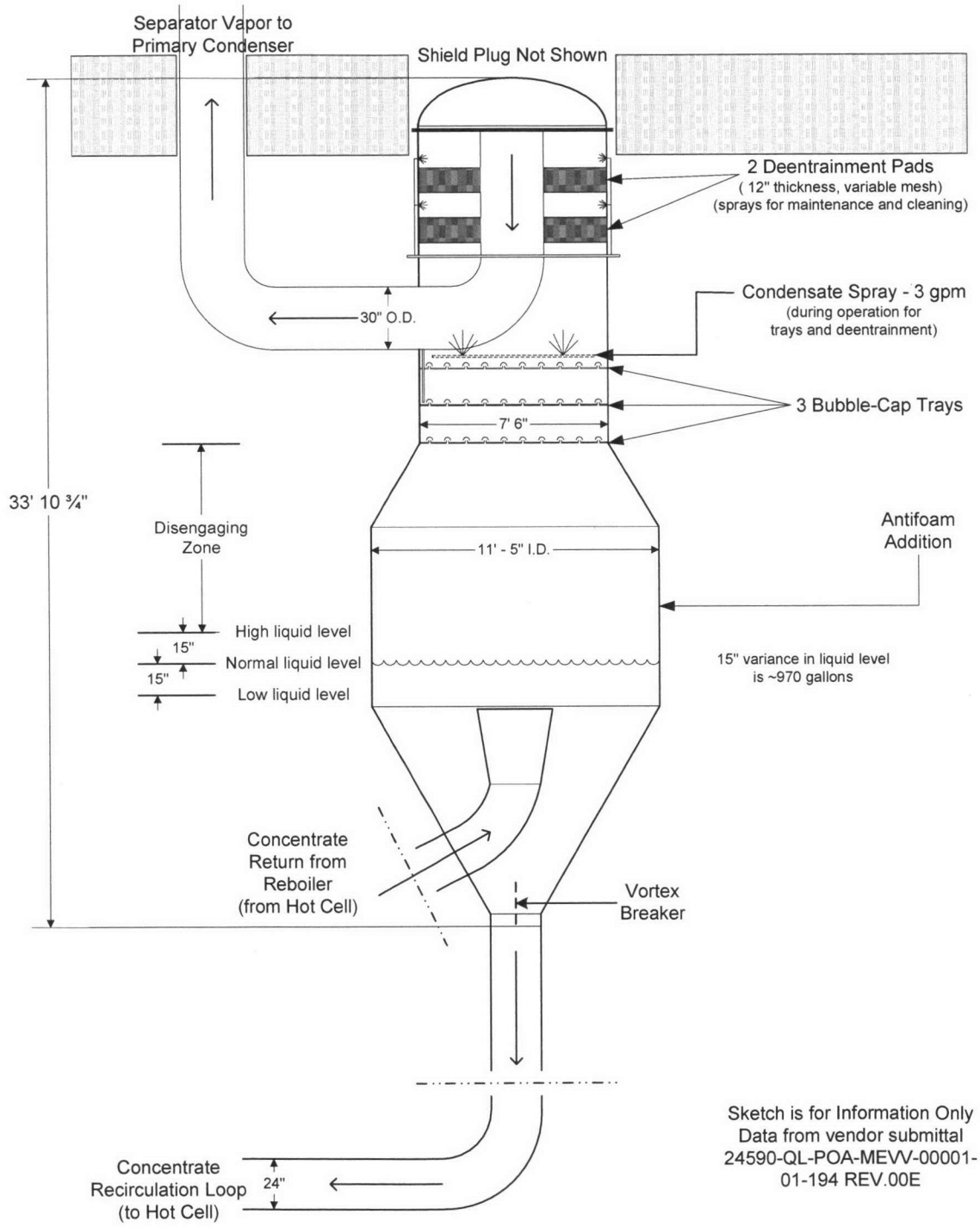
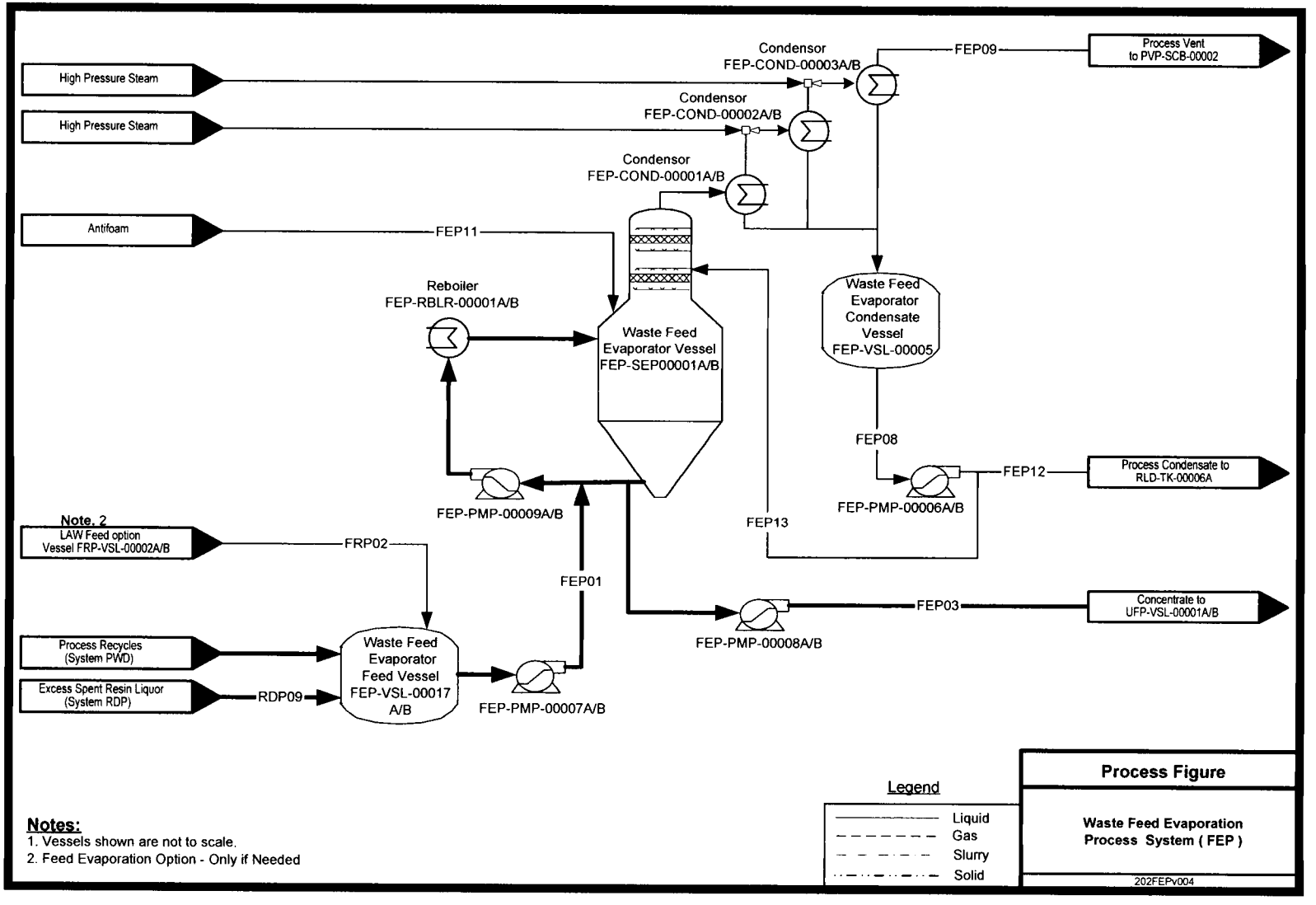


Figure 2.2-2 Feed Evaporator Process System



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2.3 System UFP: Ultrafiltration Process

2.3.1 Function and Requirements

The primary functions of the ultrafiltration process system (UFP) are:

- Precipitate dissolved complexed radionuclides, such as transuranic elements (TRU) and ^{90}Sr, in certain feed batches
- Separate undissolved solids from liquids by concentrating the solids using ultrafilters
- Dissolve certain solid species that limit waste loading in immobilized high-level waste (IHLW) (e.g., aluminum, phosphorous, and chromium)
- Separate soluble species from undissolved solids by washing
- Prevent undissolved solids from forming in the ultrafilter permeate

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136) specifies that removed solids be treated in accordance with Operations Specification, Section C.8, Specification 12, *Procedure to Determine the Waste Treatment Approach*, C.7 (a)(4) and (d)(1)(vii). The precipitation requirements are identified in Section C.7 (d)(1)(ii). This system provides the capability to wash and leach filtered solids and precipitate complexed Sr/TRU radionuclides.

Requirements are detailed in the UFP system description (24590-PTF-3YD-UFP-00001, *System Description for Ultrafiltration Process System (UFP)*).

2.3.2 Process Description

The UFP processes are detailed in 24590-PTF-3YD-UFP-00001 and are shown on process flow diagrams 24590-PTF-M5-V17T-00032001, -00032002, -00009, and -00011.

The UFP system precipitates Sr/TRU from Envelope C waste, concentrates solids by separating solids from liquids by way of ultrafilters, dissolves some non-radioactive species by caustic and oxidative leaching, treats permeate streams to prevent post-filtration precipitation, and samples permeate before transfer to the CXP system.

All wastes do not require the same processing. Some waste requires caustic leaching, while others require oxidative leaching. These determinations are made based on the results of Specification 12 testing and other process simulation testing that was performed on the waste samples taken while the waste remains in Hanford Tank Farms. If a determination is made that either chromium or aluminum will limit the waste loading in HLW, then a decision will be made as to whether or not to leach.

2.3.2.1 Major Process Changes

In March 2006 the External Flowsheet Review Team (EFRT), consisting of experts from industry, national laboratories, and universities, completed a *Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput* (CCN 132846).

A concern of the EFRT is Major Issue 3 (M3) - Inadequate Mixing Systems. The design of mixing systems for the ultrafiltration feed preparation vessels (UFPV) has been modified to enhance mixing, i.e., additional PJMs have been added to the vessels. In addition provisions for managing settled solids has

been provided for several UFP vessels. Connections for installing a temporary heel removal pump and access ports have been added to the vessels.

2.3.2.2 Envelope C Waste Processing (Presently Not in WTP Baseline Model Runs)

Envelope C waste contains organic complexing agents that have complexed with some radioactive metals, resulting in the metals being dissolved in the liquid phase rather than remaining in the solid phase. The Envelope C treatment processing involves steps to break up the complexing agents precipitating TRU species. In addition, the remaining soluble radioactive strontium isotopes are diluted by the addition of nonradioactive strontium nitrate ($Sr[NO_3]_2$) diluting the radioactive species. The waste is received from the waste feed evaporation process system (FEP) at 50 °C, and is not cooled. The sodium molarity is adjusted through concentration in the FEP system or dilution in UFP feed preparation vessel, as required, to 6 M. Then 19 M NaOH is added to reach a calculated concentration of 1 M free OH^-. Strontium nitrate is added to achieve a calculated concentration of 0.075 M Sr^{2+} and sodium permanganate ($NaMnO_4$) is added to achieve a calculated concentration of 0.05 M MnO_4^-. The calculated values assume that the waste has no hydroxide, strontium, or permanganate. After the reagent additions, the solution is allowed to react for 4 hr at 50 °C and then is cooled (4 hr) to 25 °C (24590-PTF-MEC-UFP-00001, *Spiral Plate Heat Exchanger UFP-HX-00041A/B Sizing for Vessels UFP-VSL-00001A/B*). The precipitated solids are then sent to the filter feed vessels for filtering and washing to remove sodium after the solids are concentrated to 15 wt %. The washed solids are discharged to the HLW lag storage and feed blending process system (HLP) and the wash solutions are sent to the plant wash and disposal system (PWD). Envelope C waste is never leached.

It is noted that the current feed vector (*River Protection Project System Plan*, ORP-11242, Rev 6) received from DOE-ORP and the Tank Farm Contractor does not contain LAW batches that are identified as Envelope C waste. However, the WTP is required to maintain the capability to treat Envelope C waste.

2.3.2.3 Back-End Caustic Leaching in Ultrafiltration Feed Vessels (Baseline)

A determination is made whether the waste requires caustic and/or oxidative leaching. A UFPV (UFP-VSL-00001A/B) is filled to its operating level with LAW from FRP-VSL-00002A/B/C/D and HLW from HLP-VSL-00022. The wastes are blended to achieve a target weight percent solids concentration. An initial waste volume is transferred to a UFV (UFP-VSL-00002A/B). The waste in the UFV is pumped through five bundles of cross-flow filters. The water and other soluble components of the waste permeate pass through the filter media and discharge to one of the permeate receipt vessels (UFP-VSL-00062A/B/C) via pulse pots. Caustic can be added to the permeate receipt vessels to prevent gibbsite precipitation. Dilution water can also be added to the permeate receipt vessels to prevent the precipitation of salts. The solids are re-circulated into the feed vessels, where additional waste is received from the feed preparation vessels to replace the permeate and to maintain a relatively constant volume in the UFV. The waste is concentrated to 17 to 20 wt %.

If caustic leaching is required, sufficient 19 M caustic is added to leach the dissolvable aluminum and to prevent precipitation when the solution is cooled to the filtration temperature. Sodium oxalate, sodium phosphate, and aluminum equilibrium equations can be applied in process models to predict the precipitation of oxalate, phosphate and gibbsite in vessels (CCN 150372, CCN 160514, CCN 160518, and 24590-WTP-M4C-V37T-00009, *Phosphate Solubility Algorithm*). Steam is mixed with the waste to heat it to a leaching temperature between 80 °C and 90 °C. The slurry batch is digested at its leaching temperature for 4 to 16 hr in the UFV (24590-PTF-3YD-UFP-00001). The leached waste is cooled to a filtration temperature between 25 °C and 45 °C and re-concentrated to a target of 20 wt % solids. The solids are washed using a saw tooth logic. That is, a 1000 gal addition of wash water is made to the

batch. When 1000 gal of permeate have been removed from the batch by ultrafiltration, an additional 1000 gal addition of wash water is made. The alternating 1000 gal additions of wash water and removal of permeate continue until the desired endpoint is achieved. If oxidative leaching is not required, the treated solids are discharged.

2.3.2.3.1 Double-Batching Back-End Leaching Alternative

An alternative back-end leaching strategy has been developed in response to minimum pump NPSH (Net Positive Suction Head) concerns. This alternative strategy supports solids concentration while maintaining higher liquid levels in the UFVs. This strategy is referred to as double-batching as the initial UFV volume is nearly double the initial volume of a baseline back-end leaching UFV batch. A detailed list of double-batching back-end leaching process steps can be found in section 2.3.4.3.

2.3.2.4 Up-front Caustic Alternative, Leaching in the Ultrafiltration Feed Preparation Vessels

A determination is made whether the waste requires caustic and/or oxidative leaching. If caustic leaching is required, then a UFPV is filled with the maximum quantity of leachable aluminum or until the vessel reaches its setpoint, whichever comes first. If the maximum quantity of aluminum is achieved before the vessel reaches its setpoint, additional LAW or recycles (i.e., FEP evaporator concentrate produced from the evaporation of recycled PWD solutions or the recycles streams that are collected in PWD) are added until the vessel reaches its operating limit. Sample results from FRP-VSL-00002A/B/C/D and HLP-VSL-00022 can be used to determine the quantity of leachable aluminum to transfer.

Sufficient 19 M caustic is added to the UFPV to leach the dissolvable aluminum and to prevent precipitation when the solution is cooled to the filtration temperature or lower. Sodium oxalate, sodium phosphate, and aluminum equilibrium equations can be applied in process models to predict the precipitation of oxalate, phosphate and gibbsite in vessels (CCN 150372, CCN 160514, CCN 160518, and 24590-WTP-M4C-V37T-00009, *Phosphate Solubility Algorithm*). Steam is mixed with the waste to heat it to a leaching temperature between 80 °C and 90 °C. The heat up time can be as long as 9 hr. The slurry batch is digested at its leaching temperature for 4 to 16 hr in the UFPV (24590-PTF-3YD-UFP-00001, *System Description for the Ultrafiltration Process System*).

The leached waste is cooled to a filtration temperature of 25 °C to 45 °C by a combination of vessel cooling jackets and heat exchangers. An initial volume is transferred to a UFV (UFP-VSL-00002A/B). The waste in the UFV is pumped through five bundles of sintered metal cross-flow filters. The water and other soluble components of the waste pass through the filter media and discharge to the permeate receipt vessels (UFP-VSL-00062A/B/C) via pulse pots. Caustic can be added to the permeate receipt vessels to prevent gibbsite precipitation. Dilution water can also be added to the permeate receipt vessels to prevent the precipitation of salts. The solids are re-circulated into the feed vessels, where additional waste is received from the feed preparation vessels to replace the permeate and to maintain a relatively constant volume in the UFV. While the solids are being concentrated, the filters can be periodically backpulsed. Backpulsing pushes permeate back through the filters into the concentrated slurry, dislodging solids that have built up on the filter surface or are lodged within the filter media, thus enhancing the overall permeate flux. The solids are concentrated to 17 to 20 wt %. The solids are washed using a saw tooth logic. That is, a 1000 gal addition of wash water is added to the batch. When 1000 gal of permeate have been removed from the batch by ultrafiltration, an additional 1000 gal addition of wash water is added. The alternating 1000 gal additions of wash water and removal of permeate continue until the desired endpoint is achieved. Wash filtrate is transferred to the permeate receipt vessels or to PWD-VSL-00015/16. If oxidative leaching is not required, the treated solids are discharged.

If required, sequential oxidative leaching is performed on high Cr containing wastes. The waste is washed with process condensate, in a saw tooth fashion, until its hydroxide concentration is below 0.25 M. An addition of sufficient 1 M sodium permanganate is made to the waste to provide an approximately 1.1 to 1 M ratio of permanganate to Cr. After adding sodium permanganate, the vessel contents are mixed for 6 hr at a temperature between 25 °C and 45 °C, so that dissolution can take place. The oxidation of a mole of Cr approximately consumes a mole of hydroxide (*Process Development for Permanganate Addition during Oxidative Leaching of Hanford Tanks Sludge Simulants*, CCN 159549). Two molar sodium hydroxide can be added to the UFVs to maintain free hydroxide concentration during oxidative leaching. The slurry is then reconcentrated by way of filtration to the original slurry volume and washed with process condensate, with the wash water being sent back to PWD-VSL-00015/16. The treated solids are then discharged to lag storage (HLP system). The filter train is "power flushed" during the solids discharge and, if necessary, chemically cleaned. A power flush uses a pneumatically driven burst of dilute caustic to rapidly displace an ultrafiltration loop's volume. The loop's contents can be displaced to the PWD system or to a UFV; see *UFP Process Drainage and Flush Line Sizing and Pneumatically Assisted Flush Requirements* (24590-PTF-M6C-UFP-00011).

2.3.2.5 Filter Cleaning and Power Flushes

The filters can be cleaned with either nitric acid or sodium hydroxide; in specific cases. If nitric acid is used, a dilute caustic solution is made from 2 M NaOH and process condensate, and is used to displace the liquid in the filter that is more basic, reducing the exothermic reaction when the nitric acid is pumped into the filter. After the waste is displaced, 2 M nitric acid may be re-circulated through the filters. The volume of nitric acid for cleaning is 17,076 gal (the volume necessary to prime the ultrafiltration recirculation pumps and fill the ultrafiltration loop). The cleaning solutions are discharged directly from UFP-VSL-00002A/B to the PWD system via pumps UFP-PMP-00044A/B.

2.3.2.6 Permeate Receipt Vessels

The permeate and wash solutions are sent to permeate receipt vessels UFP-VSL-00062A/B/C or to PWD-VSL-00015/16. Permeate from solids concentration is sent to UFP-VSL-00062A/B/C. The three permeate receipt vessels discharge to CXP-VSL-00004. Collectively, these four vessels are referred to as a "super-tank" (24590-WTP-RPT-PET-09-004, *Recommendation of Alternative to Mitigate Solids Precipitation in Ion Exchange Feed*). CXP-VSL-00004, which is equipped with one pulse jet mixer (PJM), has replaced CXP-VSL-00001 as the CXP feed vessel. CXP-VSL-00004 discharges through a heat exchanger (CXP-HX-00003) capable of increasing the fluid temperature to 50 °C. The majority of the discharge from CXP-VSL-00004 (approximately 110 of 140 gpm) is re-circulated back to the permeate receipt vessels. This recirculation improves mixing in the permeate receipt vessels and maintains the vessels' temperature near 50 °C. Steam ejectors can provide additional heating in the permeate receipt vessels if required. The remaining heated solution from the CXP-HX-00003 is fed to the CXP ion exchange columns by way of a guard ultrafilter (24590-PTF-RPT-M-10-001, *CXP Solids Mitigation Equipment Option - UFP/CXP Preliminary Heat and Mass Balance*).

Only a portion of the ultrafiltration wash water is sent to the permeate receipt vessels. Dilute ultrafiltration wash water is transferred to PWD-VSL-00015/16. The division of wash water between PWD-VSL-00015/16 and permeate receipt vessels is determined based on the chemistry of the super-tank. The permeate vessels have PJMs and sampling capabilities to analyze for solids. Process condensate and 19 M NaOH can be added to the permeate vessels to adjust the sodium molarity to between 0.5 and 8 to prevent precipitation of aluminum, oxalate or phosphorous compounds.

2.3.3 CXP Equipment Option/M3 Modifications

Another concern of the EFRT is the potential for solids to precipitate in feed to the cesium ion exchange process (CXP). The UFP filtrate is the feed for CXP. The CXP ion exchange (IX) columns are designed to receive solids-free feed. Precipitated solids were noted in UFP filtrate streams during pretreatment engineering platform (PEP) testing (24590-QL-HC9-WA49-00001-03-00040, *Report- Pretreatment Engineering Platform Phase 1 Final Test Report*). Subsequent chemical simulations of filtrate processing confirmed the potential for the precipitation of solids (24590-WTP-RPT-PET-10-001, *EFRT Issue M6 ESP Simulations to Mitigate Solids Precipitation in Ion Exchange Feed*). As a result of these findings alternatives were proposed for preventing and mitigating solids in CXP feed (24590-WTP-RPT-PET-09-004). The "Equipment Option" alternative, as described in 24590-WTP-RPT-PET-09-004, was selected by DOE-WTP for implementation to resolve this issue.

Permeate from the ultrafiltration trains can now be nearly simultaneously transferred to all three permeate receipt vessels UFP-VSL-00062A/B/C. In practice permeate flow is divided between the three vessels by rapidly rotating the inlet valve to each vessel.

Piping for heated permeate is insulated. The size of CXP feed pumps CXP-PMP-00001A/B has been increased to 140 gpm each, to support the re-circulation of solution to the permeate receipt vessels while still providing feed to the IX columns at up to 30 gpm.

Ultrafiltration wash solution can be transferred from the ultrafiltration pulse-pots directly to vessels PWD-VSL-00015/16, freeing UFP-VSL-00062C for use as part of the super-tank.

A dead-end guard filter has been provided upstream of the IX columns. The proposed filter has stainless steel 0.5 μm sintered elements and can be back-flushed into a dedicated back-flush receiver vessel (CXP-VSL-00028) (24590-PTF-MLC-CXP-00001, *Sizing Calculation for the CXP Filter (CXP-FILT-00001)*). Back-flush and rinse solutions are ultimately discharged to PWD-VSL-00016.

A UFP heat exchanger (UFP-HX-00003) has been added to heat process condensate used for solids washing. This heat exchanger will support washing at temperatures as high as 45 °C.

Two 8-inch observation nozzles have been added to vessels UFP-VSL-00001A/B and UFP-VSL-00002A/B. The nozzles allow observation of the pump suction and the tangent line near the bottom of each vessel (24590-PTF-M6N-M80T-00101, *Addition of Access Ports to Selective Vessels in PT Facility*).

The suction lines for UFP-VSL-00001A/B have been lowered to 3 inches above the vessels' bottom. The number of PJMs installed in each UFP-VSL-00001A/B vessel has been increased from 8 to 12 (24590-PTF-M6C-UFP-00004, *Vessel Sizing Calculation for Ultrafiltration Feed Preparation Vessels UFP-VSL-00001A/B*). As a result, the batch size for UFP-VSL-00001A/B has been reduced to 45,000 gal.

Provide the capability to transfer UFP-VSL-00001A/B to UFP-VSL-00002A/B using a temporarily installed positive displacement pump (HLP-PMP-00022). The positive displacement pump is capable of pumping UFP-VSL-00001A/B to a lower liquid level than can be achieved with normally installed pumps UFP-PMP-00041A/B. The temporary pump will be used manage solids heels within the vessels.

2.3.4 Model Parameters

The UFP system has significant operational flexibility. To ensure consistency and comparability between model runs, the following configurations have been established for G2 UFP model runs.

2.3.4.1 General G2 Model Parameters

The following are assumptions and parameters are applied to the all caustic leaching alternatives.

1 Adjustments typically made to Tank Farm-provided feed vectors are:

a $Al^{+3}_{(l)}$ in the liquid phase is converted to $Al(OH)_4^-$, aluminate.

b Four moles of "bound hydroxide" from the liquid phase are subtracted from the feed vector for every mole of $Al(OH)_4$ formed. When insufficient liquid bound hydroxide is present, then other anions are subtracted from the liquid phase. The anions are selected to minimize the impact on pretreatment chemistry. Typically $NO_2^-{}_{(l)}$, $NO_3^-{}_{(l)}$ and TIC $(CO_3^{-2})_{(l)}$ in the liquid phase are subtracted to make up for the missing bound hydroxide. This is done to prevent the charge imbalance from increasing.

c When Tank Farm feed vector leach factors are used to determine the extent of aluminum leached, $Al^{+3}_{(s)}$ in the solid phase is multiplied by the Al^{+3} leach factor that accompanies the feed vector. The product is assigned the species $Al(OH)_3$, gibbsite. This species represents the leachable aluminum species in the waste that may be both gibbsite and the portion of boehmite that is leached. Three moles of bound hydroxide(s) from the solid phase are subtracted from the feed vector for every mole of $Al(OH)_3$ assigned above.

d When boehmite dissolution rate kinetics are applied data from past feed assessments (e.g., 24590-WTP-RPT-PE-07-001, *WTP Waste Feed Analysis and Definition - EFRT M4 Final Report*) are used to allocate the leachable fraction of the $Al^{+3}_{(s)}$ between gibbsite and boehmite.

e The remaining $Al^{+3}_{(s)}$, [(1-Al^{+3} leach factor) × original $Al^{+3}_{(s)}$ value] is considered to be non-leachable aluminum and is typically tracked as $Al^{+3}_{(s)}$ in the G2 flowsheet.

f The caustic leach factors provided with a feed vector represent the leaching that will be achieved during the prescribed 4 to 16 hr leaching period in WTP.

g When boehmite dissolution rate kinetics is applied the extent of boehmite leaching is determined by operating conditions and the leach duration.

h The individual feed batches have significant charge imbalance; this indicates that there is considerable error present in the chemical composition for the individual feed vectors. It is assumed that these composition inaccuracies do not result in errors when applying equilibrium solubility algorithms for aluminum, phosphate, and oxalate during processing of the batches.

i Typically, no attempt is made to charge balance the TOC-provided feed vectors.

j Although the liquid portion of several batches may exceed Envelope A specification limits, all batches are processed as if they are Envelope A (i.e., Envelope C precipitation was not performed).

k Each batch in the adjusted feed vector is evaluated to determine if caustic and/or oxidative leaching increases HLW glass waste loading. If caustic and/or oxidative leaching reduces the volume of glass produced from a batch by 10 % or more per Section 15 of *WTP Waste Feed Analysis and Definition - EFRT M4 Final Report* (24590-WTP-RPT-PE-07-001), then the batch will be caustic and/or oxidative leached.

1 Aluminum, sodium oxalate, and phosphate solubility algorithms (24590-WTP-M4C-V37T-00009, CCNs 150372, 160514 and 160518) are applied to the feed receipts in HLP-VSL-00022 and FRP-VSL-00002B/C/D, assuming an initial temperature of 25 °C.

2 The HLW and LAW Facility throughput limits are set at 6 metric tons of glass (MTG) per day and 30 MTG/day, respectively, for the first 5 years, with PT and HLW vitrification ramping up to 7.5 MTG/day after 5 years of operation (24590-HLW-RPT-PE-07-001).

3 The supplemental LAW Facility is available to receive and process treated LAW in excess of the LAW Facility.

4 Presently only recycles are processed in the FEP system; LAW and HLW feeds are sent directly to UFP-VSL-00001A/B. The target value for recycle concentration is 4.0 wt % solids or 1.27 SpG, whichever comes first, to remain within the design basis for the waste feed receipt process system (FRP).

5 A sodium oxalate solubility algorithm (CCN 160518) is used to predict oxalate phases in PT.

6 Aluminum solubility algorithms (CCNs 150372 and 160514) are applied throughout PT to predict aluminum phase (sodium aluminate [l] or gibbsite [s]).

7 A sodium phosphate algorithm (24590-WTP-M4C-V37T-00009) is applied throughout PT.

8 It's assumed that aluminate, oxalate, and phosphate solubility equilibrium are reached within the time available for performing each process function (e.g., leaching, cooling, washing, evaporation, chemical adjustment).

9 It's assumed that other species (e.g., NaAlSi and sodium-fluoride-sulfate) for which solubility equilibriums are not modeled do not impact the accuracy of the G2 predictions.

10 Vessels PWD-VSL-00015/16 can change from discharge to receipt mode before completing a discharge if sufficient space is available in the vessel to receive a transfer. These vessels are neutralized (pH adjusted) prior to discharging.

2.3.4.2 Baseline Back-End Caustic Leaching G2 Model Parameters

1 When UFP-VSL-00001A/B becomes empty, it receives feed from upstream sources in the following order:

a HLW feed from HLP-VSL-00022.

b LAW feed from FRP-VSL-00002A/B/C/D.

c Concentrated recycle from the FEP system.

2 FEP evaporator concentrate is transferred directly to UFP-VSL-00001A/B.

3 UFP-VSL-00001A/B is filled to a setpoint of 28,300 gal with a blend of HLW and LAW. The target concentration of the blend is 7 wt % solids. Additional FEP concentrate may be added to UFP-VSL-00001A/B while the vessels are waiting to be processed in UFP-VSL-00002A/B.

4 UFP-VSL-00001A/B vessels are heated to up to 45 °C by direct steam injection.

5 An initial transfer of 16,076 gallons of slurry is made to UFP-VSL-00002A/B. Ultrafiltration recirculation is started, approximately 2,076 gallons of the slurry fills the ultrafilter train loop. The solids are concentrated to 20 wt % solids while maintaining tank level between 13,000 and 14,000 gal by transferring 1000 gal increments of slurry from UFP-VSL-00001A/B in a saw tooth fashion.

6 When receipt of additional transfers from UFP-VSL-00001A/B is no longer required or the UFP-VSL-00001A/B becomes empty, the transfer line from UFP-VSL-00001A/B to UFP-VSL-00002A/B is flushed with 480 gal of dilute sodium hydroxide. The flush water is received in UFP-VSL-00002A/B.

7 For feed batches requiring caustic leaching the following steps/times are used:
   a. The amount of 19 M NaOH needed to dissolve gibbsite and maintain all the dissolved aluminum in solution at 25 °C to 45 °C is calculated based on the dissolution reactions for each species having leach factors, the gibbsite, aluminate, and free hydroxide masses present in UFP-VSL-00002A/B and the aluminum solubility algorithm. An additional 10 % more hydroxide is added to prevent aluminum precipitation during the post-caustic-leach wash in UFP-VSL-00002A/B.
   b. Caustic leaching occurs in UFP-VSL-00002A/B at 80 to 90 °C (24590-PTF-3YD-UFP-00001).
   c. Up to 5000 gal of steam condensate are added to UFP-VSL-00002A/B during the heat-up and reaction step (24590-PTF-MCE-UFP-00006).
   d. Heating time in UFP-VSL-00002A/B is 6 hr (24590-WTP-DB-ENG-01-001).
   e. An 4 to 16 hr reaction time begins once the heat-up period is completed (24590-PTF-3YD-UFP-00001).
   f. Following the leaching the contents of the vessel are cooled, by the vessel's jacket, to the ultrafiltration temperature within 22 hr (24590-PTF-3YD-UFP-00001).

8 The effective filter area of each ultrafiltration train is 1451 ft^2 (24590-WTP-DB-ENG-01-001), which is approximately 90 % of the porous membrane area.

9 Filter flux is based on a model developed from reconciliation of the CUF (Cell Unit Filter) data (CCN 195030). The flux model considers fluid temperature, weight percent solids, and sodium molarity, and is continuously calculated to account for changing process conditions.

10 Post-transfer heel in UFP-VSL-00002A/B is conservatively set at 500 gal (actual heel may be a low as 100 gal).

11 For batches requiring oxidative leaching waste is washed until the hydroxide concentration is below 0.25 M. Oxidative leaching steps are (24590-PTF-3YD-UFP-00001):
   a. Close the permeate valves, but continue pump re-circulation and cooling of filter loop.
   b. Add 1 M $NaMnO_4$ at a 1.1:1 molar ratio with Cr in solids.
   c. Allow 6 hours for reaction
   d. Open permeate valves and concentrate to target wt%.
   e. Perform post oxidative leach wash

12 The filter recirculation loops are not drained during oxidative leaching.

13 End solids concentrations during processing in UFP-VSL-00002A/B:
   - Initial concentration---------- 15 wt % - 20 wt % solids
   - At end of initial wash---------- 17 wt % - 20 wt % solids
   - At end of post-oxidation leach wash---------- 20 wt % - 27 wt% solids (target)

14 Ultrafilter permeate flow paths:
   - For the initial slurry concentration step permeate is sent to UFP-VSL-00062A/B/C.
   - Post caustic leach wash, initially, and while permeate meets all the following conditions permeate is sent to UFP-VSL-00062A/B/C:

     [Na] ≥ 3.8 M

     [Na] ≥ 50% of peak sodium concentration

     [PO4-3]≥ 40% of peak phosphate concentration

     [C2O4-2] ≥ 40% of peak oxalate concentration
   - Post caustic leach wash permeate is sent to PWD-VSL-00015/16 for recycle to FEP evaporator when any of the above conditions are not met.

- Post oxidative leach wash and concentration steps sent to PWD-VSL-00015/16 for recycle to FEP evaporator.

15 Washing logic:

- Post caustic leach, use process condensate, if oxidative leach is to be performed and wash in saw tooth fashion until free $OH^- \leq 0.25$ M.
- Post caustic leach when no oxidative leach step performed by using 2.8 to 4.5 times the caustic leach slurry volume.
- Total volume of wash water used during post-oxidative wash is 2 to 3 times the post-oxidative leach re-concentration volume.

16 The heel volume remaining in UFP-VSL-00002A/B after transfer is conservatively set at 500 gal.

17 All treated and washed solids are transferred to HLP-VSL-00027A/B using positive displacement pump UFP-PMP-00044A/B at 55 gpm.

18 Sodium hydroxide is added to UFP-VSL-00062A/B/C as needed to prevent gibbsite from precipitating, and process condensate is added as needed to prevent the precipitation of oxalate and phosphate compounds.

19 Ultrafilter recirculation loop power flush logic:

- Two power flushes are performed after completing a UFP-VSL-00002A/B batch cycle. The power flushes replace the previous logic of draining and caustic rinse of the recirculation loop after every UFP-VSL-00002A/B batch cycle. The time to perform the power flushes is 11 minutes plus the liquid transfer times calculated in the model (24590-PTF-M6C-UFP-00011).

20 Ultrafilter chemical cleaning logic:

- Assumption: The ultrafilter will be chemically cleaned when 500 operating hours or more have elapsed since the last cleaning.

21 The scenario includes line flushes required by HPAV and plugging as described in CCN 141492, *Transmittal of Flush Requirements Following Transfers*. An exception is the new volume for the transfer from UFP-VSL-00001A/B to UFP-VSL-00002A/B, described earlier.

22 As with all G2 scenarios, 100 % equipment availability is assumed.

23 Processing times for operator steps, surveillances, and approvals are assumed to not delay processing.

24 Sampling and analytical turnaround times are based on OR model output assuming 90th percentile probability.

2.3.4.3 Double-Batching Back-End Caustic Leaching Option G2 Model Parameters

1 A UFPV is filled to its operating level with LAW from FRP-VSL-00002A/B/C/D, FEP concentrate, and HLW from HLP-VSL-00022.

- If necessary, the temperature of the waste in the UFPV is increased by the direct addition of steam or cooled using the vessel's cooling jackets and external heat exchangers (UFP-HX-00041A/B). It's estimated that 2540 gallon of steam condensate are added to each full (49,562 gal) UFP-VSL-00001A/B vessel within 3 hr to heat the full UFPV from 25 °C to 45 °C.
- The wastes are blended to achieve a target concentration of 7 wt% solids.

2 An initial waste volume, approximately 25,000 gallons, is transferred to the 'B' UFV, UFP-VSL-00002B. A minimum volume is required in the UFVs to operate the ultrafiltration recirculation pumps, approximately 15,000 gallons. To ensure there's adequate volume in UFP-VSL-00002B for pump operation, the initial transfer slurry for both UFVs is initially processed in UFP-VSL-00002B.

3 The waste in the UFP-VSL-00002B is pumped through the five 'B' train ultrafiltration bundles. Water and other soluble components of the waste permeate pass through the filter media and discharge to the permeate receipt vessels (UFP-VSL-00062A/B/C) via pulse pots.

4 Caustic can be added to the permeate receipt vessels to prevent gibbsite precipitation. Dilution water can also be added to the permeate receipt vessels to prevent the precipitation of salts.

5 The solids are re-circulated to the UFP-VSL-00002B, where additional waste is received from the feed preparation vessels to replace the permeate and to maintain a relatively constant volume.

6 When UFP-VSL-00002A is available (i.e., at its heel), the concentrated waste is divided between the two UFVs.

7 Both UFVs continue to concentrate waste while receiving additional feed from the UFPVs until the target waste concentration is achieved. The target waste concentration is typically 17 to 20 wt %.

A decision is made whether caustic or oxidative leaching is required for either, both or neither UFVs.

8 If caustic leaching is required for one or both UFVs, sufficient 19 M caustic is added to both UFVs to leach the dissolvable aluminum and to prevent precipitation when the solution is cooled to the filtration temperature.

9 Steam is mixed with the waste to heat it to a leaching temperature between 80 and 90 °C.

10 The slurry batches are digested at the leaching temperature for 8 to 16 hr in the UFVs (24590-WTP-RPT-ENG-08-016).

11 The leached waste in each vessel is cooled to a filtration temperature of 45 °C and re-concentrated to the minimum recirculation pump operation level.

12 The leached slurry in UFP-VSL-00002B is then transferred to UFP-VSL-00002A. If the slurry concentration in UFP-VSL-00002A is below the target concentration then the 'A' train ultrafilters are used to concentrate the leached slurry during the transfer from UFP-VSL-00002B.

13 The leached slurry in UFP-VSL-00002A is re-concentrated until the target concentration is achieved or the minimum volume for recirculation pump operation is achieved.

14 While UFP-VSL-00002A is re-concentrating leached slurry UFP-VSL-00002B receives a fresh batch of feed from the UFPVs and begins concentrating the feed using the 'B' train ultrafilters.

15 When UFP-VSL-00002A is finished re-concentrating the leached solids, the solids are washed using a saw tooth logic. That is, a 1,000 gal addition of wash water is made to the batch. When 1000 gal of permeate have been removed from the batch by ultrafiltration, an additional 1000 gal addition of wash water is made. The alternating additions of wash water and removals of permeate in 1000 gal quantities continue until the desired endpoint is achieved.

If oxidative leaching is not required, the UFP-VSL-00002A treated solids are discharged to HLP and UFP-VSL-00002A is available for the receipt of the next batch from UFP-VSL-00002B (step 6 above).

16 If oxidative leaching is required.

- The waste, in UFP-VSL-00002A, is washed with process condensate until its hydroxide concentration is below 0.25 M.
- An addition of sufficient 1 M sodium permanganate is made to the waste to provide an approximately 1.1 to 1 mole ratio of permanganate to Cr.
- After adding sodium permanganate, the vessel contents are mixed for 6 hr so that dissolution can take place. The oxidation of a mole of Cr consumes approximately a mole of hydroxide (Process Development for Permanganate Addition during Oxidative *Leaching of Hanford Tanks Sludge*

Simulants, CCN 159549). Sodium hydroxide at 2 molar can be added to the UFVs to maintain free hydroxide concentration during oxidative leaching.

- The slurry is then re-concentrated by filtration and washed with process condensate, the wash water sent back to PWD-VSL-00015/16.
- The treated solids are then discharged to lag storage (HLP system). The filter train is "power flushed" during the solids discharge and, if necessary, chemically cleaned. A power flush uses a pneumatically driven burst of dilute caustic to rapidly displace an ultrafiltration loop's volume. The loop's contents can be displaced to the PWD system or to a UFV (24590-PTF-M6C-UFP-00011).

17 If it was determined that caustic leaching was not required for both UFVs, then the following steps shall be performed in place of steps 8 through 15 above:

18 Transfer sufficient feed from the UFPVs to both UFVs to meet the minimum volume for operating the ultrafiltration recirculation pumps.

19 Concentrate feed in both UFVs until the target solids concentration is achieved.

20 Wash the concentrated feed in UFP-VSL-00002B using a saw tooth logic. That is, a 1000 gal addition of wash water is made to the batch. When 1,000 gal of permeate have been removed from the batch by ultrafiltration, an additional 1,000 gal addition of wash water is made. The alternating additions of wash water and removals of permeate in 1,000 gal quantities continue until the desired endpoint is achieved.

21 If oxidative leaching is not required, the UFP-VSL-00002B treated solids are discharged to HLP and UFP-VSL-00002B is available for the receipt of the next batch of feed (step 2 above).

22 If oxidative leaching is required.

- The waste, in UFP-VSL-00002B, is washed with process condensate until its hydroxide concentration is below 0.25 M.
- An addition of sufficient 1 M sodium permanganate is made to the waste to provide an approximately 1.1 to 1 mole ratio of permanganate to Cr.
- After adding sodium permanganate, the vessel contents are mixed for 6 hr so that dissolution can take place. The oxidation of a mole of Cr consumes approximately a mole of hydroxide (*Process Development for Permanganate Addition during Oxidative Leaching of Hanford Tanks Sludge Simulants*, CCN 159549). Sodium hydroxide at 2 molar can be added to the UFVs to maintain free hydroxide concentration during oxidative leaching.
- The slurry is then re-concentrated by way of filtration and washed with process condensate, with the wash water sent back to PWD-VSL-00015/16.
- The treated solids are then discharged to lag storage (HLP system). The filter train is "power flushed" during the solids discharge and, if necessary, chemically cleaned. A power flush uses a pneumatically driven burst of dilute caustic to rapidly displace an ultrafiltration loop's volume. The loop's contents can be displaced to the PWD system or to a UFV (24590-PTF-M6C-UFP-00011).

23 Repeat steps 20 through 22 for UFP-VSL-00002A. UFP-VSL-00002A is available for the receipt of the next batch from UFP-VSL-00002B (see step 6 above).

2.3.4.4 Upfront Caustic Leaching G2 Model Parameters

1 When UFP-VSL-00001A/B becomes empty, it receives feed from upstream sources in the following order:
   a HLW feed from HLP-VSL-00022.
   b Concentrated recycle from HLP-VSL-00027A.
   c LAW feed from FRP-VSL-00002A/B/C/D. It will use the next priority feed if the higher priority feed is not available at the time of request.
   d To achieve a better balance between LAW and HLW consumption, a LAW-only batch may be processed in UFP-VSL-00001A/B following every UFP-VSL-00002A/B solids discharge. The LAW-only batches may be diluted with water in UFP-VSL-00001A/B, to reduce the sodium concentration to approximately 8 M. Up to 19 M NaOH may be added to LAW-only batches to increase the hydroxide concentration to above 2 M.

2 FEP evaporator concentrate is normally routed to HLP-VSL-00027A to act as FEP concentrate lag storage. Normally, HLP-VSL-00027A will be configured to only receive, store, and transfer FEP evaporator concentrates. A contingent volume is set between the lower setpoint (27,884 gal) and the upper setpoint (84,584 gal).
   - The vessel can only receive if the volume is below the lower setpoint.
   - The vessel can receive or discharge if the volume is within the contingency area.
   - The vessel can discharge recycles-only batches to UFP-VSL-00001A/B if the volume is above the upper setpoint. Caustic leaching is not performed in this circumstance.

3 The targeted HLW feed into UFP-VSL-00001A/B is 25 kilomoles of $Al(OH)_3$ and/or 28,300 gal of HLW slurry. This is a conservative batch size based on past model runs. The UFP-VSL-00001A/B may be adjusted for individual feed vectors. The transfer from HLP-VSL-00022 is stopped when either condition is reached. The 25 kilomole gibbsite limit ensures sufficient space is available for caustic and steam condensate. **Note:** Quantity is conservative and not optimized.

4 If 25 kilomoles of $Al(OH)_3$ goal is reached before the vessel reaches 28,300 gal, then the vessel is topped off with recycle and LAW feed to reach 28,300 gal. **Note:** Quantity is conservative and not optimized.

5 The contents of UFP-VSL-00001A/B are not diluted after blending the HLP system or FRP system solutions.

6 For feed batches requiring caustic leaching the following steps/times are used:
   a The amount of 19 M NaOH needed to dissolve gibbsite and maintain all the dissolved aluminum in solution at 113 °F (45 °C) is calculated based on the dissolution reactions for each species having leach factors, the gibbsite, aluminate, and free hydroxide masses present in UFP-VSL-00001A/B and the aluminum solubility algorithm.
   b Caustic added in line with the HLW downstream of pump HLP-PMP-00021.
   c Caustic leaching occurs in UFP-VSL-00001A/B at 185 °F (85 °C) (24590-WTP-RPT-ENG-08-016).
   d A total of 9000 gal of steam condensate are added to a full UFP-VSL-00001A/B batch (49,562 gal) during heat up and reaction step, *Design Temperature for UFP Slurry Vessels* (24590-PTF-MCE-UFP-00005). The volume of steam condensate is proportionately reduced for smaller batch volumes.
   e Heating time in UFP-VSL-00001A/B is 9 hr (24590-PTF-MCE-UFP-00005).

f There is a steam availability constraint that allows only one UFP-VSL-00001 vessel to be heated at a time.

g A 4- to 16-hour reaction time begins once the heat-up period is completed (24590-WTP-RPT-ENG-08-016).

h The leached slurry is cooled by the vessel's jacket and by being recirculated through heat exchanger UFP-HX-00041A/B for up to 12 hr; the default value is 2 hr for cooling from 85 °C to approximately 45 °C in UFP-VSL-00001A/B (*Spiral Plate Heat Exchanger UFP-HX-00041A/B*, 24590-PTF-MEC-UFP-00001).

i The vessel contents are transferred to UFP-VSL-00002A/B at 140 gpm.

j When receipt of additional transfers from UFP-VSL-00001A/B is no longer required or the UFP-VSL-00001A/B becomes empty, the transfer line from UFP-VSL-00001A/B to UFP-VSL-00002A/B is flushed.

k There is a cooling water constraint that limits transfers to a single train at a time from one UFP-VSL-00001 to one UFP-VSL-00002.

7 Start ultrafiltration recirculation and concentrate the solids to 17 wt % solids while maintaining tank level between 19,000 and 18,000 gal by transferring leached slurry from UFP-VSL-00001A/B in 1000 gal increments, in a saw tooth fashion.

8 Effective filter area is 1451 ft^2, 24590-PTF-MVC-10-00001, *Ultrafiltration System (10-UFP) Vessel Batch Sizing Calculation.*

9 Filter flux is based on a model developed from reconciliation of cell unit filter (CUF) data (CCN 195030). The flux model considers fluid temperature, percent solids by weight, and sodium molarity, and is continuously calculated to account for changing process conditions.

10 Post-transfer heel in UFP-VSL-00002A/B is conservatively set at 500 gal.

11 Time for the oxidative leaching reactions is 6 hr (CCN 110724).

12 The filter recirculation loops are not drained during oxidative leaching.

13 End solids concentrations during processing in UFP-VSL-00002A/B:

- Initial concentration----------17 wt % solids
- At end of initial wash----------17 wt % solids
- At end of post-oxidation leach wash----------20 - 27 wt % solids

14 Ultrafilter permeate flow paths:

- For the initial slurry concentration step, permeate is sent to UFP-VSL-00062A/B.
- For slurry that will be oxidative leached, the post-caustic leach wash is sent to UFP-VSL-00062A/B/C until all the following conditions are true:
  - Wash sodium concentration is less than 3.8 M.
  - Wash sodium concentration is less than 50 % of peak wash sodium concentration.
  - Wash phosphate concentration is less than 40 % of peak wash phosphate concentration.
  - Wash oxalate is less than 40 % of the peak wash oxalate concentration.

    Discontinue washing forward when all conditions are true or if the wash free hydroxide concentration is 0.25 or less.
  - Close the permeate valves, but continue pump re-circulation and cooling of filter loop.
  - Add 1 M $NaMnO_4$ at a 1.1:1 molar ratio with Cr in solids.
  - Allow 6 hours for reaction

  - Open permeate valves and concentrate to target wt%.
  - Perform post oxidative leach wash
- For slurry that will not be oxidative leached, always wash with at least 2.8 slurry volumes and never more than 4.5 slurry volumes of wash water. As long as the free hydroxide exceeds 0.25 M, always wash forward (to UFP-VSL-00062A/B/C) until all the following conditions are true:
  - Wash sodium concentration is less than 3.8 M.
  - Wash sodium concentration is less than 50 % of peak wash sodium concentration.
  - Wash phosphate concentration is less than 40 % of peak wash phosphate concentration.
  - Wash oxalate is less than 40 % of the peak wash oxalate concentration.

  Discontinue washing forward when all four conditions are met.
- Post-caustic-leach wash that is sent forward is sent directly from the ultrafiltration pulse pots to PWD-VSL-00015/16.
- Post oxidative leach wash and concentration steps permeate is sent to PWD-VSL-00015/16 for recycle to FEP evaporator.

15 All treated and washed solids are transferred to HLP-VSL-00027B using a positive displacement pump, UFP-PMP-00044A/B, at 55 gpm.

16 Sodium hydroxide is added to UFP-VSL-00062A/B/C as needed to prevent gibbsite from precipitating and process condensate is added as needed to limit the sodium concentration in CXP-VSL-00004 to between 0.5 M and 8 M.

17 Ultrafilter recirculation loop power flush logic:

- Two power flushes are performed during solids discharge of a UFP-VSL-00002A/B batch. The time to perform a power flushes displacement is 11 minutes.

18 Ultrafilter chemical cleaning logic:

- It is presumed that the ultrafilter will be chemically cleaned when 500 operating hours or more have elapsed since the last cleaning or after every fourth UFV batch, whichever comes first.
- Chemical cleaning involves two power flushes, a 2 M nitric acid cleaning rinse, draining the acid to PWD and neutralization of the vessel heel with 2 M NaOH. The time provided in the model to perform these activities is 18 hr.

19 The scenario includes line flushes required by mitigation of hydrogen in piping and ancillary vessels (HPAV) and plugging as described in CCN 141492, *Transmittal of Flush Requirements Following Transfers.*

20 As with all G2 scenarios, 100 % equipment availability is assumed.

21 Processing times for operator steps, surveillances, and approvals are assumed to not delay processing.

22 Sampling and analytical times are based on 24590-WTP-PL-PR-04-0001, Rev 2, *Integrated Sampling and Analysis Requirements Document.*

23 DOE-provided services and utilities as defined in the contract interface control documents in the WTP SOW, Section C.9, are provided to support the WTP design capacity.

2.3.5 Basis

The solids and liquids are separated in the UFP system in two parallel trains of ultrafilters. In operation, the permeate flow will vary depending on the feed composition, viscosity, solids content, transmembrane pressure, temperature, and cross-flow velocity.

Generally, the operation of the two trains is coordinated. The Envelope C treatment process occurs in the ultrafiltration feed preparation vessels (UFPV). The UFP system is designed such that caustic leaching can occur either in the UFPVs (i.e., upfront caustic leaching) or the ultrafiltration feed vessels (UFV) (back-end leaching). Oxidative leaching occurs only in the UFV.

2.3.5.1 Technology Selection

The LAW/HLW waste stream is composed of varying quantities and compositions of solids (metal hydroxides, oxides, and precipitated salts) and salt solutions. Solids removal must be very efficient to prevent blinding of the downstream IX columns and to meet the maximum concentration limits for radionuclides other than Cs in the immobilized low-activity waste (ILAW) glass. Experiments were conducted in the early phase of the WTP design to select the optimal solid-liquid separation (SLS) technology for use in the flowsheet.

2.3.5.1.1 REDOX/PUREX Sludge Tests

Gravity thickening, centrifugation, air flotation, and cross-flow filtration were tested on simulated REDOX (reduction-oxidation) and Plutonium Uranium Extraction Facility (PUREX) sludges at Hanford. Dissolved and induced air flotation techniques were found to be ineffective, even with the additions of polymers as flotation aids. Gravity thickening was effective at concentrating the sludge content to > 10 wt %, with a supernate containing < 100 ppm of suspended solids. Two bowl centrifuges (a Sharples P600 and a Bird horizontal bowl) were effective at concentrating the sludge content to 16 to 20 wt %, with a supernate containing ~100 ppm of suspended solids. A 0.5 μm Mott cross-flow filter was effective at concentrating the simulated REDOX and PUREX sludge to 10 to 15 wt %, with a filtrate containing "virtually no solids." The filtrate flow rate was approximately 0.22 gpm/ft^2 for PUREX sludge and 0.13 gpm/ft^2 for REDOX sludge. The cross-flow filter also proved effective in removing soluble salt by constant volume washing (McCabe 1995). Testing was also conducted on simulated Hanford cladding removal wastes with centrifugation, sedimentation, cross-flow filtration, and dead-end filtration (inverted pneumatic hydropulse Mott filter). The cross-flow filter was determined to be the best overall option for this application (Gibson 1987).

2.3.5.2 Cross-Flow Filtration

In both the cross-flow filters and dead-end filters, differential pressure drives permeate through the filter media. In dead-end filters the feed is perpendicular to the filter media and must pass through a constantly increasing filter cake. Eventually the cake becomes too thick and there is insufficient pressure to maintain an adequate permeate rate. The cake must be removed or the filters replaced. In cross-flow filters the feed is tangential to the filter media. The pressure gradient drives permeate through the filter media, while the velocity gradient minimizes the effect of solids buildup on the filter surface. Figure 2.3-2 shows a simplified version of a cross-flow filter.

The type of material to be filtered influences the filter selection and sizing. The Research and Technology department (R&T) work has focused on determining the performance characteristics of 0.1 micron nominal porosity sintered metal filters with simulated and actual waste. Some tests have been done to compare 0.5 μm with 0.1 μm filters. With AZ-101/102 simulant at 5 and 15 wt % slurries, the 0.1 μm filter produced higher permeate flux rates. Figure 2.3-3 and Figure 2.3-4 show the permeate rate under the conditions tested (24590-101-TSA-W000-0004-119-01, Rev 00B). Other testing with 0.1 μm filter and AN-105 simulant supports the 0.1 μm filter media selection (BNF-003-98-0221).

Tests have been conducted that support the final selection of cross-flow filtration as the preferred SLS technology for the WTP flowsheet, using a 0.1 μm CUF. The primary focus of these tests was to validate the design permeate flux and the sludge pretreatment effectiveness (insoluble component removal) for the different HLW feed streams. Simulated and actual samples of tanks AY-102, AZ-101, AZ-102, C-104, and C-106 have been tested. As part of the EFRT major issue M12/M13 (Undemonstrated Leaching Process/Inadequate Ultrafilter Area and Flux) issue response plan (IRP), an extensive R&T program has been developed for comprehensively evaluating the filtration behavior of Hanford Tank Farm waste. A portion of this program is the characterization, leaching, and filtration of actual waste samples from eight waste groups (*Characterization and Small Scale Testing of Hanford Wastes to Support the Development and Demonstration of Leaching and Ultrafiltration Pretreatment Processes,* TP-RPP-WTP-467, Rev 0 [CCN 152430]). The selected waste groups are:

- Group 1 - Bismuth Phosphate Sludge (24590-QL-HC9-WA49-00001-03-00016)
- Group 2 - Bismuth Phosphate Saltcake (BY, T) (24590-QL-HC9-WA49-00001-03-00016)
- Group 3 - PUREX Cladding Waste (CWP) Sludge (24590-QL-HC9-WA49-00001-03-00020)
- Group 4 - REDOX Cladding Waste Sludge (24590-QL-HC9-WA49-00001-03-00020)
- Group 5 - REDOX Sludge (24590-QL-HC9-WA49-00001-03-00010/18)
- Group 6 - S-Saltcake (S) (24590-QL-HC9-WA49-00001-03-00010/18)
- Group 7 - Tribuyl Phospate (TBP) Waste Sludge (24590-QL-HC9-WA49-00001-03-00021)
- Group 8 - FeCN Wastes (24590-QL-HC9-WA49-00001-03-00023)

The CUF filtration tests were performed on individual as well as blended waste group samples. The transmembrane pressure (TMP) and axial velocity (AV) were varied from the baseline filtration operating conditions of TMP = 40 psid and AV = 13 ft/s during the tests (CCN 195030). The tests were performed on unleached low wt % solids slurries (<10 wt % UDS) and high wt % slurries (>15 wt % UDS). Tests were performed on caustic leached slurries and oxidative leached slurries. Finally, filter fluxes were evaluated during post-caustic-leach and post-oxidative-leach washing.

Before the M12 tests C-104 actual waste was tested (BNFL-RPT-030), Battelle evaluated approximately 1400 g of wet sludge for ultrafiltration, dilute caustic washing, and elevated temperature caustic leaching. The permeate flux was obtained using a 0.1 μm sintered metal Mott filter in a 24 in. long, single tube, cross-flow configuration (i.e., CUF). At a solids loading of 6.9 wt %, the permeate flux ranged from 0.038 to 0.083 gpm/ft^2, depending on AV and TMP. The optimum operating conditions derived from modeling of the test results are 15 ft/sec axial velocity and 30 psig TMP. For a solids loading of 23 wt %, the permeate flux ranged from 0.0095 to 0.0172 gpm/ft^2, depending on AV and TMP. Table 2.3-1 is a compilation of permeate flux rates for pre-M12 CUF tests.

Figure 2.3-13 is flux data vs. wt % solids for Envelope C pilot-scale work (SCT-M0SRLE60-00-141-03, Rev B) and Figure 2.3-14 is flux data vs. wt % solids for AZ-101 CUF work (24590-101-TSA-W000-0004-87-09, Rev 00C). A waste simulant is used for the Envelope C test. The Envelope C pilot-scale data is not incorporated into the flowsheet because the latest system plan has the Envelope C treatment occurring in the Tank Farms. The Envelope C solids will be blended with other wastes in the Tank Farms before being received in the WTP. Figure 2.3-15 and Figure 2.3-16 show flux vs. sodium molarity from the same reports. Most of the solids in precipitated Envelope C waste are a result of the chemical additions, so it is likely that the simulant accurately reflects the actual waste.

Cross-flow filter flux is directly affected by flow resistance. Resistance is caused by the filter media and the filter cake that develops on the media. At lower percent solids concentration by weight, the filter media is the dominant source of resistance, while at higher percent solids concentration by weight the filter cake is the dominant source of resistance. Filter cake resistance can be affected by a number of factors, including AV. Separate filter flux models are used to describe filtration flux behavior at low and high percent solids by weight conditions (24590-QL-HC9-WA49-00001-03-00022). The low percent solids by weight filter behavior is described by Darcy's equation:

Equation 2.3-1

$$J_1 = \frac{\Delta P_m}{\mu_{permeate} R_m}$$

where:

J_1 is flux (m/s)

Note: Flux can be presented in volumetric or imperial units by the application of conversion factors. At fixed conditions of TMP ΔP_m, R_m, and unit conversion factors can be combined into a single mass transfer coefficient.

ΔP_m is the transmebrane differential pressure

$\mu_{permeate}$ is the permeate viscosity

R_m is the overall resistance of the filter membrane

Flux behavior at a high percentage of solids by weight is best described by a "gel concentration" model (24590-QL-HC9-WA49-00001-03-00022):

Equation 2.3-2

$$J_2 = k * \ln\left(\frac{C_s}{C_g}\right)$$

where:

J_2 is flux

k is a mass transfer coefficient

C_s is UDS concentration (wt % UDS)

C_g is gel concentration (wt % UDS), i.e. the projected concentration at which the filter flux is zero.

Waste groups 8/7/AY-102, when blended after being caustic leached and washed, are an example of waste whose filtration behavior conforms to a gel concentration model, with a gel concentration value of 34 wt % (Figure 2.3-5).

As a given waste is concentrated in the ultrafilters, at conditions of constant TMP and AV, there is a transition point, with an associated transition concentration (C_{ts}), where the filtration behavior transitions from the regime of low percent solids by weight (Darcy's equation) to the regime of high percent solids by weight ("gel concentration" filtration). See Figure 2.3-6.

In addition to TMP, AV, and UDS concentration, waste temperature and viscosity affect filtration rates. Temperature affects filter flux by altering the permeate viscosity and filter resistance. A temperature correction term can be added to either Equation 2.3-1 or Equation 2.3-2 (CCN 106666).

Equation 2.3-3

$$J_T = J_{25} * \left(\frac{1}{e^{2500*\left(\frac{1}{273+T} - \frac{1}{298}\right)}} \right)$$

Where:

J_T is flux at temperature T (°C)
J_{25} is flux at 25 °C
T is filtration temperature (°C)

A viscosity correction term derived from the behavior of actual wastes can also be applied to either flux equation, sodium concentration is used as surrogate for permeate viscosity (CCN 195030).

Equation 2.3-4

$$J_{[Na]} = J_{[5]} * \left(\frac{1}{e^{0.445*([Na]-5)}} \right)$$

where:

$J_{[Na]}$ is the flux permeate with a sodium concentration of [Na] (M)
$J_{[5]}$ is the flux of permeate with a sodium concentration of 5.0 M
[Na] is permeate sodium concentration (M)

For the relevant UFP UDS concentration range (0 to 20 wt %), the filter behavior of a majority of actual wastes tested in the CUF is best described by Equation 2.3-1 (CCN 195030). That is, the transition concentration occurs at >20 wt % UDS.

Hence, the flowsheet uses Darcy's equation with temperature and viscosity correction factors:

Equation 2.3-5

$$J = J_o * \left(\frac{1}{e^{0.445*([Na]-5)}} \right) * \left(\frac{1}{e^{2500*\left(\frac{1}{273+T} - \frac{1}{298}\right)}} \right)$$

Where:

J_o is the filter flux at 25 °C and at a sodium concentration of 5.0 M (gpm/ft^2).

The treatment of waste before filtration affects filtration performance. In the UFP, caustic leaching can occur before or after initial solids concentration. Dissolved components are separated from the solids by washing with the ultrafilters. Washing occurs after caustic leaching and after oxidative leaching. Leaching and washing change the chemical composition and physical properties of the waste. Evaluations of CUF filtration tests indicate that filtration behavior differs for unleached, leached, and washed waste (CCN 195030). Hence, separate Darcy equation coefficients were developed for unleached solids, leached solids, post-caustic-leach washing, and post-oxidative-leach washing.

For unleached solids, the following correlation was derived based on the average fluxes of actual wastes tested in the CUF (Figure 2.3-7):

Equation 2.3-6 Unleached Solids Flux

$$J = \left(0.014 \frac{gpm}{ft^2}\right) * \left(\frac{1}{e^{0.445([Na]-5)}}\right) * \left(\frac{1}{e^{2500\left(\frac{1}{273+T}-\frac{1}{298}\right)}}\right)$$

The filter flux of caustic leached waste, at fixed conditions of AV and TMP, decreased over time. This decay in flux is most likely attributable to depth filter fouling (i.e., the blockage of filter pores with fines). To account for this decay, J_o in Equation 2.3-5 is replaced by a f(X), where X is the wt % UDS. The wt % UDS increases over time as the solids are concentrated (Figure 2.3-8). The function f(X) was determined by fitting data from CUF wastes tests (CCN 195030). The maximum flux during the reconcentration of leached slurry shall be limited to 0.45 gpm/ft^2, to prevent unrealistic fluxes for slurries at low percent solids by weight.

Equation 2.3-7 Caustic Leached Solids Flux

$$J = \left(\left[\frac{2.1*10^{-4}}{X^{1.3}}\right] + 0.0112\right) * \left(\frac{1}{e^{0.445([Na]-5)}}\right) * \left(\frac{1}{e^{2500\left(\frac{1}{273+T}-\frac{1}{298}\right)}}\right)$$

The average flux during post-caustic-leach washing differs from the pre-caustic-leach flux (Figure 2.3-9). The following correlation is applied in the flow sheet for post-caustic-leach washing (CCN 195030):

Equation 2.3-8 Post Caustic Leach Wash Flux

$$J = \left(0.012 \frac{gpm}{ft^2}\right) * \left(\frac{1}{e^{0.445([Na]-5)}}\right) * \left(\frac{1}{e^{2500\left(\frac{1}{273+T}-\frac{1}{298}\right)}}\right)$$

Only M12 waste groups containing significant chromium were oxidative leached, i.e., blended Group 1/2 and Group 5/6 wastes (Figure 2.3-10). The post-oxidative-leach wash filtration behavior is incorporated into the flowsheet as (CCN 195030):

Equation 2.3-9 Post Oxidative Leach Wash Flux

$$J = \left(0.008\frac{gpm}{ft^2}\right) * \left(\frac{1}{e^{0.445([Na]-5)}}\right) * \left(\frac{1}{e^{2500\left(\frac{1}{273+T}-\frac{1}{298}\right)}}\right)$$

Ordinary differential equations (ODE) derived from the change in flux over time for Equation 2.3-6 through Equation 2.3-9 are integrated between the expected beginning and ending UDS and sodium concentration conditions. The solutions of these ODEs provide the expected process times and average permeate flow rates that are incorporated into the Steady State flowsheet.

2.3.5.2.1 Ultrafiltration of Waste with Organics

Tests have been completed with an AZ-101 simulant spiked with tribuyl phosphate and normal paraffin hydrocarbon. These organics were added to the simulant and filtered using the 0.1 μm sintered metal Mott filter element. Tests were done to satisfy Standard 2 of the WTP Contract, which requires an evaluation of the effects of trace quantities (25 ppm) of separable organics in the liquid feed to the WTP and the fate of the separable organics within the system. Based on the results of the tests, there was no effect on ultrafiltration flux at 25 to 2500 ppm of separable organics (SCT-M0SRLE60-00-96-01, Rev 00C).

2.3.5.2.2 Solids Removal Efficiency

It is assumed that the ultrafilters remove 99.99 % of solids; Envelopes A/B/D are concentrated to 20 wt % solids; and Envelope C is concentrated to 15 wt % solids (BNF-003-98-0226). The flowsheet filtering temperature is 25 to 45 °C. Most of the simulant and actual waste filter testing was conducted at 25 °C, and the process was designed to match the test conditions. Testing to date using simulated and actual waste tank samples has shown that cross-flow filtration can meet the flowsheet throughput requirements under most of the conditions tested.

Assumption 2.3.1. Closed, see Appendix C for resolution.

M12 CUF actual waste test results and integrated engineering platform simulant results have been used to develop new flux correlations (CCN 195030).

2.3.5.3 Backpulsing

An aid to maintaining an adequate permeate flux rate is to periodically backpulse the filter media. While the solids are being concentrated, a subsurface layer of fine particulate builds on the media. As this layer increases in thickness, the permeate flux rate declines. A backpressure pulse dislodges the layer and partially restores the permeate flux rate. The manufacturer of one of the filters tested recommends backpulsing at least once per hour. However, preliminary PEP test results indicate less frequent backpulsing is required. During a backpulse, the filter cake layer protecting the filter media is dislodged, which can allow smaller particles to have greater access to the media. The smaller particles can move deeper into the media pores. Although there is a risk of depth fouling, testing has shown improved permeate flux rates with backpulsing. In pilot-scale testing with AN-105 simulant, the average permeate flux rate increased from 0.12 to 0.14 gpm/ft^2 when the backpulse interval was decreased from approximately 7.5 hr to approximately 2 hr (BNF-003-98-0221). Semi-Integrated Pilot Plant (SIPP) data demonstrated the poor recovery of filter fluxes from backpulsing performed during solids concentration

(SCT-M0SRLE60-00-208-00003, Rev 00A). Backpulsing has been recommended as part of the ultrafiltration cleaning process (24590-PTF-RPT-PET-10-001).

2.3.5.4 Filter Cleaning Basis

The CUFs used in the filtration studies were cleaned after each test. Both nitric acid and caustic were used after filtering C-104 solids (BNFL-RPT-030). Two nitric acid cleaning steps were performed after filtering AZ-102 solids (BNFL-RPT-038). Fines were noted after the second acid cleaning, and additional cleaning steps would have been used if there were plans to use the CUF again. When nitric acid cleaning was used during tests on AN-102 waste, it was noted that the nitric acid dissolved many of the radioactive elements (BNF-003-98-0317).

Beaker dissolution tests (with nitric, oxalic, and glycolic acid) were also completed at Savannah River Technology Center (SRTC) using an AY-102/C-106 sludge stimulant (SCT-M0SRLE60-00-90-00002, Rev A). This testing showed that oxalic acid is the most effective of the acids tested for dissolving iron. Nitric acid is the most effective acid to dissolve manganese and silicon, while all cleaning agents are equally effective at dissolving aluminum. Sodium oxalate that is present in the sludge may improve the effectiveness of nitric acid for dissolving iron due to the complexant behavior of the oxalate ion.

An evaluation of alternative ultrafilter chemical cleaning methods was conducted (CCN 081599) to identify the solubility of various species in each Envelope A (AN-105), Envelope C (AN-102), and Envelope D (AZ-101). The reagent which provided the highest solubility was then incorporated in the CUF under process conditions. Several reagents were tested: 0.5 M oxalic acid, 0.5 M, 1.0 M, 2.0 M nitric acid, and 2.0 M NaOH at 25 and 50 °C. The test confirmed that in most cases nitric acid was the most effective at dissolving the solids and cleaning the filter. The 1 M nitric acid was almost as effective as 2 M at dissolving solids. The report recommends that nitric acid continue to be the baseline cleaning reagent.

The SIPP data (SCT-M0SRLE60-00-208-00003, Rev 00A) demonstrate that during solids concentration the observed filter flux declines dramatically and rapidly (Figure 2.3-17). This decline is attributed to ultrafilter fouling. The acid cleaning during SIPP testing demonstrated that nitric acid (if required) is acceptable as a filter cleaning solution. The filter cleaning process during SIPP testing consisted of a dilute caustic rinse, followed by three 2 M nitric cleanings, followed by two more dilute caustic rinses (Figure 2.3-18). The "clean water" filter fluxes were lower post-filtration and cleaning than they were pre-filtration. The observed filter fluxes for the AY102/C106 simulant and for a blend of AY102/C106 and AP-101 simulants with recycles were nearly identical (Figure 2.3-17). This demonstrates that even though the filter fluxes could not be restored to pre-filtration level, the pre-filtration level of cleaning is not required to obtain the required filter fluxes during processing. Furthermore, the filters were cleaned to a repeatable performance after each filter cleaning process. The third nitric cleaning further showed minimal increase in filter fluxes and may not be necessary. Caustic rinse #1 in Figure 2.3-18 shows a significant improvement in filter flux compared to filter flux shown in Figure 2.3-17 (~0.08 gpm/ft^2 vs. ~0.005 gpm/ft^2). In addition, caustic rinse #3 shows only marginal improvement in the filter flux from caustic rinse #1 (0.16-0.08 gpm/ft^2 versus ~0.08 gpm/ft^2).

The addition of backpulsing during filter rinsing can also help restore filter flux if permeate collection is restrained after backpulsing. Figure 2.3-19 shows that filter flux is quickly re-established after backpulsing. This is because the slurry is at ~24 wt % UDS and the filter cake is allowed to reestablish by collecting the permeate. This is to clarify that the need to acid clean after every ultrafilter campaign may not be required.

The design of the UFP system allows for multiple batch contacts of 2 M nitric acid and up to 2 M NaOH to clean the ultrafilters after every solids campaign or batch (24590-PTF-3YD-UFP-00001).

Lessons learned from the CUF work and ultrafiltration cleaning tests have led to a preliminary cleaning process for the ultrafilters. The volume of nitric acid used is 17,076 gallons, sufficient to operate the ultrafiltration recirculation pumps and fill an ultrafiltration loop.

Assumption 2.3.2. Each ultrafilter train is chemically cleaned following the next solids discharge when 500 hr of operating time has elapsed since the last cleaning, or after every fourth UFP-VSL-00002A/B batch, whichever comes first. Chemical cleaning involves two 2000 gal power flushes and a single 17,076 gal 2 M nitric acid cleaning rinse, draining the acid to PWD and neutralization of the vessel heel with 2 M sodium hydroxide. The time provided in the model to perform these activities is 18 hr.

An evaluation of ultrafiltration cleaning recommends that the ultrafiltration trains be cleaned every 500 operating hours or after every fourth batch of solids (24590-PTF-RPT-PET-10-001).

2.3.5.5 Leaching

Caustic leaching is one of the two primary pretreatment steps used to reduce the quantity of IHLW produced by dissolving some nonradiological chemical components such as Al, Cr, Na, and PO_4 that limit waste loading in IHLW. The waste components dissolved in the leaching process will be processed into ILAW.

Assumption 2.3.3. The general form of the leaching reaction used is $C_x(OH)_y(s) + x\ NaOH(\ell) \rightarrow x\ NaC(OH)_{x+y}(\ell)$ where C = component.

A simplification of the aluminum reaction is provided below as an example:

$$Al(OH)_3(s) + NaOH_{(\ell)} \rightarrow NaAl(OH)_{4(\ell)}$$

The leach factors are reaction extents. For example, the experimentally determined leach factor for aluminum in AZ-102 is 0.667 (i.e., 66.7 % of the solid aluminum dissolves during the leach process). The leach factors used in the flowsheet vary depending on whether validated test data is available and based on the feed vector. Tank-specific leach factors derived from leaching actual waste are used when available; otherwise, TFCOUP or Tank Waste Information Network System (TWINS) leach factors are used. The tank-specific leach factors derived from waste are further developed to include process impacts when the data is available (CCN 082502). Table 2.3-5 shows the available R&T leach data CCN 030166 and 24590-101-TSA-W000-0004-87-09, Rev 00C. If an average feed vector is used, weighted average leach factors are used.

Assumption 2.3.4. The WTP process will produce similar results as TFCOUP or TWINS supplied leach factors.

Tank farm provided leach factors can be used to predict the fraction of solid aluminum that will be dissolved by caustic leaching or to speciate the solid aluminum into chemical compounds. Once solid aluminum is apportioned into compounds appropriate for leaching behavior can be applied to compounds (e.g., see Section 1.3.5 for kinetics based leaching of boehmite behavior).

In general, test results have demonstrated that the pretreatment flowsheet using cross-flow filtration and caustic leaching is acceptable. A review of past caustic leaching tests of actual waste was compiled as part of the program specified by the IRP for major issue M12, *Review of Caustic Leaching Testing with Hanford Tank Waste Sludges,* WTP-RPT-151, Rev 0 (CCN 151520).

2.3.5.6 Oxidative Leaching

2.3.5.6.1 Functional Requirement

The function of oxidative leaching is to remove chromium from HLW and entrained solids. Chromium is a target for removal because its presence in HLW solids may limit the waste loading in the IHLW glass and reduce the life of the melters. The allowable limit for chromium in the melter feed for vitrification is kept low (0.5 % to 1.2 % of the total oxides weight in HLW glass) due to anticipated melter operational concerns. According to the feed vector supplied with TFCOUP Rev 6, there are about 451,500 metric tons of undissolved chromium oxide. Chromium in excess of the HLW glass limit will reduce glass waste loading and require more HLW glass canisters to be produced, which means longer mission duration and a larger disposal repository. If chromium is not removed, then excessive amounts of glass formers are added to the waste to dilute the concentration of chromium oxide to acceptable concentration in the glass.

2.3.5.6.2 Process Description

Oxidative leaching is a process in which an oxidizing reagent is used to remove chromium from HLW and entrained solids. The process of removing chromium from HLW sludge involves adding a sufficient quantity of sodium permanganate to the washed waste sludge to convert the insoluble Cr(III) to the soluble Cr(VI), preferably without affecting any other components in the waste. The solution containing the dissolved Cr will be combined with other LAW feed to produce LAW glass. Experiments were conducted by Pacific Northwest National Laboratory (PNNL) to determine the optimum condition under which the chromium could be dissolved. The results of these experiments provide the basis for oxidative leaching.

The Cr(III) oxidation that produces soluble chromium (Cr(VI)) can be represented by the reaction:

$$Cr(OH)_3(s) + MnO_4^-(l) + OH \longleftrightarrow CrO_4^{-2}(l) + MnO_2(s) + 2H_2O$$

Concurrent caustic/oxidative leaching with a high permanganate-to-chromium molar ratio and at elevated temperature was considered unsuitable for Hanford Tank Farm sludges due to the increased plutonium dissolution.

2.3.5.6.3 Experimental Results

Information on the nature of chromium phase in Hanford Tank Farms sludge was obtained by various analyses. The relative amounts of these phases were not quantified when multiple phases were observed. Table 2.3-6 summarizes the chromium-containing phases identified thus far (24590-101-TSA-W000-0004-99-00012, page 1.6). Substantial dissolution of Cr(III) into alkaline solution was anticipated in early sludge washing and caustic leaching experiments with Hanford tank sludges. However, more recent results from caustic leaching indicate that chromium behavior is more complex. While significant concentrations of Cr(III) hydroxide can exist in high-caustic solutions at room temperature, it is also

shown that heating such solutions causes guyanaite (CrOOH) to precipitate. This precipitate is insoluble in caustic media. It is possible that the elevated temperature in the tanks may have generated poorly soluble Cr(III) phase than amorphous Cr(III) hydroxide.

The reagents tested to achieve Cr dissolution were:

- Hydrogen peroxide (H_2O_2)
- Ozone (O_3)
- Persulfate ($S_2O_8^{-2}$)
- Ferrate (FeO_4^{-2})
- Oxygen (O_2)
- Air
- Permanganate (MnO_4^-)

Several of the tested reagents were effective in oxidizing chromium. But these reagents would lead to undesirable attributes such as instability, corrosiveness, and increased oxidation of TRU. Sodium permanganate was considered to be the best suited for the removal of chromium from Hanford tank sludges.

One of the earliest applications of oxidative-alkaline leaching to Hanford tank sludges was by Lumetta et al. 1995 (*Process Chemistry for the Pretreatment of Hanford Tank Wastes*), and Lumetta and Swanson 1993 (PNL-8601), who examined hydrogen peroxide treatments and permanganate treatments of SY-102 Hanford tank sludge. Severe foaming and no chromate formation was observed when treated with hydrogen peroxide. However, permanganate treatment resulted in rapid formation of a yellow solution characteristic of chromate solution. No alpha activity was detected in the mildly alkaline (0.1 M hydroxide) leach solution following permanganate treatment. Persulfate, oxygen, and hydrogen peroxide were tried (Krot et al. 1999) to convert Cr(III) to Cr(VI) with limited success. Rapko and co-workers used a variety of oxidants and various washed Hanford tank sludge with a high solution to solid ratio (typically 100:1) with a contact time of 24 to 48 hr to measure chromium dissolution (Rapko et al. WTP-RPT-117, page 1.9). Table 2.3-7 summarizes their results. Significant plutonium dissolution was observed at 3 M NaOH and high temperature in certain Hanford Tank Farm waste.

Oxidation of Cr-containing, non-radioactive simulant with permanganate/hydrogen peroxide in 0.1 M NaOH was performed (24590-QL-HC9-WA49-00001-03-00002, page 3.20). Simulants using ground $Cr(OH)_3 \cdot 2.2H_2O$ (simulant #1) and a mixture of ground $Cr(OH)_3 \cdot 2.2H_2O$ and Cr(III) oxide (simulant #2) were studied for oxidative leaching at 0.1 M NaOH at room temperature. The simulants 1 and 2 were mixed with varying ratios of permanganate. The percentage of Cr dissolved showed a minimum at 0.75 [Mn/Cr] and then increased with increasing [Mn/Cr] ratios. The dip in the percentage of Cr dissolved was attributed to the degree of mixing provided by 200 rpm shaking; 500 rpm magnetic stirring provided better mixing. More Cr was dissolved as chromate when a 500 rpm stirring system was used. Higher Cr dissolution was also observed with 3 M NaOH leaching when compared to that with 0.25 M NaOH. An increase in temperature from 25 °C to 45 °C showed a marked increase in the extent of chromate formation. Testing was performed under identical conditions of hydroxide concentration (0.25 M), temperature (45 °C) and agitation (500 rpm stirring), but with the initial molar equivalents of permanganate-to-Cr ratios of 0.75, 0.9, 1.0, and 1.25. A substantial enhancement in Cr dissolution was observed when the [Mn/Cr] ratio was increased from 0.7 to 0.9. Further increase in the [Mn/Cr] ratio did not produce any noticeable improvement in chromate formation. The study of chromate formation was

continued using radioactive simulant with the target [Mn/Cr] ratio of 1 and at temperatures of 25 °C and 45 °C. The actual [Mn/Cr] ratios varied from 1.25 to 2.1, as compared to the target ratio of 1.0. The dissolution of Cr was monitored as a function of time. In most cases the formation of chromate was complete within a short time (less than 2 hr) and the percentage of Cr dissolved did not change significantly after that period. A slight increase in Cr dissolution was observed at a [Mn/Cr] ratio of 2.10 and at a temperature of 45 °C. It is not evident from the report why the [Mn/Cr] ratio of 1.0 could not be achieved in these tests.

Of all the oxidants tested, permanganate was effective with a short contact time (i.e., hours). At low hydroxide concentrations, the reduced form of permanganate is manganese dioxide, which will add MnO_2 mass to the HLW stream but is not as likely to limit waste loading as chromium during vitrification. Plutonium dissolution was observed when contacted with strongly alkaline solutions. One concern about employing oxidative-alkaline leaching is that concomitant oxidation of plutonium to Pu(VI) would lead to an undesirable enhanced dissolution of plutonium. This possibility was evaluated by measuring the radionuclide content of the leachate and wash solutions, in particular actinide dissolution. The results under several experimental conditions shown in Table 2.3-8 are shown in Table 2.3-9. The results for both the SY-102 and SX-101 sludges show similar trends. With respect to plutonium dissolution, adding permanganate to a standard (i.e., condition number 1) caustic-leach solution results in the most enhanced plutonium dissolution. Additional information on alkaline permanganate treatments of Hanford Tank Farm sludges are shown in Table 2.3-10.

Additional sludge samples from BY-110, S-107, and SX-107 were leached with an alkaline oxidative solution (Rapko et al. WTP-RPT-117, page 1.9). These sludge samples were previously subjected to caustic leaching. The samples represented the type of waste containing significant amount of Cr which showed poor dissolution during standard caustic leach. The experiments involved three chemical oxidants, permanganate, ozone, and oxygen. The effect of varying hydroxide concentration of the leachate (from 0.1 to 3 M) and time and temperature (from room temperature to 80 °C) was also examined. Permanganate and ozone were the most effective for Cr dissolution, with 83 to 94 % dissolution in BY-110, with 58 to 87 % dissolution for S-107 and 22 to 45 % dissolution in SX-108. Heating to 80 °C was required in several cases to achieve maximum Cr dissolution. Low Cr dissolution in SX-108 was attributed to the presence of a mixed Al/Cr phase. More effective removal of Al through extended leaching was expected to lead to a higher Cr dissolution in oxidative leaching. Leaching at 3 M free hydroxide resulted in enhanced Pu dissolution, with up to 14 % of the total Pu dissolving in BY-110 sludge with permanganate. For the majority of samples, permanganate treatment can reduce the residual chromium concentration to about 5000 ppm. The hydroxide concentration used for oxidative-alkaline leaching has several impacts. The oxidation of chromium by permanganate consumes hydroxide, so if too little hydroxide is in the system, the pH may drop to neutral from alkaline levels. Increased temperature and hydroxide concentration appear to slightly enhance chromium removal, but may also increase the extent of plutonium dissolution. Organic materials in the waste consume hydroxide instead of the chromium. It is preferable to avoid this oxidative-alkaline leaching of chromium from washed sludge. The effect of the order in which caustic and oxidative leach were performed was analyzed (24590-101-TSA-W000-0004-168-00002). The results are shown in Table 2.3-11, Table 2.3-12, and Table 2.3-13.

Major radioactive and non-radioactive components distributed in the caustic leachate, the oxidative leachate and the residual solids under various alkaline and temperature conditions were determined (24590-QL-HC9-WA49-00001-03-00002) and are shown in Table 2.3-14 to Table 2.3-19. Several conclusions were drawn from these results. The 8 hr caustic leach was ineffective in removing Cr from the simulant solids, with only 1 to 2 % of the available Cr in the simulant being dissolved. Simple caustic leaching dissolved only small amounts (less than 2 %) of other components (e.g., Zn, U, and Pu). In all

cases, the amount of U found in the caustic leachate was less than 1 percent. Oxidative alkaline leaching resulted in marked enhancements in removal of the chromium from the simulant. Finally, the amount of chromium dissolved in oxidative leaching is independent of hydroxide concentration and temperature, although a slight increase in Cr dissolution occurred at higher temperatures.

The $Pu^{239+240}$ concentrations were measured for a [Mn/Cr] ratio of 1.25 at each sampling time. The concentrations of mobilized $Pu^{239+240}$ are shown in Figure 2.3-20. The dissolved Pu concentration increased 3 times (1.89E-4 to 5.26E-4 μCi/mL) as the temperature increased from 25 °C to 50 °C at 0.25 NaOH. At 3 M NaOH concentration, the dissolved Pu concentration increased by 1.2 times (3.97E-3 to 4.82E-3 μCi/mL) as the temperature increased from 25 to 50 °C. The free hydroxide concentration was found to have a large effect on the Pu dissolution. At a [Mn/Cr] ratio of 1.25 the Pu dissolution was 1.89E-4 μCi/mL at 0.25 M NaOH. Pu dissolution increased to 3.07E-3 μCi/mL at 1.25 M NaOH and to 3.97E-3 μCi/mL at 3.0 M NaOH. (24590-QL-HC9-WA49-00001-03-00010, Appendix C)

Tank waste sludge and saltcake at the Hanford Site have been categorized into eight general groupings representing approximately 75 wt% of the total HLW mass expected to be processed through the WTP. Group 1 represents bismuth phosphate sludge waste containing a high fraction of phosphate; Group 2 represents bismuth phosphate saltcake, which contains a large fraction of the tank waste aluminum, chromium, phosphate, and sulfate. (24590-QL-HC9-WA49-00001-03-00016).

A portion of the caustic leached and washed Group 1/2 sample was subjected to parametric leaching with permanganate. The parameters examined included NaOH concentration (0.25 and 1.25 M) and a [Mn/Cr] molar ratio (0.59, 0.79, and 1.19). The amount of chromium removed was dependent upon the [Mn/Cr] ratio, with the most impact observed in going from a [Mn/Cr] ratio of 0.59 to 0.79. Above a [Mn/Cr] ratio of 0.79 there was no significant improvement in Cr dissolution. About 65 % of the Cr from the caustic-leached Group 1/2 solids was removed by treatment with 0.79 molar equivalent of Mn(VII) in 0.25 M NaOH at 45 °C. The Pu dissolution during oxidative leaching of the Group 1/2 solids was strongly dependent on the free-hydroxide concentration, with the Pu concentration increasing by approximately 6-fold when the NaOH concentration was increased from 0.25 M to 1.25 M; Pu concentration at 0.25 M NaOH was 2.54E-04 μCi/mL, while the Pu concentration increased to 1.54E-03 μCi/mL at 1.25 M NaOH.

The Group 5 waste was expected to be high in boehmite, requiring caustic leaching, whereas Group 6 waste was expected to contain a significant fraction of water-insoluble chromium that required oxidative leaching. Because there was an insufficient quantity of solids in Group 6 waste to achieve 20 wt% solids for the initial dewatering process, the Group 6 waste was blended with Group 5 waste to provide a higher feed concentration for the initial dewatering. The best estimate of the percent by weight of Group 5 and Group 6 sludge minerals are shown in Table 2.3-20 and Table 2.3-21, respectively. Radionuclide characterization of Group 5 and Group 6 are shown in Table 2.3-22 and Table 2.3-23, respectively (24590-QL-HC9-WA49-00001-03-00010, Rev 00B). Oxidative leaching dissolved 90 % of the solid chromium in the blended Group 5/6 waste.

Assumption 2.3.5. Closed, see Appendix C for resolution

2.3.5.6.4 Oxidative-Alkaline Leaching Process modeled in G2

The baseline oxidative leaching process is performed in the ultrafilter feed vessels (UFP-VSL-00002A/B) following caustic leaching and washing of the solids. The process steps are:

1 Cool the slurry after caustic leach wash to 40 °C to 45 °C.
2 Wash the slurry with process condensate (until the free hydroxide is ≤ 0.25 M and route the wash permeate to PWD. In some cases 19M NaOH is added to increase free hydroxide to near 0.25 M.
3 Add 1 M $NaMnO_4$ at a 1.1:1 molar ratio with Cr in solids.
4 Allow 6 hr for reaction time.
5 Re-concentrate the slurry to the original re-concentrated slurry volume and route the permeate produced to the PWD system.
6 Wash the slurry with process condensate (i.e., at least two times re-concentrated slurry volume) and route the wash permeate produced to the PWD system.

The sequential oxidative leaching process steps outlined above have been implemented in the flowsheet models.

2.3.5.7 Heel Dilution/Cleanout

The closure of EFRT issue M3 recommends providing heel dilution and cleanout capability for vessels UFP-VSL-00001A/B (CCN 220453 *Technology Steering Group - Issue Closure Record - Partial Closure EFRT Issue M3 (Closure Package Volume 7, UFP-VSL-00001A/B), Inadequate Mixing System Design*). Heel dilution shall be applied to UFP-VSL-00001A as described in 24590-WTP-RPT-PET-10-013, *Pretreatment Vessel Heel Dilution/Cleanout Feasibility Study*, with the exception that temporary transfer pump HLP-PMP-00022 shall be used for heel management activities rather than UFP-PMP-00044A/B:

- A temporary positive displacement pump, capable of pumping vessels down to a lower liquid level than the permanently installed pumps, shall be installed for heel dilution.
- UFP-VSL-00001A/B liquid level will be lowered to 1,191 gallons by the temporary pump; the temporary pump will discharge to UFP-VSL-00001A/B.
- Dilution liquid will be added to UFP-VSL-00001A/B until liquid level is 5,757 gallons. The dilution liquid shall be (in order of preference): LAW from FRP-VSL-00002A/B/C/D, process condensate, or de-ionized water (DI).
- Fluidize heel solids by operating UFP-VSL-00001A/B PJMs
- Lower vessel level to 1,191 gallons by using temporary pump to transfer fluidized heel to UFP-VSL-00001A/B.
- Flush UFP-VSL-00001A/B to UFP-VSL-00002A/B route with 150 gallons of flush water after transfer.

To assist heel management, two 8-inch diameter visual access ports have been added to vessels UFP-VSL-00001A/B, 24590-PTF-M6N-M80T-00101.

2.3.5.8 Envelope C Precipitation

Envelope C waste (AN-102 and AN-107) contains organic complexants or chelators which sequester ^{90}Sr and TRU in the supernate. The concentration of chelated ^{90}Sr and TRU for this envelope precludes processing the waste to make ILAW without additional processing steps. Because of the high concentration of chelates in the waste, IX and other separation processes were ineffective. To reduce the quantity of chelated isotopes in solution, a precipitation process was developed.

Figure 2.3-11 and Figure 2.3-12 provide the minimum decontamination factors (DF) for 10, 15, and 20 wt % waste sodium oxide loading ILAW. The glass density used for the strontium plots was 2.6. Americium represents 94 to 95 % of the TRU and for simplification is used as TRU.

The first precipitation process developed involved isotopic dilution for Sr removal and iron coprecipitation for TRU removal (Herting 1994 and Herting 1995). Although the required removal of isotopes was achieved, the precipitate from this process was unfilterable. Several other divalent coprecipitants were tested in conjunction with the Sr isotopic dilution: lanthanum, nickel, cobalt, calcium, and iron. After evaluating these alternatives for decontamination and filterability, sodium permanganate and calcium were selected for further study, along with strontium nitrate for isotopic dilution (BNF-003-98-0171). A similar process had been successfully tested for Sr and TRU removal in tank SY-101 waste (Orth and others 1995). Proof-of-concept testing was followed by some process optimization and sensitivity studies (Hallen 2000a and Rosencrance and others 1999).

During testing, the DFs for ^{90}Sr were normally greater than 50. The DFs for ^{241}Am were normally greater than 25. Specific DFs are calculated for each of the major TRU components from the laboratory data (Hallen 2000b, Hallen 2000c, Nash and others 2000a, and Nash and others 2000b). Baseline treatment conditions (1 M free OH^-, 0.075 M Sr^{2+}, 0.05 M MnO_4^-) were established in testing done at SRTC and Battelle (Nash and others 2000a, Nash and others 2000b, Hallen 2000b and 2000c). Statistical optimization testing has been conducted, in addition to proof-of-concept and other precipitation testing. The optimization testing confirmed that the initial treatment conditions are adequate to achieve the desired decontamination of Sr and TRU for AN-102 and AN-107 wastes (Rosencrance and others 1999).

Sodium hydroxide is added to ensure that there is sufficient hydroxide present for the precipitation reactions involved with precipitation and to maintain the conditions necessary for the carbonate/bicarbonate equilibrium to be on the carbonate side. The presence of bicarbonate increases TRU solubility and decreases permanganate effectiveness (Hallen 2000a). Nonradioactive strontium nitrate is added and competes with ^{90}Sr for chelates and increases the Sr level above the saturation point. The Sr reacts with carbonate in the waste and forms a precipitate. As the temperature increases, strontium carbonate solubility decreases, further enhancing Sr precipitation. However, as the temperature cools, some Sr dissolves back into the waste.

The permanganate initiates TRU precipitation and possibly replaces some of the complexed TRU in solution. The composition of the precipitated compounds is uncertain. There is some evidence that crystal birnessite ($Na_4Mn_{14}O_{27}$) is formed with actinides coprecipitating onto the crystal structure. The precipitation reactions for strontium and TRU in the UFP are reflected by the following reactions (24590-101-TSA-W000-0004-98-03, Rev 00B):

Equation 2.3-10

$$Sr^{+2}{}_{(\ell)} + CO_3^{-2}{}_{(\ell)} \leftrightarrow SrCO_{3(s)}$$

$$14NaMnO_{4(l)} + 7NaHCO_{2(l)} + 2Na_2C_2O_{4(l)} + NaOH_{(l)} \rightarrow Na_4Mn_{14}O_{27(s)} + 7.5O_{2(g)} + 11Na_2CO_{3(l)} + 4H_2O_{(l)}$$

The $MnO_{4(l)}$ precipitates are 99 % crystal birnessite ($Na_4Mn_{14}O_{27(s)}$). The actinides coprecipitate onto the birnessite at a ratio of 1 M/14 M Mn in birnessite. After the actinides have coprecipitated to the extents of reaction listed below, the remaining birnessite will remain as the non-substituted crystal shown above. The substitution proceeds according the following reactions:

Equation 2.3-11

$$Np^{+4}_{(\ell)} + 4OH^{-}_{(l)} + 13NaMnO_{4(l)} + 6.5NaHCO_{2(l)} + 2Na_2C_2O_{4(l)} + 1.5NaOH_{(l)} \rightarrow Na_4NpMn_{13}O_{27(s)} + 7O_{2(g)} + 10.5Na_2CO_{3(l)} + 6H_2O_{(l)}$$

Equation 2.3-12

$$Pu^{+4}_{(\ell)} + 4OH^{-}_{(l)} + 13NaMnO_{4(l)} + 6.5NaHCO_{2(l)} + 2Na_2C_2O_{4(l)} + 1.5NaOH_{(l)} \rightarrow Na_4PuMn_{13}O_{27(s)} + 7O_{2(g)} + 10.5Na_2CO_{3(l)} + 6H_2O_{(l)}$$

Equation 2.3-13

$$Am^{+3}_{(\ell)} + 3OH^{-}_{(l)} + 13NaMnO_{4(l)} + 6.5NaHCO_{2(l)} + 2Na_2C_2O_{4(l)} + 1.5NaOH_{(l)} \rightarrow Na_4AmMn_{13}O_{27(s)} + 6.75O_{2(g)} + 10.5Na_2CO_{3(l)} + 5.5H_2O_{(l)}$$

Equation 2.3-14

$$Cm^{+3}_{(\ell)} + 3OH^{-}_{(l)} + 13NaMnO_{4(l)} + 6.5NaHCO_{2(l)} + 2Na_2C_2O_{4(l)} + 1.5NaOH_{(l)} \rightarrow Na_4CmMn_{13}O_{27(s)} + 6.75O_{2(g)} + 10.5Na_2CO_{3(l)} + 5.5H_2O_{(l)}$$

Equation 2.3-15

$$Eu^{+3}_{(\ell)} + 3OH^{-}_{(l)} + 13NaMnO_{4(l)} + 6.5NaHCO_{2(l)} + 2Na_2C_2O_{4(l)} + 1.5NaOH_{(l)} \rightarrow Na_4EuMn_{13}O_{27(s)} + 6.75O_{2(g)} + 10.5Na_2CO_{3(l)} + 5.5H_2O_{(l)}$$

AN-102 Reactions

Equation 2.3-16

$$Al(OH)_{3(s)} \rightarrow Al^{+3}_{(l)} + 3OH^{-}_{(l)}$$

Equation 2.3-17

$$Ca^{+2}_{(l)} + CO_3^{-2}{}_{(l)} \rightarrow CaCO_{3(s)}$$

Equation 2.3-18

$$Cr^{+3}_{(l)} + 3OH^{-}_{(l)} \rightarrow Cr(OH)_{3(s)}$$

Equation 2.3-19

$$Fe^{+3}_{(l)} + 3OH^{-}_{(l)} \rightarrow Fe(OH)_{3(s)}$$

Equation 2.3-20

$$Pb^{+2}_{(l)} + CO_3^{-2}{}_{(l)} \rightarrow PbCO_{3(s)}$$

AN-107 Reactions

Equation 2.3-21

$$Al^{+3}_{(l)} + 3OH^{-}_{(l)} \rightarrow Al(OH)_{3(s)}$$

Equation 2.3-22

$$Ca^{+2}_{(l)} + CO_3^{-2}{}_{(l)} \rightarrow CaCO_{3(s)}$$

Equation 2.3-23

$$Cr^{+3}_{(l)} + 3OH^{-}_{(l)} \rightarrow Cr(OH)_{3(s)}$$

Equation 2.3-24

$$Fe^{+3}_{(l)} + 3OH^{-}_{(l)} \rightarrow Fe(OH)_{3(s)}$$

Equation 2.3-25

$$Pb^{+2}_{(l)} + CO_3^{-2}{}_{(l)} \rightarrow PbCO_{3(s)}$$

The R&T reaction extent for Sr^{+2} is 0.98; MnO_4^- is 0.99; Np^{+4} is 0.78; Am^{+3} is 0.86; Cm^{+3} is 0.83; Pu^{+4} is 0.78; Eu^{+3} is 0.91; and other actinides are 0.78 (SCT-M0SRLE60-00-78-01). The AN-102 specific reaction extent for $Al(OH)_{3(s)}$ is 0.72; Ca^{+2} is 0.47; Cr^{+3} is 0.33; Fe^{+3} is 0.83; and Pb^{+2} is 0.17 (BNF-003-98-0317). The AN-107 specific reaction extent for Al^{+3} is 0.20; Ca^{+2} is 0.43; Cr^{+3} is 0.50; Fe^{+3} is 0.99; and Pb^{+2} is 0.60 (Hallen 2000b).

Assumption 2.3.6. The exact mechanism and solid products for the reactions have not been determined. The research to date suggests that the Sr reaction is a good representation of the process, but the TRU is not likely precipitating as discrete hydroxide phases, as published in project R&T results. Additional hydroxide did not improve the TRU decontamination as would be expected in a simple formation of metal hydroxide (24590-101-TSA-W000-0004-101-02A, Rev 00B). The TRU is likely precipitating as a coprecipitated birnessite crystal. Although the compounds that are precipitating are not entirely understood, the overall process removes sufficient quantities of Sr and TRU so that the liquid can be processed into ILAW.

A process optimization study was completed for AN-102 waste at PNNL (24590-101-TSA-W000-0004-101-02A, Rev 00B). The study primarily focused on minimizing the addition of strontium nitrate and sodium permanganate, but also evaluated the need to add sodium hydroxide and to elevate temperature.

An optimization study was performed because preliminary work with AN-107 waste indicated that the target reagent concentrations could be reduced. Testing at Battelle yielded DFs for ^{90}Sr and TRU that were much higher than required to meet ILAW glass requirements. It was noted that adequate DFs were obtained after the reagent addition and before digesting at an elevated temperature (Hallen 2000c). Similar observations were noted at SRTC with AN-102 waste (BNF-003-98-0317).

The initial process performance optimization study was conducted at SRTC with AN-102 waste. The goal of the statistical testing was to optimize precipitation performance by maximizing DFs. The testing included analysis of adding calcium as a precipitation reagent along with Sr and permanganate. This test established the boundaries of Sr and permanganate additions and further clarified areas for improvement. Some of the significant observations were that calcium addition decreased solids filterability and that the process was robust with respect to temperature (Rosencrance and others 1999). Sufficiently high DFs for TRU were obtained without calcium, so calcium was eliminated as a precipitation reagent. The SRTC work provided a platform for additional process refinement.

There is a good degree of confidence that the Sr precipitate is strontium carbonate by isotopic dilution and that strontium solubility is mostly affected by temperature. With this knowledge, a fixed level of Sr was used for the optimization work at Battelle. The Battelle test matrix set the Sr level at 0.02 M and varied hydroxide, permanganate, and temperature. The hydroxide addition was 0 and 0.5 M, the permanganate 0 and 0.02 M, and the temperature was ambient (26.1 °C) and 50 °C. The test results indicate that additional hydroxide is not needed and may decrease the Sr removal. Permanganate addition slightly increases the Sr removal and reacting at 50 °C is not necessary to achieve ILAW glass loading requirements. To summarize, the precipitation at 0.02 M Sr and permanganate, with no additional hydroxide and at ambient temperature, yielded a 7.1 DF for ^{90}Sr and a 4.8 DF for TRU (^{241}Am) at 15 % waste sodium oxide loading in ILAW.

Optimization tests have provided promising results and indicate that the flowsheet baseline for Envelope C can be improved. However, additional testing and data analysis is warranted. All of the optimization work to date has been done on AN-102 waste. The organic loading in AN-107 waste is higher than AN-102, which requires higher reagent strikes. There is also a contrast between the two optimization studies regarding hydroxide addition. The SRTC study recommended that the highest level of hydroxide tested (1.0 M) be used, but the Battelle work recommended no additional hydroxide be added.

Work at SRTC using conditions similar to the optimized conditions above (0.03 M final concentration of strontium nitrate, 0.03 M final concentration of permanganate, 0.3 M final concentration of free hydroxide, and 25 °C) indicates that the precipitate does not filter well under the optimized precipitation conditions (SCT-M0SRLE60-00-141-03, Rev 00B). Baseline conditions will be used to obtain the sufficient filterability.

The time required to cool the precipitated Envelope C slurry from 50 °C to 25 °C (before filtration) is 2 hr (24590-PTF-MEC-UFP-00001).

2.3.5.9 Envelope C Filtration

Testing with simulant (AN-107) has demonstrated that concentrations up to 38 wt % of a combined entrained solids and Sr/TRU precipitate feed is feasible (BNF-003-98-0226). Pilot-scale testing results show no measurable solids (< 0.0001 wt %) in the filtrate over the range of 2 to 38 wt % solids loading (BNF-003-98-0226).

Data from actual waste has been difficult to produce because of the limited size and low solids content of the radioactive samples. Table 2.3-1 shows the experimental permeate flux rates of several Envelope C wastes. Most of the solids in precipitated Envelope C wastes are a result of the chemical additions, so it is likely that the simulant accurately reflects the tank waste.

Effectiveness of 0.075 M strontium nitrate and 0.05 M sodium permanganate after adjusting to 1 M caustic in precipitating Sr/TRU in AN-107 simulant was tested in a pilot-scale test. The reduction in concentrations of strontium and nonradioactive surrogate TRU elements cerium, lanthanum, and neodymium in the slurry were measured. Mechanical agitators were used for mixing the slurry.

A 634-liter (167.485 gal) sample of AN-107 simulant was used in the precipitation and filtration test at 20 °C (SCT-M0SRLE60-00-110-06). The liquid, solid, and gaseous products were sampled and analyzed over a period of 8 hr to determine the concentration of solids removed from the initial feed. About 85 % of lanthanide elements, cerium, lanthanum, and neodymium (surrogates for plutonium, americium and uranium) were precipitated out within 7.5 min. After 4 hr, the DF for cerium, lanthanum, and neodymium were determined to be 9.4, 11.1, and 7.5 respectively. The DF for Sr, assuming complete isotopic mixing, was calculated to be 37. No volatile products were detected in the evolved gases.

Four hours after the reagent addition, some of the contents of the precipitation tank were transferred to the crossflow test facility and filtered under various conditions. Filter flux varied between 0.026 gpm/ft^2 at an axial velocity of 10 ft/sec and transmembrane pressure of 50 psid, and 0.038 gpm/ ft^2 at a slurry velocity of 18 ft/sec and transmembrane pressure of 45 psid.

In an earlier pilot scale precipitation test (SCT-M0SRLE60-00-110-03), using 647 liters (170.919 gal) of AN-107 simulant under similar conditions without caustic adjustment, the DFs at 50 °C were 5.2 for cerium, 8.4 for lanthanum, and 7.1 for neodymium. Assuming complete isotopic mixing, a DF of 1000 was calculated for strontium. Crossflow filtration achieved fluxes as high as 0.05 gpm/ft^2 with tube axial velocity of 20.8 ft/sec and a transmembrane pressure of 29.2 psid. During initial dewatering, a steady flux of 0.02 gpm/ft^2 was obtained at a velocity of about 16 ft/sec and a transmembrane pressure of about 42 psid.

In a separate test (BNF-003-98-218) a 1.2 liter (.317 gal) actual AN-102 waste sample, with caustic adjustment and strontium and permanganate addition, produced a filtrate product decontamination factor of 30 for ^{90}Sr, 9.2 for ^{241}Am, and 7.2 for ^{244}Cm.

The addition of caustic to increase the simulant concentration by 1 M NaOH before addition of precipitating agents reduced the removal of strontium slightly, but increased the removal of cerium and lanthanum compared to that without caustic addition.

A test plan to repeat the test using PJMs in place of mechanical agitators to reflect a mixing condition more representative of that expected in the plant is in the planning stages.

2.3.5.10 Solids and Sr/TRU Precipitate Washing

The solids and Sr/TRU precipitates (Envelope C) are washed to remove interstitial sodium after they are concentrated to 15 or 20 wt % solids. This washing process may be warranted to minimize the volume of IHLW glass. Washing effectiveness was demonstrated using C-104, C-106, and AZ-102 solids (PNWD-3024, PNWD-3013, PNNL-11432, and BNFL-RPT-038). The Sr/TRU solids were washed, and 90 to 95 % of the interstitial liquid was replaced with deionized water. The solids content after the first wash decreased, indicating that some of the solids are being removed during washing (BNF-003-98-0317). Currently no washing extent has been defined. For non-Envelope C washing, the flowsheet uses a wash volume that is four times the slurry volume. This volume is used to remove dissolved sodium and sulfate so glass loading is not limited to HLW. For Envelope C, approximately twice the slurry volume of wash water is used after concentrating the precipitate to 15 wt % solids.

2.3.5.11 UFP Antifoam

Some of the waste processed through UFP is expected to foam due to air sparging and the chemical and physical makeup of the waste. The DOW Q2-3183A antifoam agent has proved to be the best antifoam in both LAW evaporation foaming studies and UFP foaming studies. Several small-scale studies have been preformed to investigate foaming and the use of an antifoam agent (AFA) during ultrafiltration. These studies are summarized below.

The effectiveness of DOW Q2-3183A in mitigating the foaming in WTP tanks equipped with air spargers and PJMs was evaluated in SCT-M0SRLE60-00-199-00001, Rev 00B. From these results a baseline AFA addition strategy was recommended: an initial charge of 350 mg/L Q2-3183A followed by small batch additions of 70 mg/L every 24 hr. This addition strategy is based on small-scale testing and may not reflect actual full-scale requirements.

The degradation of the AFA was evaluated under caustic leach conditions of high temperatures (90 °C) and radiation (SCT-M0SRLE60-00-99-00009). The study determined the rate of degradation and the formation of degradation products as a function of temperature (>60 °C), time (~2 weeks), and radiation (2.1×10^4 rad/hr) of Q2-3183A under leaching conditions. The test showed that the two main polymers, polydimethylsiloxane (PDMS) and polypropylene glycol (PPG), did not degrade after 24 hr of heating (90 °C) and exposure to radiation (2.1×10^4 rad/hr). Some breakdown of the AFA was seen after 48 hr, which supports the AFA addition strategy. Decomposition of the polymers was accelerated by radiation.

Based on the chemical stability of the AFA within the first 24 hr of addition, the effectiveness of the AFA appears to be governed by the physical process separation (e.g., mixing, filtration, and washing). During the UFP steps, the components relative to each other change, reducing the effectiveness of the AFA, and thus replenishment will be needed (e.g., 70 mg/L). This was demonstrated in testing (SCT-M0SRLE60-00-99-00009) when the simulated waste was washed per the caustic leach protocol. After washing, the PPG polymer was mainly present in the combined washes and the PDMS remained with the washed solids.

A study (SCT-M0SRLE60-00-217-00001) was performed to investigate the production of hydrogen from Q2-3183A AFA added to simulated waste to determine if the organic compounds in the AFA produced hydrogen in the same manner as the native organic species in Hanford Tank Farm waste. Comparison of the measured and predicted hydrogen generation rates (HGR) found that the WTP HGR correlation overpredicted the measured values. A better correlation was found when the AFA total organic carbon was treated as immiscible instead of being treated in the same manner as native soluble organics; however, treating the AFA organic compounds in the same manner as native soluble organics is conservative.

Gas holdup tests (*Effects of Alternate Antifoam Agents, Noble Metals, Mixing Systems and Mass Transfer on Gas Holdup and Release from Non-Newtonian Slurries,* SRNL-RPP-2007-00023 [SCT-M0RSLE60-00-224-00001]) performed with Hanford waste simulants indicate that Q2-3183A AFA increased gas holdup in the waste simulant by about a factor of four and, counter intuitively, that the holdup increased as the simulant shear strength decreased (apparent viscosity decreased). This finding is relevant to the waste's capability to retain and release flammable gases. This is of particular concern during design basis events, when normal agitation is unavailable.

2.3.5.11.1 Effect of Anti-Foaming Agent (AFA) on leaching

Tests were conducted to determine the effect of the AFA, Dow Corning Q2-3183A, on oxidative-alkaline leaching of Cr(III), Pu, and other nuclear criticality-related elements, such as Fe, Ni, and Mn by permanganate (24590-QL-HC9-WA49-00001-03-00042). The effect of AFA on the efficiency of dissolving chromium from radioactive sludge was investigated. The simulant used was developed for monitoring the impact of permanganate dosage on the conversion of insoluble Cr(III) to soluble chromate in alkaline solutions. Actual radioactive samples were not used in these tests, with the assumption that the results of the simulant test would be conservative. During the oxidative leaching process, Mn was added as liquid permanganate solution, which gets converted to the insoluble solid MnO_2. Water and sodium hydroxide were added to each test sample to give a leachate volume equal to three times the simulant sludge volume with a caustic concentration of 3 M NaOH. The AFA was mixed with a small quantity of NaOH solution and was added to the test samples. Removal of chromium from simulated tank sludge by oxidative leaching resulted in 83 to 97 % of initial chromium being removed based on the analysis of washed and dried solids.

The amount of AFA added ranged from 0 ppm to 700 ppm. The solids and liquids were sampled to determine the initial concentrations of elements of interest. Caustic leaching was performed at 85+/- 5 °C for 8 hr followed by an oxidative leach by adding Mn as liquid permanganate at a temperature of 25 °C and/or 45 °C for 6 hr. The quantities of key components that partition to the caustic leachate were determined by the combined analysis of supernatant solution and wash solutions. The amount of Mn, U, and Zn dissolved in caustic leachate ranged from 0 % to 4.29 %, 0 % to 12.14 %, and 0 % to 9.29 %, respectively of the initial content in the solid waste. Quantity of Cr, Fe, Pu, and Am dissolved in caustic leachate were less than 1 % of the initial content in solid waste. Dissolution of key elements during caustic leach testing was independent of the amount of AFA in the samples. The amount of Cr, U, and Zn dissolved during oxidative leach test ranged from 83 % to 97 %, 0 % to 3.9 %, and 0 % to 59 %, respectively of the initial waste composition and were also independent of the amount of AFA in the samples. All the other key components partitioned less than 1 % during oxidative leach. The study showed that the addition of AFA to suppress foaming in process vessels did not alter the effectiveness of either the caustic or the oxidative leach process. Experimental results on chromium removal with and without AFA are shown in Table 2.3-24.

It was noted that, although most of the chromium is leached from the waste, the overall mass of waste did not decrease due to the replacement of chromium with MnO_2 in the solids. These data show no correlation between the concentration of AFA and the effectiveness of the oxidative leaching for removal of chromium, iron, nickel, and zinc from the simulated sludge. Removal of uranium from simulated tank sludge by oxidative leaching resulted in 0.40 % to 3.9 % of the initial uranium being removed. At 25 °C, the data showed no correlation between the concentration of AFA and removal of uranium by oxidative leaching, while at 45 °C, there appeared to be a correlation, with more uranium removed at higher AFA concentration. Removal of $Pu^{239+240}$ from simulated tank sludge by oxidative leaching resulted in 0 to 0.24 % of initial plutonium being removed and showed no correlation to the amount of AFA in the sample. Although plutonium and americium were not analyzed separately, the data indicated that plutonium was preferentially removed and more of americium remained with the solids. In general effective removal of chromium using permanganate was observed in all the tests conducted thus far.

An additional test was performed to determine the effectiveness of AFA during oxidative leaching (SCT-M0SRLE60-00-199-00002). The tests showed that DOW Q2-3183A was not effective during baseline oxidative leaching and sparging (2.2 $ft^3/min/ft^2$ sparger air flow). The amount of foam was a strong function of the amount of $NaMnO_4$ added and sparger airflow. The performance of DOW Q2-3183A was satisfactory (less than 7 % foam) during oxidative leaching when the sparger flux was idle

(0.22 $ft^3/min/ft^2$ sparger air flow). Three other agents, DeBourg 747, DOW 1520US, and DOW Q2-3315, were tested and were found to be less effective than DOW Q2-3183A.

Many of the wastes processed by WTP may not foam, negating the need for AFA. Evaluating the need for use of antifoam on a 'by batch' basis may be required when glass production starts. Small-scale waste batch studies may be conducted prior to transfer to WTP, providing an opportunity to tailor an AFA addition strategy for each batch (SCT-M0SRLE60-00-199-00001).

2.3.5.12 Energy Balance

The operating temperatures in UFP are based on expected plant conditions, laboratory tests, and downstream system limitations. Waste feed into the plant is expected to be at ambient conditions or warmer due to decay heat. The filtration testing for both simulants and actual waste began at ambient temperature and were cooled, or the data were corrected to ambient temperature. As previously noted, Cs ion exchange (CIX) performance decreases as temperature increases. If waste is filtered at an elevated temperature, there is an increased probability of precipitation as the permeate cools in CXP. Limited high pressure steam supplies will limit the concurrent heat-up of UFP vessels in the PT Facility.

2.3.5.13 Dimethyl Mercury Formation in UFP Leach Vessels

Elemental mercury reacts at elevated temperatures (CCN 195033) with a number of organic species. It initially forms monomethyl mercury (MMHg), and subsequently at a slower rate, dimethyl mercury (DMHg). The AFAs to be used in the WTP PT Facility are expected to promote DMHg formation by acting as methyl donors. For WTP, processes with the highest potential DMHg formation rates are in the UFP vessels during caustic leaching, at 85 °C and in the presence of AFAs. Because of its volatility, a majority of the DMHg generated in the UFP system during caustic leaching enters the offgas system. Once in the offgas system, since the pulse jet ventilation system (PJV) does not have any components credited for controlling mercury, any mercury or DMHg may be retained in the pretreatment vessel vent process system (PVP) carbon bed adsorber. However, it was concluded in the above reference that the percentage of mercury converted to DMHg is low enough to preclude incorporation of this conversion into the flowsheets.

2.3.6 Pretreatment Engineering Platform Scaling Factors

The PEP was designed, constructed, and operated as part of a plan to respond to issue M12 "Undemonstrated Leaching Processes," of the EFRT IRP. The PEP is a 1/4.5-scale test platform designed to simulate the WTP PT Facility caustic leaching, oxidative leaching, ultrafiltration solids concentration, and slurry washing processes. The PEP replicates WTP processes with prototypic equipment and control strategies.

The results of laboratory bench-scale tests were compared to parallel PEP-scale tests to determine scale-up factors for caustic leaching, oxidative leaching, solids concentration, and slurry washing. The bases for flowsheet caustic leach factors, oxidative leach factors, solids concentration fluxes and washing efficiencies are data from laboratory bench-scale tests. It's presumed that the scale-up from laboratory bench-scale to PEP-scale will be same as the scale-up from bench scale to facility-scale (24590-QL-HC9-WA49-00001-03-00009). The PEP scale-up factors will be applied to the flowsheet to improve the fidelity of model predictions.

2.3.6.1 Solids Concentration Scaling Factors

Scale-up factors for low solids concentration and high solids concentration filtration were determined, i.e., Darcy equation and gel concentration filtration regimes. The scale-up factor for both regimes was 1.0 (CCN 200286). That is, on a per unit of filter surface area basis there is no significant difference between the bench scale and the PEP scale solids concentration filter flux.

2.3.6.2 Slurry Washing Scaling Factors

PEP testing indicated that the slurry washing operations can be modeled as an ideally mixed reactor (CCN 200288). That is, on a per unit of mass basis there is no significant difference between the bench scale and the PEP scale washing efficiency.

2.3.6.3 Oxidative Leaching Scaling Factors

The scale-up factor for oxidative leaching of chromium was 1.0 (CCN 200289). On a per unit of mass basis, there is no significant difference between the fraction of chromium oxidized at the bench scale and at the PEP scale.

2.3.6.4 Caustic Leaching Scaling Factors

The caustic leaching scale-up factor only applies to the leaching of boehmite. An alternate dynamic model aluminum caustic leaching algorithm was developed to better predict the impact of extended leaching times and alternative free hydroxide concentrations (See "Boehmite Dissolution Rate Kinetics," in Section 1.3.5). For this algorithm, aluminum solids in the WTP feed are allocated between an easily leached form (gibbsite), a difficult-to-leach form (boehmite), and a form that cannot be leached (cancrinite). During caustic leaching all the gibbsite is leached while none of the cancrinite is leached. Hence, there is no need for caustic leaching scale-up factors for gibbsite and cancrinite. The extent of boehmite conversion is estimated using a chemical reaction, kinetics-based correlation derived from bench-scale caustic leaching experiments. The kinetics correlation is a function of free hydroxide concentration, aluminate concentration, and initial boehmite mass. The kinetics correlation includes an Arrhenius reaction rate coefficient term. The scale-up factor for caustic leaching applies to the reaction rate coefficient. Separate scale-up factors were determined for upfront and backend caustic leaching.

Equation 2.3-26

$$\frac{dM}{dt} = -Ao \cdot e^{\left(\frac{-Ea}{R}\frac{1}{T+273}\right)} \cdot M^{2/3} \cdot [OH]^{n} \cdot \left(1 - \frac{C}{a \cdot C_{Sat}}\right)$$

where:

M is the fraction of boehmite yet to dissolve

Mo is not used directly in the equation but is used to adjust some parameters. Mo is the concentration of Al contribution from the dissolved boehmite if all the boehmite were to dissolve

Ao is the pre factor and equals 1.5063E+07

Ea is 60 kJ/mole

R is the gas constant, 8.314 J/moleK

n is 0.21 (empirically determined coefficient)

C is the total concentration of aluminate in solution

C_{Sat} is the boehmite equilibrium concentration of aluminate in solution

a is 1.12 and represents a correction to C_{Sat} to better represent the equilibrium in Hanford waste

The upfront caustic leaching PEP scale-up factor is 0.87 (CCN 200287). That is the value of the reaction rate coefficient measured in the PEP appears to be only 87 % of the value measured in bench scale tests. This scale-up factor has not been permanently incorporated into the Dynamic (G2) flowsheet as there is significant uncertainty regarding this value. The 95 % confidence interval surrounding the 0.87 value extends from 0.4 to 1.6. This scale-up factor has been applied to a limited number of dynamic model runs (24590-WTP-MRQ-09-0019).

The backend caustic leaching PEP scale-up factor is 1.38 (CCN 200287). There is significant uncertainty regarding this value, the 95 % confidence interval extends from 0.8 to 2.6 for this scale-up factor.

2.3.7 Ongoing Work and Potential Changes

- Additional full-scale vessel mixing tests are planned in the future.
- Process control parameters for "super-tank" operations are being developed as part of the resolution of EFRT issue M6, Process Operating Limits Not Completely Defined.
- Project Issue Evaluation report (PIER) 24590-WTP-PIER-MGT-12-0401-C states that several PTF hot cell pump sizing calculations may not adequately account for pump restart at vessel batch levels below the suction piping high point when determine minimum Net Positive Suction Head Available (NPSHa).

  Vessels in the PTF black cells were designed such that their pump suction nozzles are located above the lower vessel tangent line. In most cases, the suction nozzle is the suction pipe high point and located above the vessel's minimum operating level. The underlying assumption in pump sizing calculations for determination of NPSHa is fully developed fluid flow has been attained in the pump suction piping. The minimum reported NPSHa does not account for the pump performing any lift at start-up to flood its suction in the event that it drains due to interruption of pump operation when vessel fluid levels are below the suction highpoint. Although the vessel liquid level is typically above the highpoint in the pump suction line when the pump is started, there is possibility of pump interruption during vessel pump-down near the end of a vessel batch. Minimum NPSHa determined for pump sizing should consider all potential operating scenarios (i.e., worst-case conditions). The batch and heel volumes of UFP-VSL-00001A/B may require adjustment in response to 24590-WTP-PIER-MGT-12-0401-C.

2.3.8 References

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Table 2.3-1 Experimental Permeate Flux Data

Waste Source	Target TMP(psid)	Experimental TMP (psid)	Target Velocity (ft/s)	Experimental Velocity (ft/s)	Flux (gpm/ft2)	References
AZ-102 5.1 wt% solids	29.5	N/A	13.1	N/A	0.078	BNFL-RPT-038 Rev.0
AZ-102 13.7 wt% solids	29.4	N/A	11.5	N/A	0.050	
C-104 6.9 wt% solids	30	30.6	15	12	0.080	BNFL-RPT-030 Rev. 0
C-104 23 wt% solids	70	33.7	15	11.5	0.014	
AZ-101 7.6 wt% solids	51.5	N/A	12.7	N/A	0.031	24590-101-TSA-W000-0004-87-09 Rev.00B
AZ-101 17.9 wt% solids	49.1	N/A	12.7	N/A	0.023	
AN-107 dilute	50	49	12	11.9	0.028	BNFL-RPT-027 Rev. 0
AN-107 concentrated	50	49	12	N/A	0.030	
AN-102 14 wt% (14.5 wt%) solids	30	30	15	15.2	0.020	BNF-003-98-0317
AN-107 1.1 wt% solids	40	40	11	11.3	0.088	SCT-MOSRLE60-00-110-00020 Rev. 00A
AN-107 6.6 wt% solids	40	40	11	11.0	0.014	

TMP= Transmembrane Pressure which is the differential pressure between the concentrate (tube side) and permeate (shell side) sides of the filter membrane.

Table 2.3-2 Experimental Permeate Flux Data at High Solids Content

Waste Source (Actual Waste)	Weight Percent Solids (wt %)	Permeate Flux Range (gpm/ft^2)	Reference
AZ-101	17.9	0.011-0.025	24590-101-TSA-W000-0004-87-09, Rev 00B
AZ-102	13.7	0.02-0.051	BNFL-RPT-038, Rev 0
AY-102/C-106	16	0.013	SCT-M0SRLE60-00-187-00005, Rev 00B

Table 2.3-3 Average Initial Dewatering Filter Flux to 20 Wt % UDS

	Blended Grp 1/2	Blended Grp 3/4	Grp 5	Grp 6	Blended Grp 6/5	Grp 7	Blended Grp 7/ AY-102	Grp 8
Na Molarity, M	4.4	3.0	3.2	5.2	4.7	4	3.7	3.4
Average Measured J_1*, gpm/ft^2	0.017	0.022	0.06	0.011	0.034	0.018	0.015	0.027

(1) *All filter flux measurements were taken at standard transmembrane pressure (TMP) and axial velocity (AV), TMP= 40 psid and AV=13 ft/s and corrected for temperature.

(CCN 195030)

Table 2.3-4 Group 1 through 8 Average Filter Flux during Post-Caustic Wash

	Grp 1/2		Grp 3/4		Grp 5		Grp 6/5		Grp 7+AY-102	
Post Caustic Leach Washes	Average Filter flux at 5M (GPM/ft2)	% Increase*	Average Filter flux at 5M (GPM/ft2)	% Increase*	Average Filter flux at 5M (GPM/ft2)	% Increase*	Average Filter flux at 5M (GPM/ft2)	% Increase*	Average Filter flux at 5M (GPM/ft2)	% Increase*
1	0.015	-6.3	0.015	82.6	0.043	63.9	0.019	-69.2	0.005	-40.8
2	0.017	7.8	0.009	9.8	0.039	55.0	0.017	-64.6	0.004	-50.2
3	0.006	-27.4	0.007	-20.9	0.027	36.9	0.023	-44.2	0.004	-56.0
4	0.011	-20.2					0.012	-50.1	0.003	-61.4
5	0.009	-31.2					0.012	-59.8		
6							0.009	-60.5		

* % increase is from average dewatering flux before caustic leaching (CCN 195030)

Table 2.3-5 Experimental Leach Factors

Component	AZ-101	AZ-102	C-104	C-106	C-107
Al	0.70	0.667	0.971	0.31	0.82
Cr	0.93	0.583	0.521	0.49	0.7
F	>1	nd	nd	nd	nd
Fe	0	0.0003	0.004	0.00	0.00
La	0	nd	nd	nd	nd
Mn	0	nd	nd	nd	nd
Na	0.91	nd	nd	nd	nd
Ni	0	<0.001	0.466	0.02	nd
NO_2	>1	nd	nd	nd	nd
NO_3	>1	nd	nd	nd	nd
Pb	nd	<0.053	0.008	0.11	0.07
Si	0.40	nd	nd	nd	nd
SO_4	0.93	nd	nd	nd	nd
Sr	0	nd	nd	nd	nd
Zr	0	<0.001	0.001	0.02	0.00
^{60}Co	nd	<0.007	0.000	<0.043	0.031
^{90}Sr	0	0.0001	0.00004	0.0037	0.0014
^{125}Sb	nd	<0.099	0.00	nd	0.00
^{137}Cs	>1	nd	nd	nd	nd
^{154}Eu	<0.0060	<0.003	<0.001	0.01	0
^{155}Eu	<0.083	nd	nd	nd	nd
^{241}Am	0	0.000012	<0.005	nd	0.00

nd = not determined

Table 2.3-6 Summary of Chromium Phase Information in Hanford Tank Sludges

Phase	Tank	Waste Type[a]		Present After Caustic Leach
$Bi_{38}CrO_{60}$	B-111	2C	5-6	Yes
$Bi_{38}CrO_{60}$	T-104	1C	None	Yes
Cr(O)(OH) (grimaldite)	BY-110	TBP-F	EB-ITS	Yes
$CrPO_4$	T-104	1C	None	Yes
$Al/Cr(OH)_3(am)$[b]	SY-103	CC	None	Yes
$Al/Cr(OH)_3(am)$[b]	U-108	EB	CW	Not Determined
Cr(oxide/hydroxide)(am)[c]	U-108	EB	CW	Not Determined
$NaAlO_2/Cr(OH)_3(am)$[d]	AN-104	DSSF	None	Yes
Ca/Cr phase	AN-104	TBP-F	None	Yes
$Fe(Cr_3Fe)_2O$ (donathaite)	BY-104	TBP_F	EB-ITS	Yes
$FeCr_2O_4$	S-111	R	EB	Yes
$CrMn_2O_4$	S-111	R	EB	Yes
$Cr_{1.5}Mn_{1.5}O_4$	S-111	R	EB	Yes

(a) Based on SORWT Model (Hill et al. 1995);R=high-level reduction-oxidation waste, EB=evaporator bottom, CC=Complex concentrate, DSSF=double shell slurry feed, 1C= first decontamination cycle waste, 2C=second decontamination cycle waste, ITS=in-tank solidification, 5-6=high-level B plant waste from the bottom of Section 5, CW=Cladding waste, TBP-F=Tributyl phosphate ferrocyanide scavenged waste.

(b) Chromium and aluminum hydroxide associated with each other.

(c) Chromium in an oxide or hydroxide environment.

(d) Chromium associated with amorphous sodium aluminate.

Table 2.3-7 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Samples are from washed sludge composite unless noted otherwise

Tank	Oxidant	Initial $[OH]^-$ M	Temp(°C)	% Cr Removed	% Pu Removed	Reference
SY-103	$[MnO_4]^-$	0.01	80	90	0.01[c]	Rapko et al. 1996b
	O_3	0.01	80	89	5.3	Rapko et al. 1996b
	air	0.01	80	34	0.02	Rapko et al. 1996b
B-111	$[MnO_4]^-$	0.01	80	18	0.02[c]	Rapko et al. 1996b
	O_3	0.01	80	12	0.07[c]	Rapko et al. 1996b
	air	0.01	80	5	0.07[c]	Rapko et al. 1996b

Table 2.3-7 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Samples are from washed sludge composite unless noted otherwise

Tank	Oxidant	Initial $[OH]^-$ M	Temp(°C)	% Cr Removed	% Pu Removed	Reference
BY-110	$[MnO_4]^-$	0.01	80	83	0.01	Rapko et al. 1997
	O_3	0.01	80	83	0	Rapko et al. 1997
	O_2	0.01	80	2	<0.01	Rapko et al. 1997
	Ar	0.01	80	8	<0.01	Rapko et al. 1997
	$[MnO_4]^-$	3	80	94	13.4	Rapko et al. 1997
	O_3	3	80	90	3.91	Rapko et al. 1997
	O_2	3	80	11	0.19	Rapko et al. 1997
	Ar	3	80	28	0.17	Rapko et al. 1997
SX-108	$[MnO_4]^-$	0.1	80	22	0.09	Rapko et al. 1997
	O_3	0.1	80	42	0.01	Rapko et al. 1997
	$[MnO_4]^-$	3	80	45	2.09	Rapko et al. 1997
	O_3	3	80	33	0.09	Rapko et al. 1997
S-107	$[MnO_4]^-$	0.1	80	58	0.11	Rapko et al. 1997
	O_3	0.1	80	84	0.01	Rapko et al. 1997
	O_2	0.1	80	8	<0.01	Rapko et al. 1997
	Ar	0.1	80	5	<0.01	Rapko et al. 1997
	$[MnO_4]^-$	3	80	80	4.97	Rapko et al. 1997
	O_3	3	80	87	0.13	Rapko et al. 1997
	O_2	3	80	65	<0.01	Rapko et al. 1997
	Ar	3	80	ND	ND	Rapko et al. 1997
U-108[a]	$[MnO_4]^-$	0.1	80	97	1	Rapko et al. 1998
	O_3	0.1	80	5	0	Rapko et al. 1998
	air	0.1	80	0.6	0.02	Rapko et al. 1998
	$[MnO_4]^-$	3	80	99.6	50	Rapko et al. 1998
	O_3	3	80	94	2	Rapko et al. 1998
	air	3	80	5	0.09	Rapko et al. 1998

Table 2.3-7 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Samples are from washed sludge composite unless noted otherwise

Tank	Oxidant	Initial $[OH]^-$ M	Temp(°C)	% Cr Removed	% Pu Removed	Reference
U-109[a]	$[MnO_4]^-$	0.1	80	96	1	Rapko et al. 1998
	O_3	0.1	80	14	0	Rapko et al. 1998
	air	0.1	80	2	0	Rapko et al. 1998
	$[MnO_4]^-$	3	80	99	36	Rapko et al. 1998
	O_3	3	80	98	1	Rapko et al. 1998
	air	3	80	5	0.03	Rapko et al. 1998
SX-108[b]	$[MnO_4]^-$	0.1	80	29	0.53	Rapko et al. 1998
	O_2	0.1	80	5	0.0053	Rapko et al. 1998
	$[MnO_4]^-$	3	80	64	2	Rapko et al. 1998
	O_2	3	80	71	0.25	Rapko et al. 1998
S-110	$[MnO_4]^-$	0.1	30	87	0.6	Rapko et al. 2002
	$[S_2O_8]^{2-}$	0.1	30	48	0.1	Rapko et al. 2002
	$[FeO_4]^{2-}$	1.1	30	88	9	Rapko et al. 2002
	air	0.1	30	5	0.01	Rapko et al. 2002
	$[MnO_4]^-$	0.1	80	90	1.5	Rapko et al. 2002
	$[S_2O_8]^{2-}$	0.1	80	89	5.3	Rapko et al. 2002
	$[FeO_4]^{2-}$	1.1	80	95	1.1	Rapko et al. 2002
	air	0.1	85	25	<0.01	Rapko et al. 2002
	$[MnO_4]^-$	3	30	93	7	Rapko et al. 2002
	$[S_2O_8]^{2-}$	3	30	89	8	Rapko et al. 2002
	$[FeO_4]^{2-}$	3	30	90	8	Rapko et al. 2002
	air	3	30	10	0.5	Rapko et al. 2002
	$[MnO_4]^-$	3	80	95	11	Rapko et al. 2002
	$[S_2O_8]^{2-}$	3	80	94	10	Rapko et al. 2002
	$[FeO_4]^{2-}$	3	80	94	3	Rapko et al. 2002
	air	3	85	72	0.8	Rapko et al. 2002

Table 2.3-7 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Samples are from washed sludge composite unless noted otherwise

Tank	Oxidant	Initial $[OH]^-$ M	Temp(°C)	% Cr Removed	% Pu Removed	Reference
U-108	$[MnO_4]^-$	0.1	30	91	0.2	Rapko and Vienna 2002
	$[ONOO]^-$	0.1	30	60	0.7	Rapko and Vienna 2002
	air	0.1	30	1	0.7	Rapko and Vienna 2002
	$[MnO_4]^-$	3	85	99	69	Rapko and Vienna 2002
	$[ONOO]^-$	3	85	58	0.5	Rapko and Vienna 2002
	air	3	85	13	1.8	Rapko and Vienna 2002

(a) From washed saltcake.

(b) From caustic leached sludge

(c) Based on total activity.

ND = Not Determined

$[MnO_4]^-$ = Leach solution contacted with permanganate.

O_3 = Leach solution contacted with ozone.

O_2 = Leach solution contacted pure oxygen

air = Leach solution contacted with atmosphere

$[ONOO]^-$ = Leach solution contacted with peroxynitrite

$[S_2O_8]^{2-}$ = Leach solution contacted with persulfate

$[FeO_4]^{2-}$ = Leach solution contacted with ferrate

Table 2.3-8 Experimental Conditions for Oxidative-Alkaline Leaching Tests (24590-101-TSA-W000-0004-99-00012)

Test #	Caustic (OH^-) Oxidative (MnO_4^-) Leach Order	NaOH Conc. (M) during Oxidative Leach	Temperature during Oxidative Leach (°C)	Permanganate to Chrome (moles/mole)
1	Concurrent	3	85	1.1
2	Concurrent	5	85	5
3	OH^- then MnO_4^-	0.25	25	1.1
4	OH^- then MnO_4^-	0.25	85	1.1
5	MnO_4^- then OH^-	0.25	25	1.1
6	MnO_4^- then OH^-	0.25	85	1.1

Table 2.3-9 Radionuclide Removals from SX-101 and SY-102 Washed Sludge by Oxidative-Alkaline Leaching (24590-101-TSA-W000-0004-99-00012)

Test #	% Component Removal						
	$Pu^{239/240}$	Am^{241}	$Cm^{243,244}$	Total Alpha	Co^{60}	Cs^{137}	Eu^{154}
SX-101-1	13	<0.1	<0.1	3.2	<0.1	27	<0.1
SX-101-2	<0.1	<0.1	<0.1	<0.1	<0.1	33	<0.1
SX-101-3	<0.1	<0.1	<0.1	<0.1	<0.1	33[(a)]	<0.1
SX-101-4	<0.1	<0.1	<0.1	<0.1	<0.1	33[(a)]	<0.1
SX-101-5	1.1[(a)]	<0.1	<0.1	0.3[(a)]	<0.1	38	<0.1
SX-101-6	2.8[(a)]	<0.1	<0.1	0.7[(a)]	<0.1	29	<0.1
SY-102-1	0.6	<0.1	<0.1	0.1	<0.1	22	<0.1
SY-102-2	<0.1	<0.1	<0.1	<0.1	<0.1	37	<0.1
SY-102-3	<0.1	<0.1	<0.1	<0.1	<0.1	40[(a)]	<0.1
SY-102-4	<0.1	<0.1	<0.1	<0.1	<0.1	41[(a)]	<0.1
SY-102-5	<0.1[(a)]	<0.1	<0.1	<0.1[(a)]	<0.1	41[(a)]	<0.1
SY-102-6	0.2[(a)]	<0.1	<0.1	<0.1[(a)]	<0.1	37	<0.1

(a) Component fraction removed during standard caustic leach greater than that removed during oxidative-alkaline leaching.

Table 2.3-10 Additional Experimental Results of Permanganate Leaching of Hanford Tank Sludge

Tank sample	Waste Source Type	$[MnO_4]$, $[OH]^-$ M, Temp °C	$[Cr]_{initial}$ (µg/g dried solid)	$[Cr]_{final}$ (µg/g dried solid)	% Cr Removed	Reference Document
SY-103	Caustic-Leached Sludge	0.01, 80	220000	Not available	90	Rapko et al. 1996b
B-111	Caustic-Leached Sludge	0.01, 80	7000	Not available	18	Rapko et al. 1996b
Sy-102	Washed Sludge	0.1, RT	11600	Not available	65	Lumetta and Swanson 1993
Sy-102	Washed Sludge	0.1, 100	11600	Not available	72	Lumetta and Swanson 1993
U-108	Washed Sludge Composite	0.1, 30	200000	20108[(a)]	91	Rapko and Vienna 2002
U-108	Washed Sludge Composite	3, 85	200000	3038	99	Rapko and Vienna 2002
S-110	Washed Sludge Composite	0.1, 30	23050	3290	87	Rapko et al. 2002

Table 2.3-10 Additional Experimental Results of Permanganate Leaching of Hanford Tank Sludge

Tank sample	Waste Source Type	$[MnO_4]$, $[OH]^-$ M, Temp °C	$[Cr]_{initial}$ (µg/g dried solid)	$[Cr]_{final}$ (µg/g dried solid)	% Cr Removed	Reference Document
S-110	Washed Sludge Composite	3, 85	23050	2310	95	Rapko et al. 2002
U-108	Washed Saltcake Solids	0.1, RT	112000	3775	96.6	Rapko 1998
U-108	Washed Saltcake Solids	3, 80	112000	1200	99.6	Rapko 1998
U-109	Washed Saltcake Solids	0.1, RT	255000	8870[(a)]	96.3	Rapko 1998
U-109	Washed Saltcake Solids	3, 80	255000	2840	98.9	Rapko 1998
SX-108	Caustic-Leached Sludge	0.1, RT	1320	5240[(a)]	29	Rapko 1998
SX-108	Water-Washed Sludge Composite	3, 80	4270	4820	64	Rapko 1998
BY-110	Water-Washed Sludge Composite	0.1, 80	19250	3800	83	Rapko et al. 1997
BY-110	Water-Washed Sludge Composite	3, 80	19250	703	94	Rapko et al. 1997
S-107	Water-Washed Sludge Composite	0.1, 80	13100	3850	58	Rapko et al. 1997
S-107	Water-Washed Sludge Composite	3, 80	13100	1090	80	Rapko et al. 1997
SX-108	Water-Washed Sludge Composite	0.1, 80	5760	4205	22	Rapko et al. 1997
SXC-108	Water-Washed Sludge Composite	3, 80	5760	1270	45	Rapko et al. 1997

(a) Tests that exceed 5000 ppm residual chromium; RT = Room Temperature.

Table 2.3-11 Key Components Leach Response to Sequential Caustic Leaching (CL)/Oxidative Leaching (OL) (24590-101-TSA-W000-0004-168-00002)

	Al, % Removed		Cr, % Removed		Pu, % Removed	
Test #	OL	CL	OL	CL	OL	CL
SX-101-3; CL, then OL, 30 °C	4	79	82	6	0	0
SX-101-4; CL, then OL, 85 °C	10	79	89	5	0	0
SX-101-5; OL, 30 °C, then CL[(a)]	44/93	53/0	35/81	29/9	0/29[(b)]	1/1[(b)]

Table 2.3-11 Key Components Leach Response to Sequential Caustic Leaching (CL)/Oxidative Leaching (OL) (24590-101-TSA-W000-0004-168-00002)

Test #	Al, % Removed		Cr, % Removed		Pu, % Removed	
	OL	CL	OL	CL	OL	CL
SX-101-6; OL, 85 °C, then CL	14	83	94	3	0	3
SY-102-3; CL, then OL, 30 °C	5	72	76	4	0	0
SY-102-4; CL, then OL, 85 °C	9	69	91	4	0	0
SY-102-5; OL, 30 °C, then CL[(a)]	53/0	42/87	42/81	33/11	0/0	0/0
SY-102-6; OL, 85 °C, then CL	5	84	90	6	0	0

(a) Left hand column calculated with the standard method; right hand column calculated with the following alternative method: OL% removed = 100*[Feed - (Residue+Caustic Leachate)]/Feed.

(b) Suspect data - see text for discussion.

Table 2.3-12 Summary of Al and Cr Leach Behavior with SX-101 Washed Sludge

Component	SX-101-3, % Removed			SX-101-4, % Removed		
	CL	OL	Total	CL	OL	Total
Cr	6	82	88	5	89	94
Al	79	4	83	79	10	89
Component	**SX-101-5, % Removed**			**SX-101-6, % Removed**		
	OL	CL	Total	OL	CL	Total
Cr	35	29	64	94	3	97
Al	53	44	97	14	83	97

Table 2.3-13 Summary of Al and Cr Leach behavior with SY-102 washed sludge

Component	SY-102-3, % Removed			SY-102-4, % Removed		
	CL	OL	Total	CL	OL	Total
Cr	4	76	80	4	91	95
Al	77	5	76	69	9	78
Component	**SY-102-5, % Removed**			**SY-102-6, % Removed**		
	OL	CL	Total	OL	CL	Total
Cr	35	33	75	90	6	96
Al	53	42	94	5	84	89

Table 2.3-14 Key Component Distribution for Test with 0.25 M NaOH at 25 °C

Component	Caustic Leachate, %	Oxidative Leachate, %	Residual Solids, %
Cr	1.35	83.56	15.09
Fe	0	0	100
Mn	0	29.94	70.06
Ni	0.06	0	99.94
U(ICP-OES)	0.23	0.27	99.5
Zn	0.80	0	99.2
Pu	.06	0.46	99.48
U(KPA)	0.37	1.18	98.45

Table 2.3-15 Key Component Distribution for test with 1.25 M NaOH at 25 °C

Component	Caustic Leachate, %	Oxidative Leachate, %	Residual Solids, %
Cr	1.35	83.56	15.09
Fe	0	0	100
Mn	0	29.94	70.06
Ni	0.06	0	99.94
U(ICP-OES)	0.23	0.27	99.5
Zn	0.80	0	99.2
Pu	.06	0.46	99.48
U(KPA)	0.37	1.18	98.45

Table 2.3-16 Key Component Distribution for test with 3 M NaOH at 25 °C

Component	Caustic Leachate, %	Oxidative Leachate, %	Residual Solids, %
Cr	1.44	81.148	17.42
Fe	0	0	100
Mn	0	42.60	57.4
Ni	0.0	0.0	100
U(ICP-OES)	0.21	1.55	98.24
Zn	0.90	0	99.1
Pu	0.29	2.7	97.01
U(KPA)	0.30	2.41	97.29

Table 2.3-17 Key Component Distribution for test with 0.25 M NaOH at 45 °C

Component	Caustic Leachate, %	Oxidative Leachate, %	Residual Solids, %
Cr	1.23	84.40	14.37
Fe	0	0	100
Mn	0	31.26	68.74
Ni	0.0	0	100
U(ICP-OES)	0.18	5.15	94.66
Zn	0.85	0	99.15
Pu	0.18	0.2	99.62
U(KPA)	0.23	2.74	97.03

Table 2.3-18 Key Component Distribution for test with 1.25 M NaOH at 45 °C

Component	Caustic Leachate, %	Oxidative Leachate, %	Residual Solids, %
Cr	1.55	86.07	12.38
Fe	0	0	100
Mn	0	41.68	58.32
Ni	0.0	0.11	99.89
U(ICP-OES)	0.33	0.55	99.11
Zn	1.03	0.0	98.97
Pu	0.49	0.23	99.28
U(KPA)	0.37	1.23	98.40

Table 2.3-19 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Component	Caustic Leachate, %	Oxidative Leachate, %	Residual Solids, %
Cr	2.02	86.91	11.07
Fe	0.01	0.0	99.99
Mn	0.0	64.64	35.36
Ni	0.0	0.17	99.47
U(ICP-OES)	0.53	0.0	99.5
Zn	2.15	0.0	97.85
Pu	1.38	1.51	97.11
U(KPA)	0.53	0.90	98.57

Table 2.3-20 Group 5 REDOX Sludge Mineral Phases (24590-QL-HC9-WA49_00001-03-00010 Rev 00B)

Crystalline Phase	Chemical Structure	Weight %	Basis[a]
Boehmite	AlOOH	66.8	Observed
Gibbsite	$Al(OH)_3$	5.1	Observed
Zeolite A (Protopic and bounding based [Si])	$NaSiAlO_4$	3.1	Assigned
Sodium Uranium Oxide	$Na_2U_2O_7$	2.6	Observed
Cancrinite (prototypical and bounding based on [Ca])	$Na_6Ca_2Al_6Si_6O_{24}(CO_3)_2$	1.7	Assigned
Iron Oxide	Fe_2O_3	1.0	Observed
Unknown or amorphous Cr, Mn, Ni, Sr	Cr, Mn, Ni, Sr	0.8	Chem Analysis
Unaccounted Sodium	Na	2.0	Assigned
Entrained Na salts from supernatant	Various	9.6	Observed and calculated
Assumed counter ions	oxides, hydroxides, etc.	7.3	Balance
Sum		100	

(a) *Observed* indicates that the characteristic crystal diffraction pattern of the identified crystalline phase was observed in the sample XRD pattern.

Chemical Analysis indicates that the element mass was determined from the solids chemical characterization.

TGA indicates that the structure was inferred from the TGA analysis study

Calculated indicates that the mass associated with supernatant entrainment was calculated based on the Supernatant dilution factor during solids washing.

Balance is the mass balance resulting in 100% composition. This mass is probably associated with oxides, hydroxides, etc. associated with the metals (e.g., iron hydroxide).

Table 2.3-21 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Crystalline Phase	Chemical Structure	Weight %	Basis[a]
Gibbsite		39.4	Observed
Boehmite		8.9	Observed
Sodium oxalate		14.1	Observed
Cancrinite		6.7	Observed
Silicon Dioxide		1.0	Observed
Sodium uranium oxide		0.6	Observed
Chromium oxide		13.6	TGA
Unknown or amorphous Na		2.3	Chemical analysis
Unknown or amorphous Bi, Fe, Mn, Ni, P, Sr, Zn		3.0	Chemical analysis

Table 2.3-21 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Crystalline Phase	Chemical Structure	Weight %	Basis[a]
Entrained Na salts from supernatant		3.1	Observed and Calculated
Assumed Counter ions		7.3	Balance
	Total	100	

(a) *Observed* indicates that the characteristic crystal diffraction pattern of the identified crystalline phase was observed in the sample XRD pattern.

Chemical Analysis indicates that the element mass was determined from the solids chemical characterization.

TGA indicates that the structure was inferred from the TGA analysis study

Calculated indicates that the mass associated with supernatant entrainment was calculated based on the Supernatant dilution factor during solids washing.

Balance is the mass balance resulting in 100% composition. This mass is probably associated with oxides, hydroxides, etc. associated with the metals (e.g., iron hydroxide).

Table 2.3-22 Radionuclide Characterization of Group 5 REDOX Washed Solids (24590-QL-HC9-WA49-00001-03-00010, Page 5.8)

Analyte	µCi/g[a]	RPD
^{137}Cs	5.33E+1	1.7
^{60}Co	1.23E-2	4.1
^{241}Am	2.9E-1	16
^{238}Pu	2.27E-2	3.5
$^{239+240}Pu$	8.83E-1	9.0
^{90}Sr	6.62E+2	0.15
Gross alpha	8.71E-1	35
Alpha sum	1.22E+0	4.1
Gross beta	1.52E+3	0.66
Sum of beta	1.38E+3	0.88
Opportunistic		
^{54}Mn	9.16E-3	31.4
^{154}Eu	1.23E-1	2.4

Table 2.3-23 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Analyte	µCi/g[a]	RPD
^{137}Cs	1.00E+2	2
^{60}Co	6/35E-2	4

Table 2.3-23 Summary of PNNL Oxidative-Alkaline Leaching with Washed Hanford Tank

Analyte	µCi/g[(a)]	RPD
^{241}Am	4.57E+0	11
^{238}Pu	1.22E-1	7.4
$^{239+240}$Pu	9.23E-1	1.7
^{90}Sr	2.66E+2	2.3
Gross alpha	5.54E+2	0.54
Alpha sum	5.61E+0	8.4
Gross beta	6.27E+2	3.7
Opportunistic		
^{54}Mn	1.43E+0	4.2
^{154}Eu	5.47E-1	6.4

Table 2.3-24 Effect of AFA on Chromium Removal from Simulated Tank Sludge by Oxidative Leach Tests

Test #	AFA mg/L	Initial Cr, µg/g	Initial Total Cr µg	Final Cr µg/g	Final Total µg	Fraction Removed
1	0	120,000	540,000	29,000	90,000	.83
2	0	79,000	530,000	37,000	110,000	.79
3	0	110,000	570,000	22,000	65,000	.89
4a	175	110,000	570,000	23,000	68,000	.88
4b	350	110,000	570,000	27,000	81,000	.86
4c	350	120,000	570,000	8,800	26,000	.95
5	700	100,000	580,000	6,300	19,000	.97
6	700	100,000	770,000	8,000	24,000	.97
7	700	92,000	560,000	8,700	27,000	.95
8a	700	86,000	560,000	7,800	24,000	.96
8b	350	88,000	560,000	8,800	27,000	.95
8c	350	57,000	550,000	7,200	22,000	.96
9	700	110,000	700,000	10,000	31,000	.96
10	700	99,000	550,000	6,700	21,000	.96

Figure 2.3-1 Ultrafiltration Process System

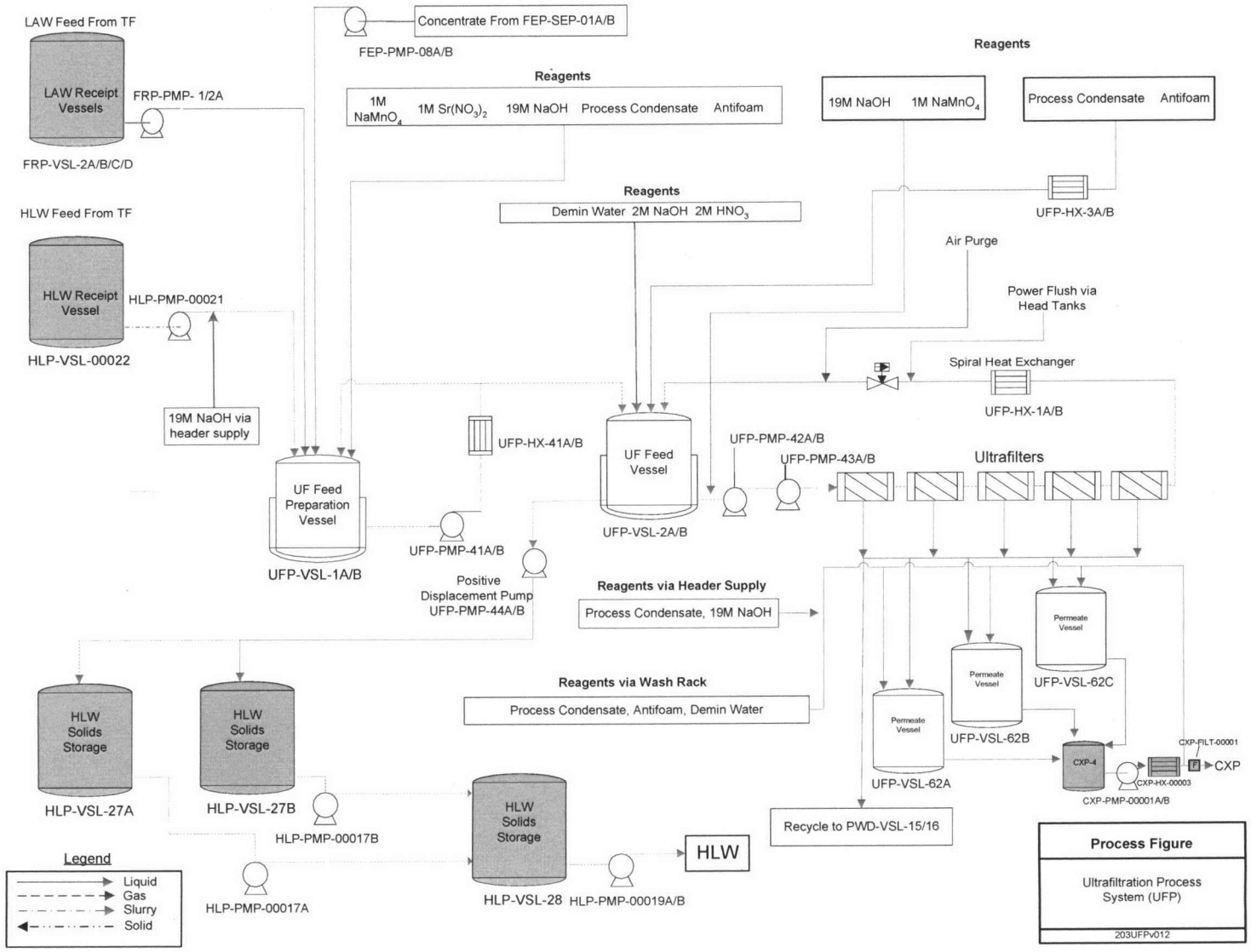


Figure 2.3-2 Simplified Crossflow Filter

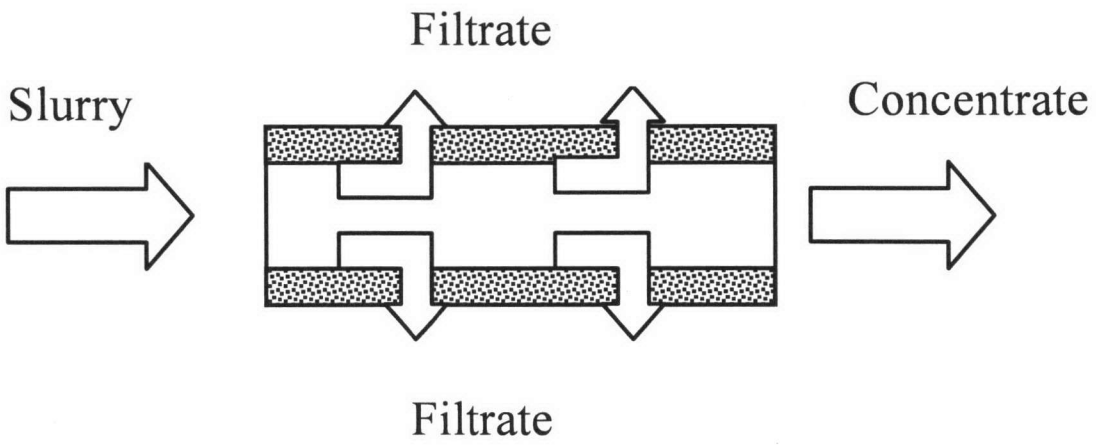
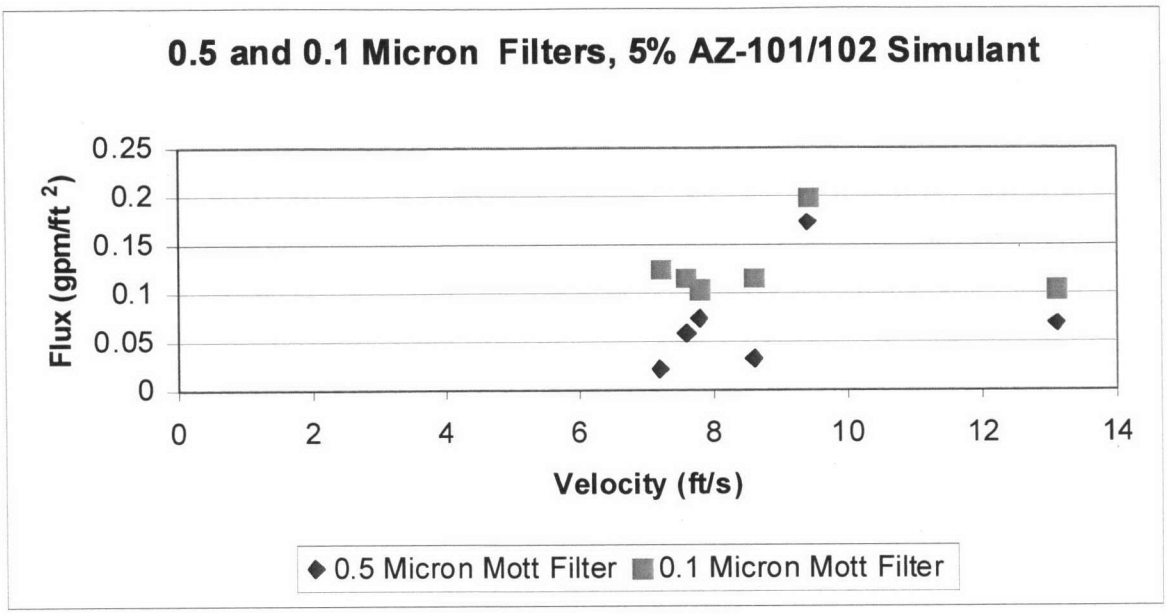


Figure 2.3-3 0.5 and 0.1 Micron Filter, 5 % AZ-101/102 Simulant



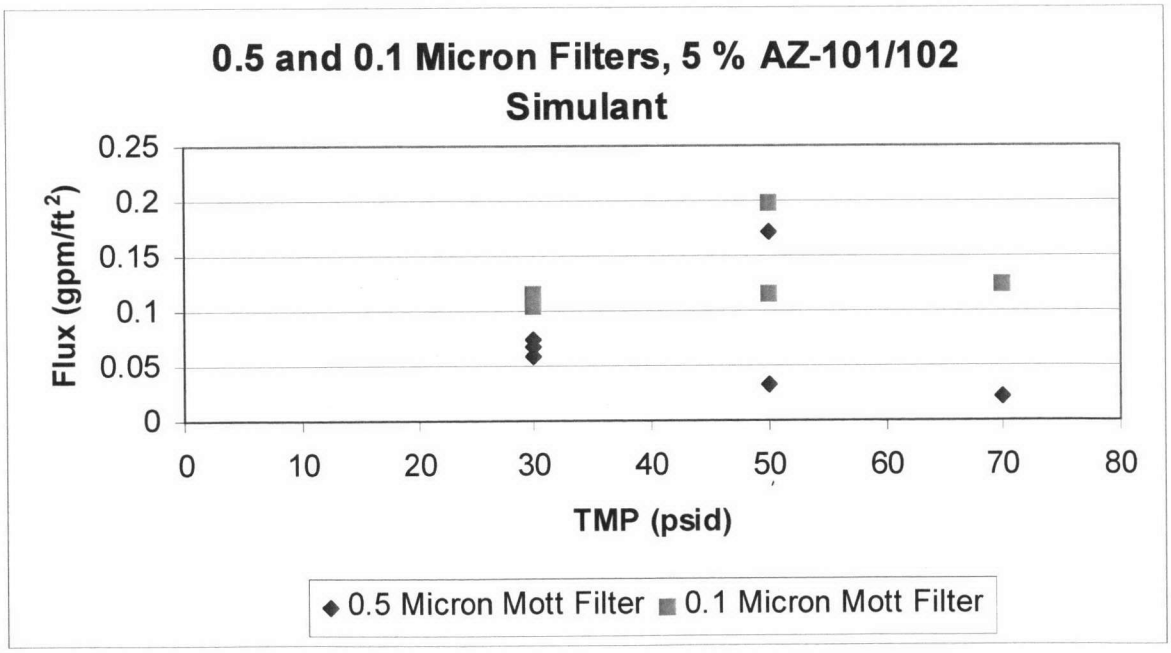
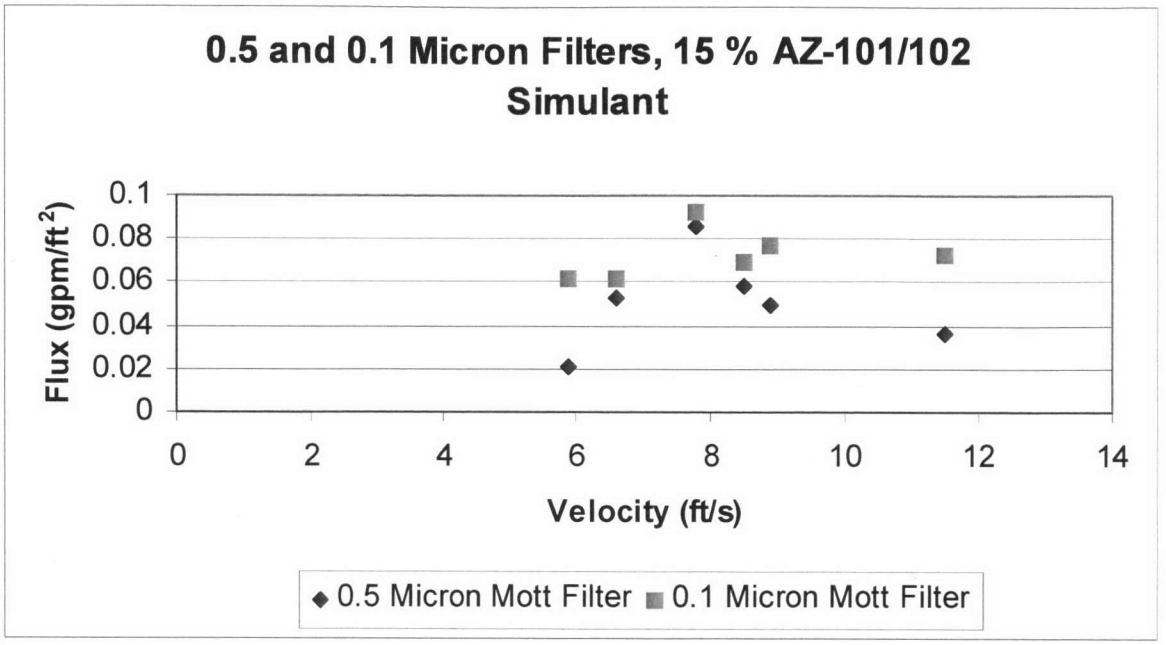


Figure 2.3-4 0.5 and 0.1 Micron Filter, 15 % AZ-101/102 Simulant



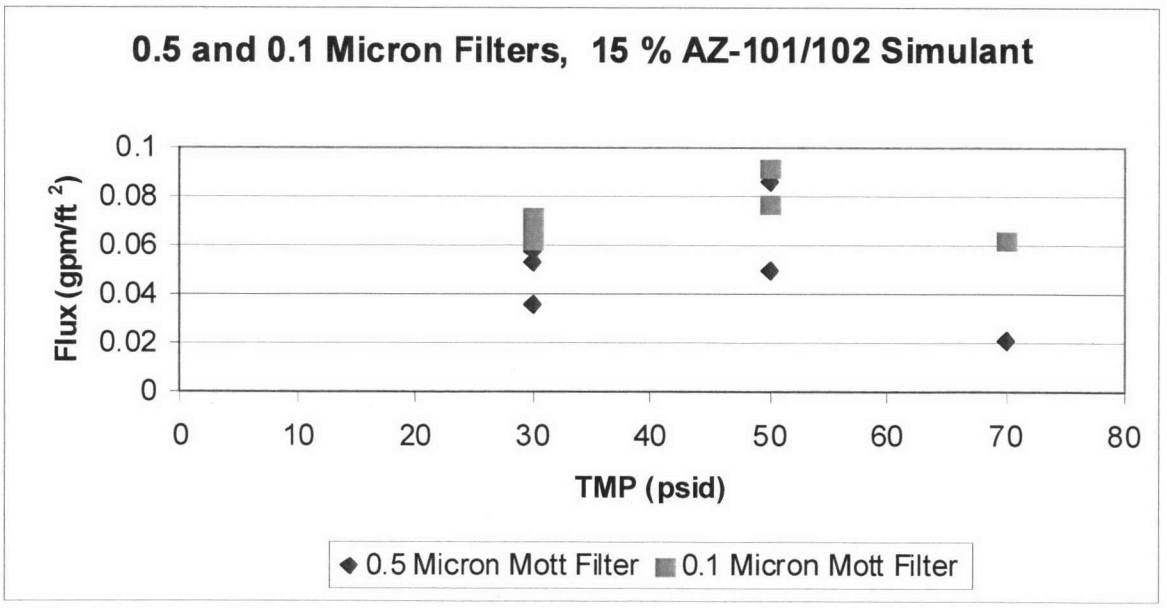


Figure 2.3-5 Caustic Leached Group 8/7/AY-102

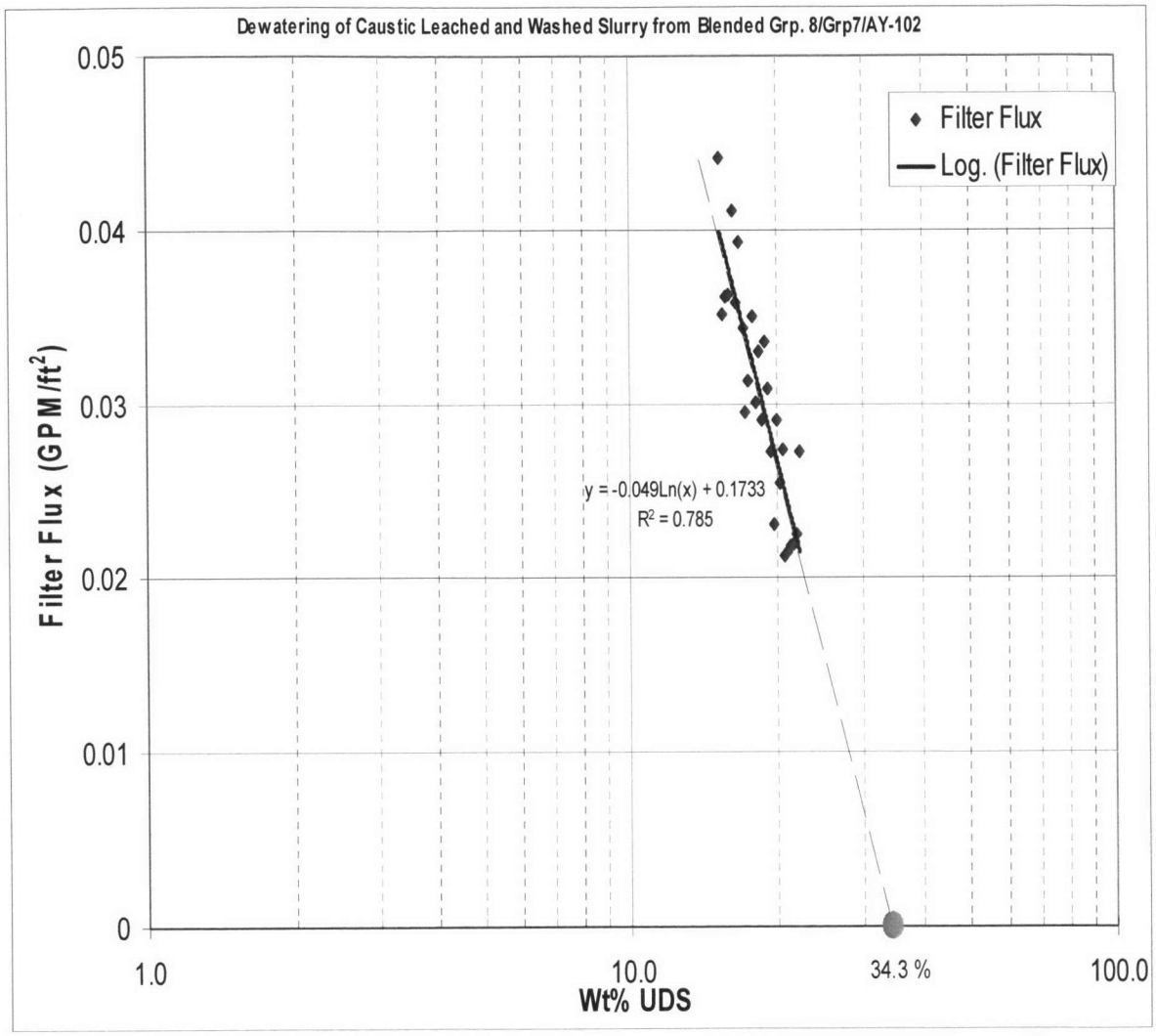


Figure 2.3-6 Darcy and Gel Concentration Models

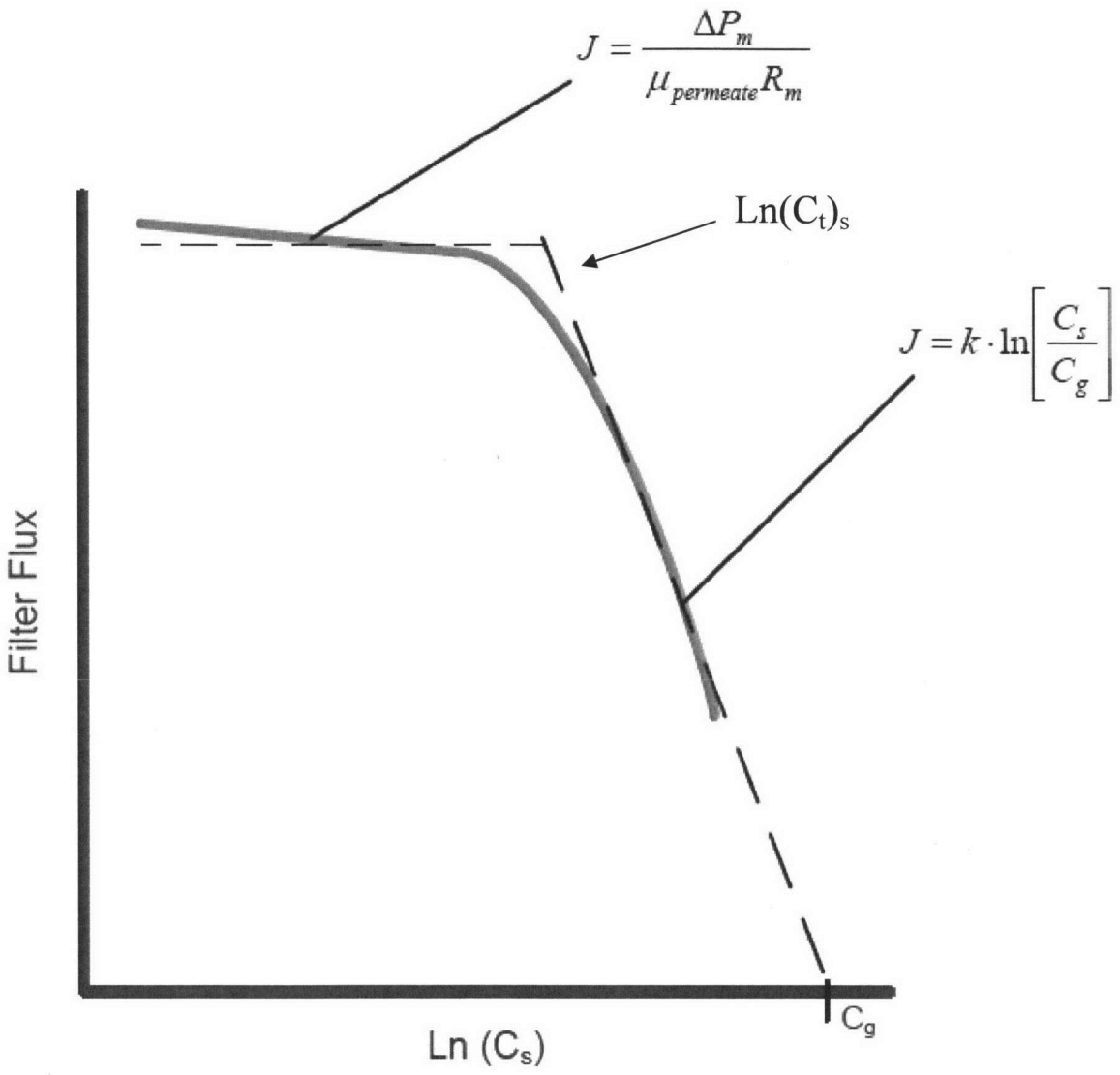


Figure 2.3-7 Groups 1 through 8 Pre Caustic Leach

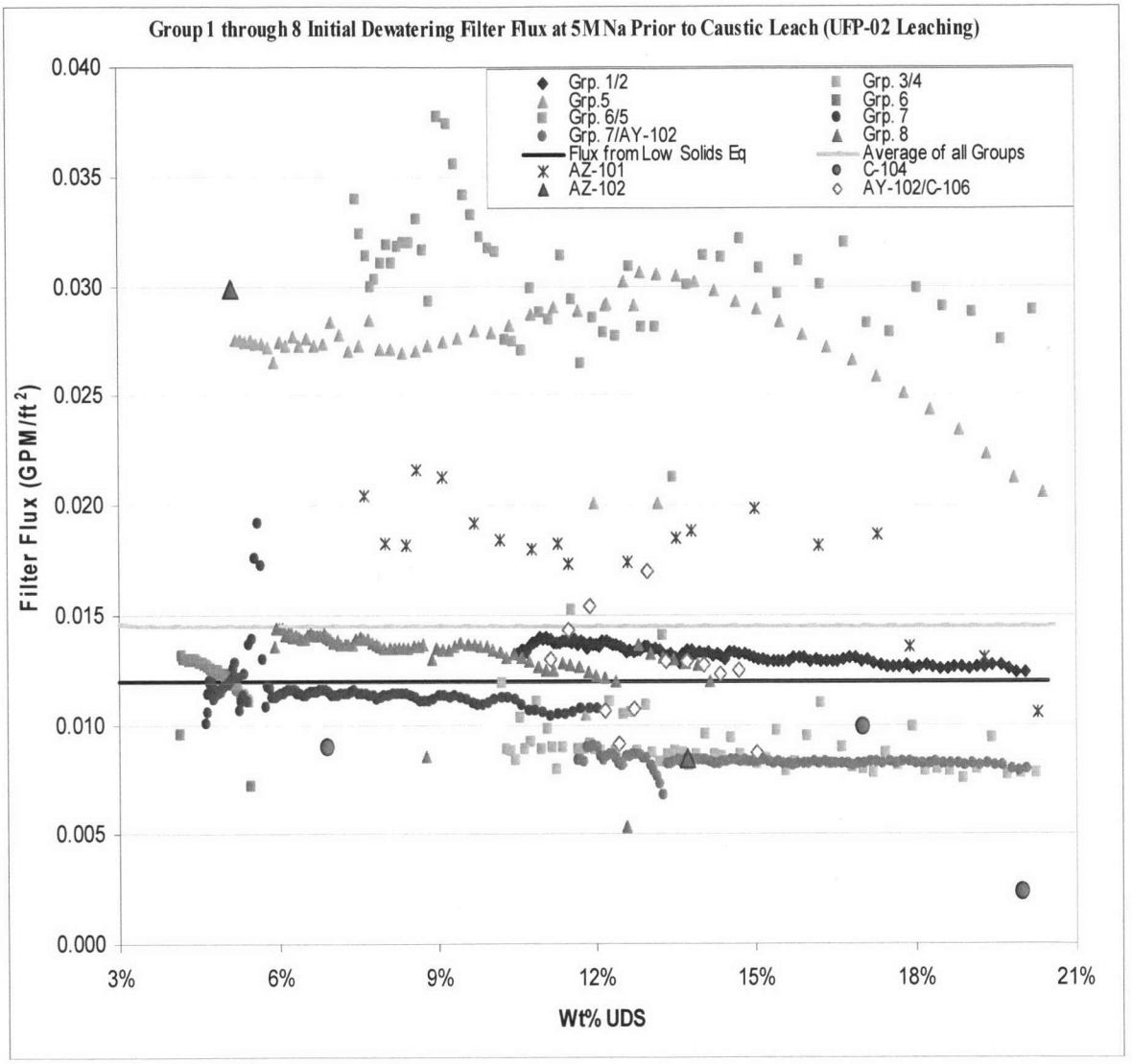


Figure 2.3-8 Post Caustic Leach Data with Avg Curve Fit

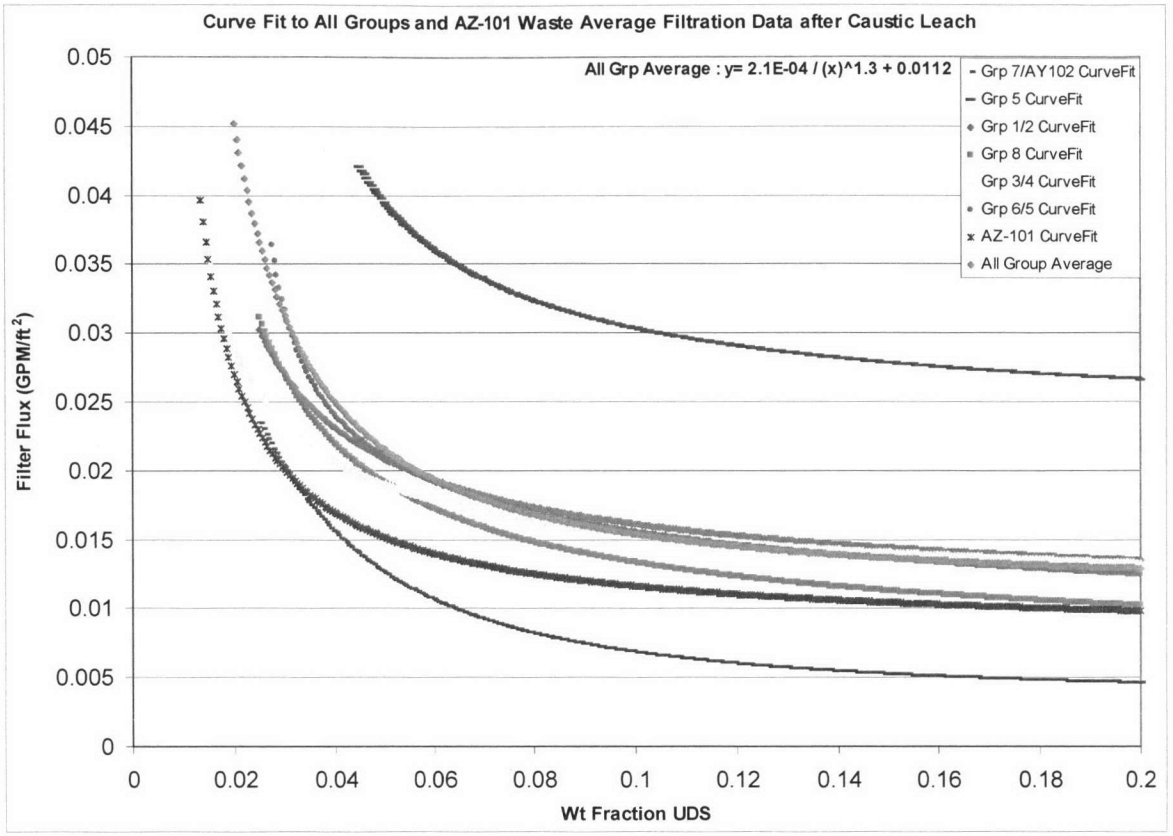


Figure 2.3-9 Group 1 through 7 Post Caustic Leach Wash

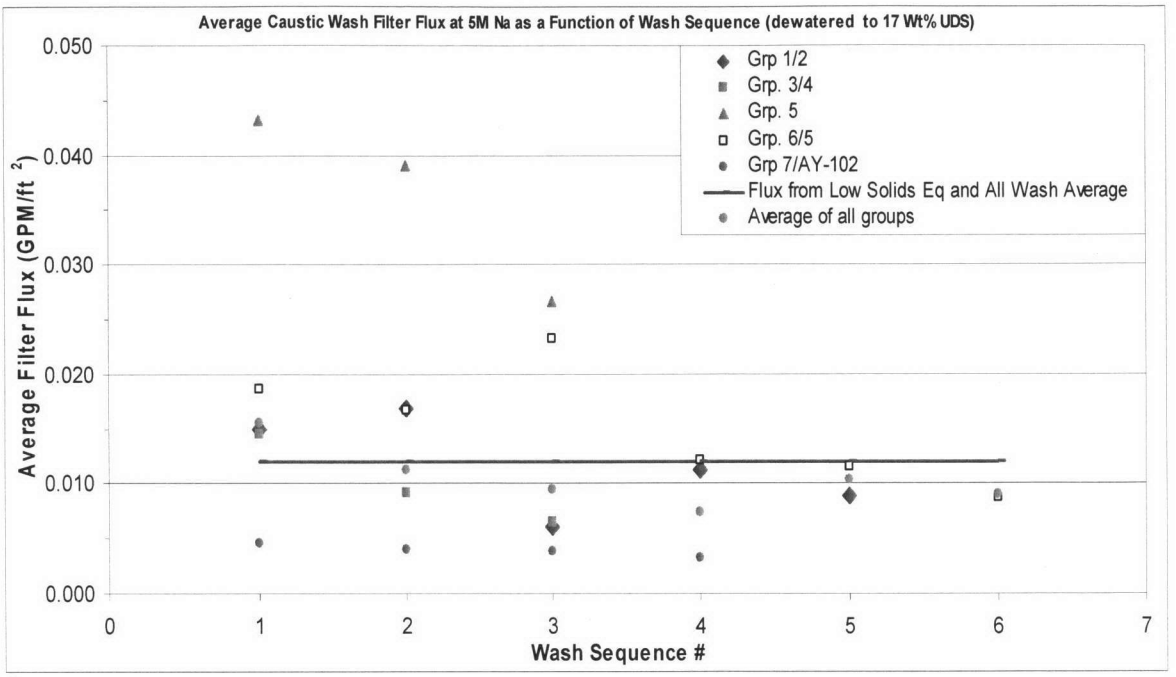


Figure 2.3-10 Post Oxidative Leach Washing

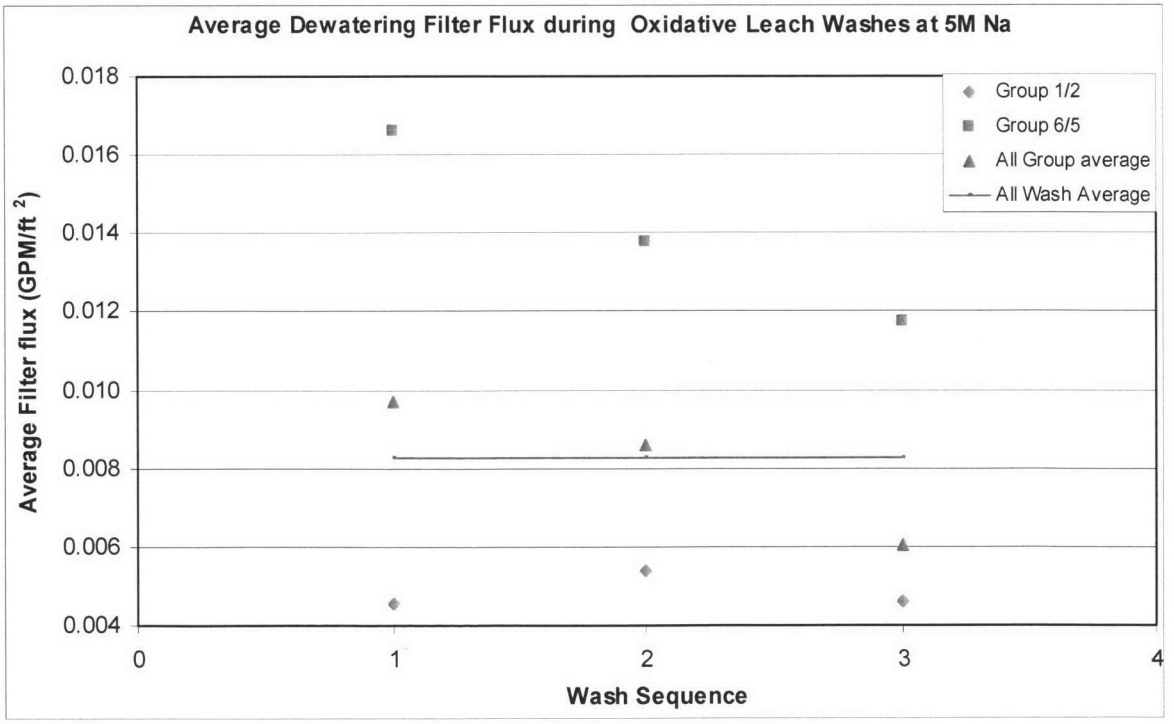


Figure 2.3-11 Required Strontium Decontamination Factors

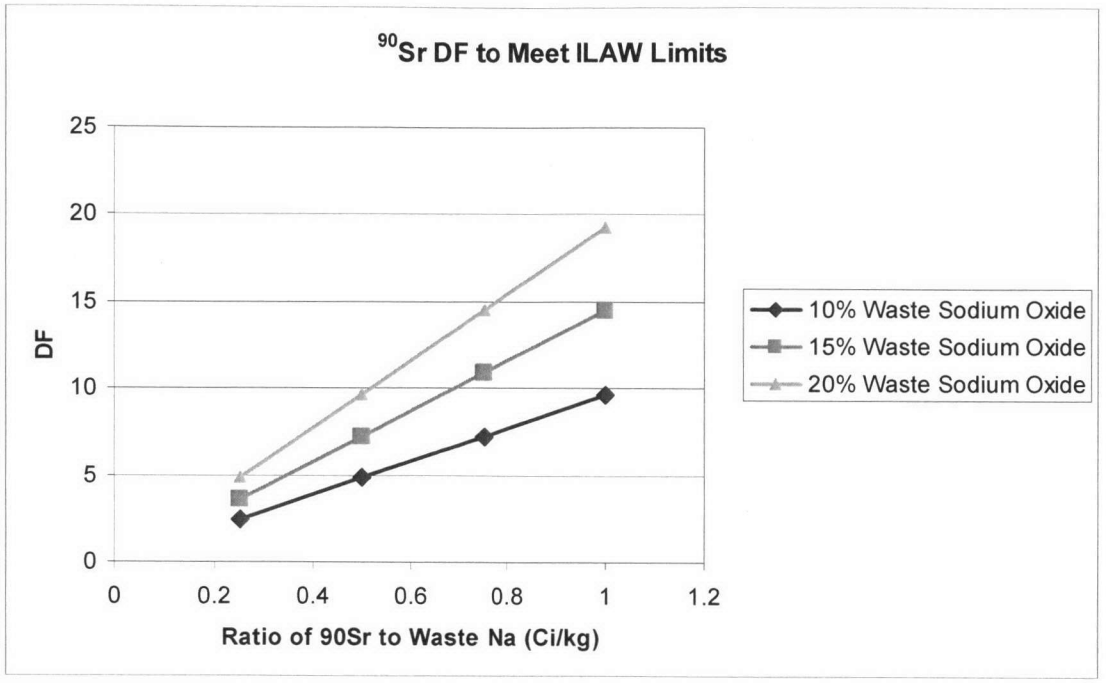


Figure 2.3-12 Required TRU (^{241}Am) Decontamination Factors

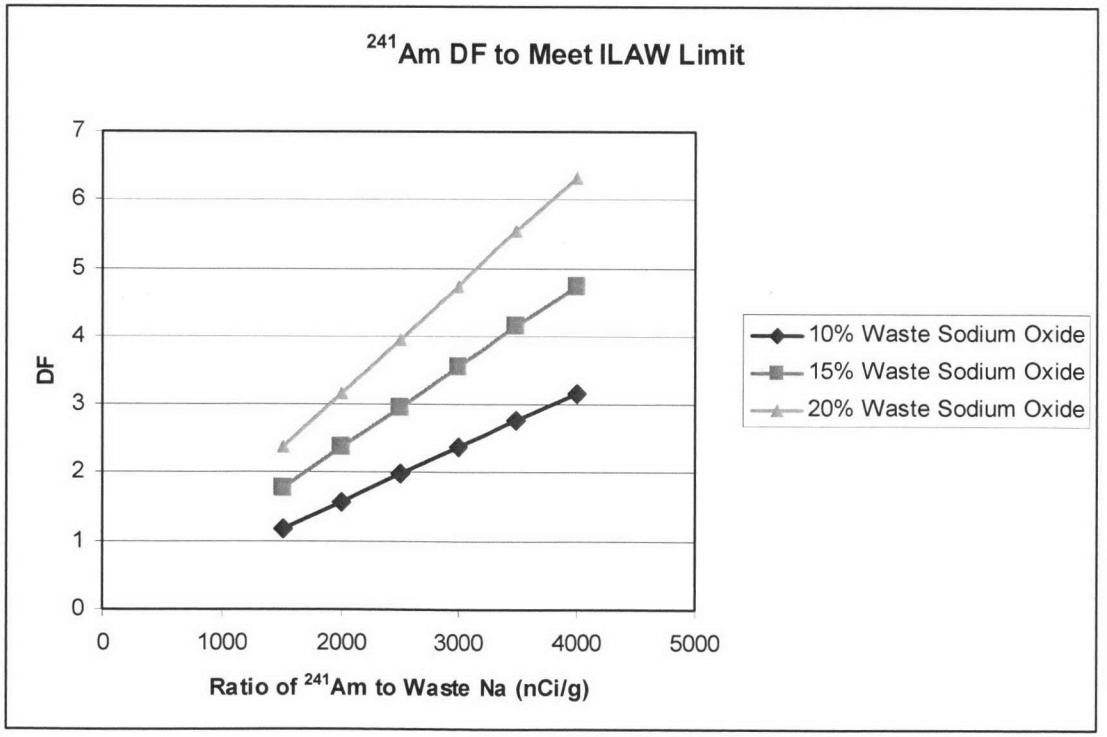


Figure 2.3-13 Flux vs. Wt % Solids for Envelope C Dewatering

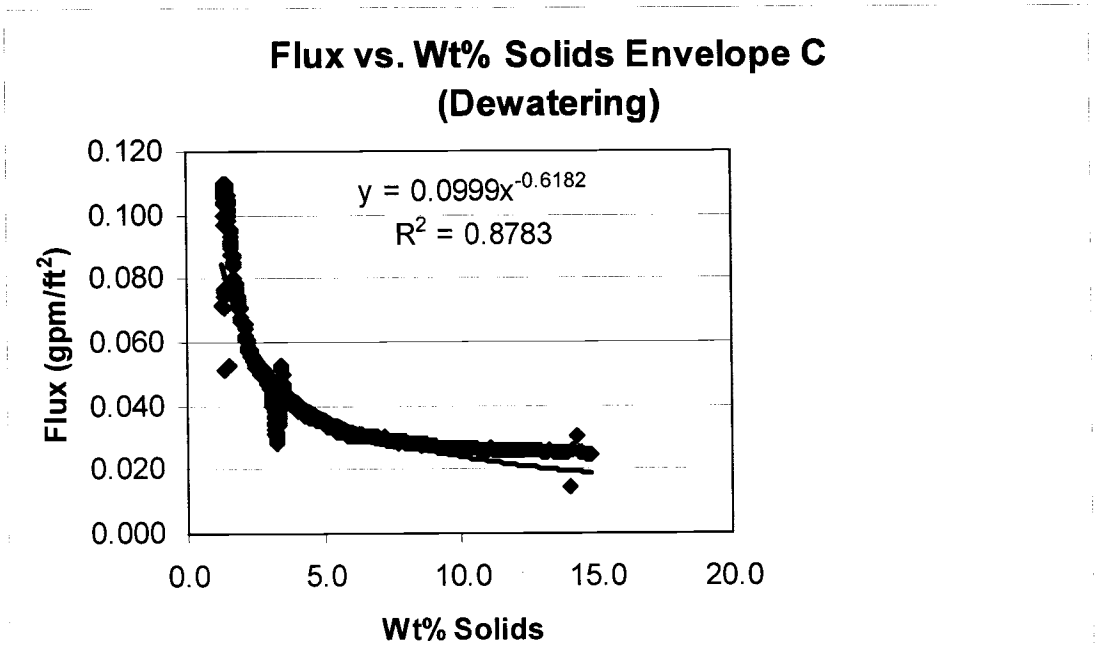


Figure 2.3-14 Flux vs. Wt % Solids for AZ-101 CUF Test

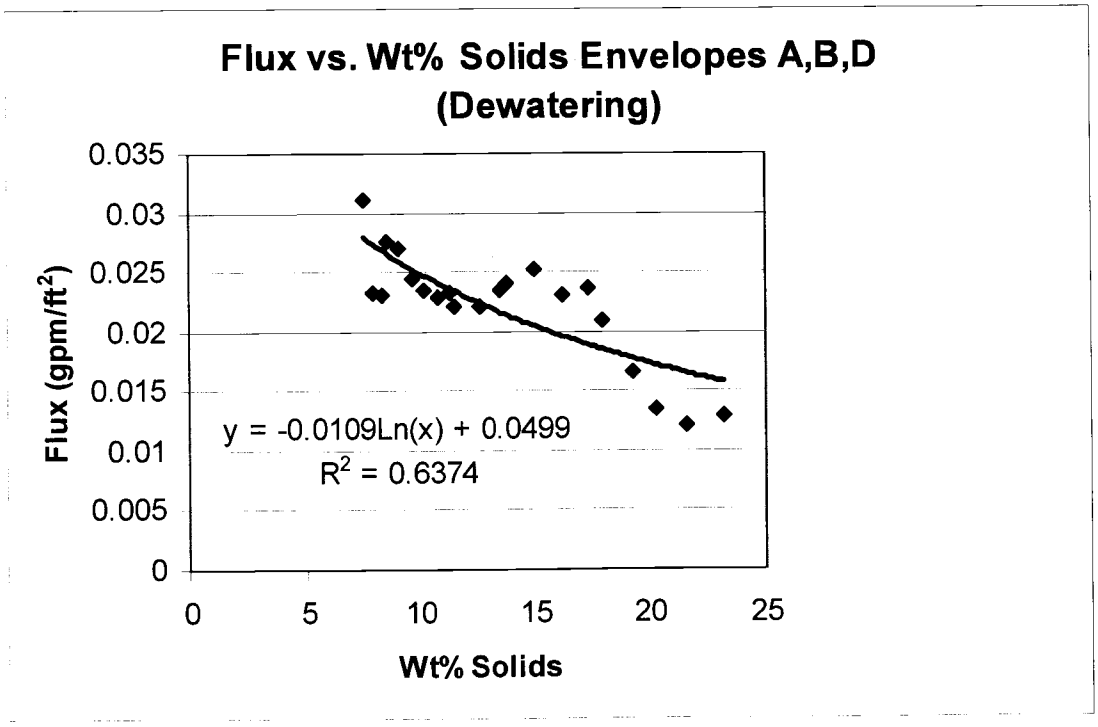


Figure 2.3-15 Flux vs. Sodium Molarity for Envelope C Washing

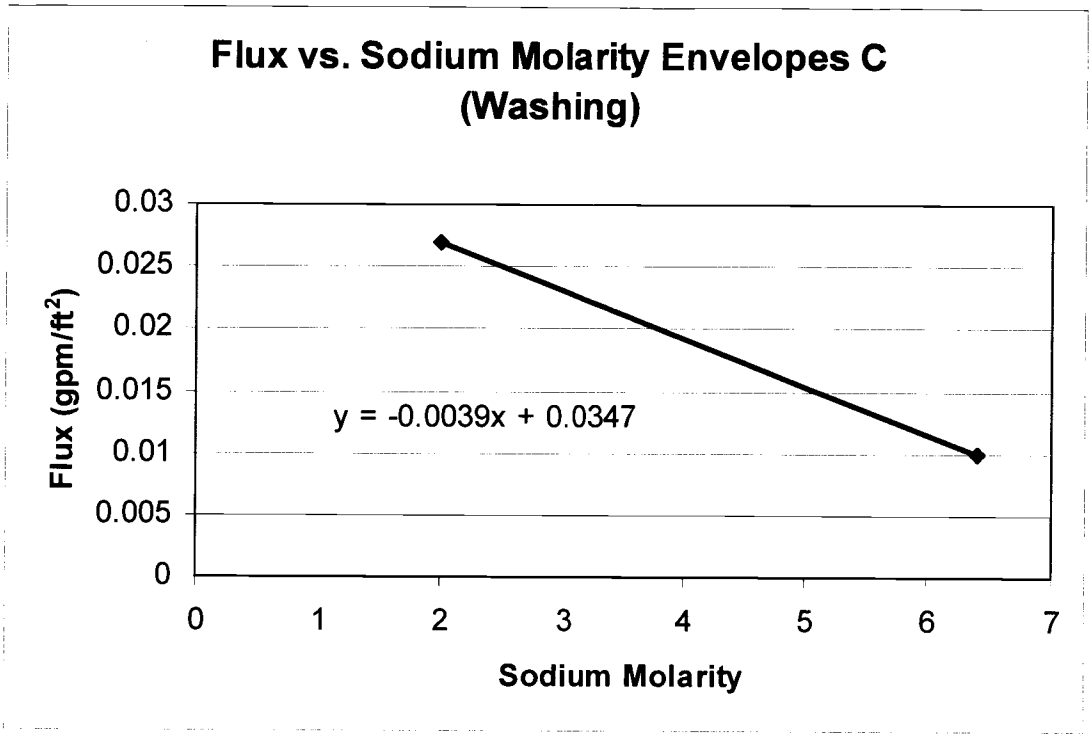


Figure 2.3-16 Flux vs. Sodium Molarity for AZ-101 CUF Test

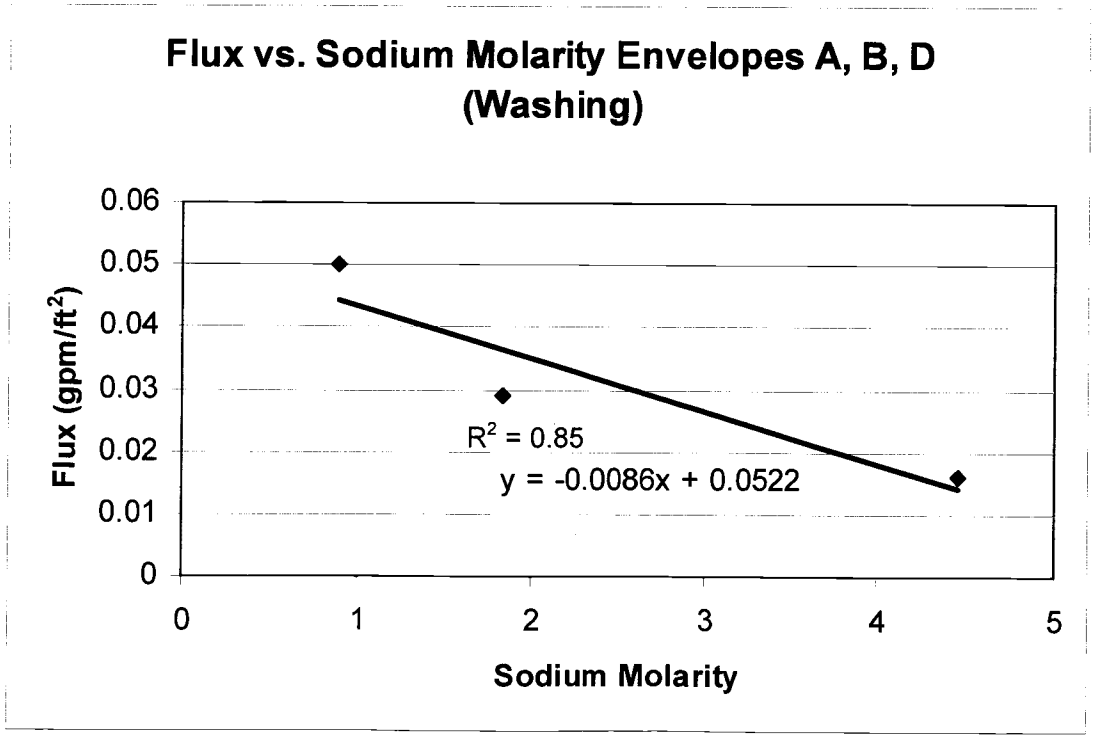
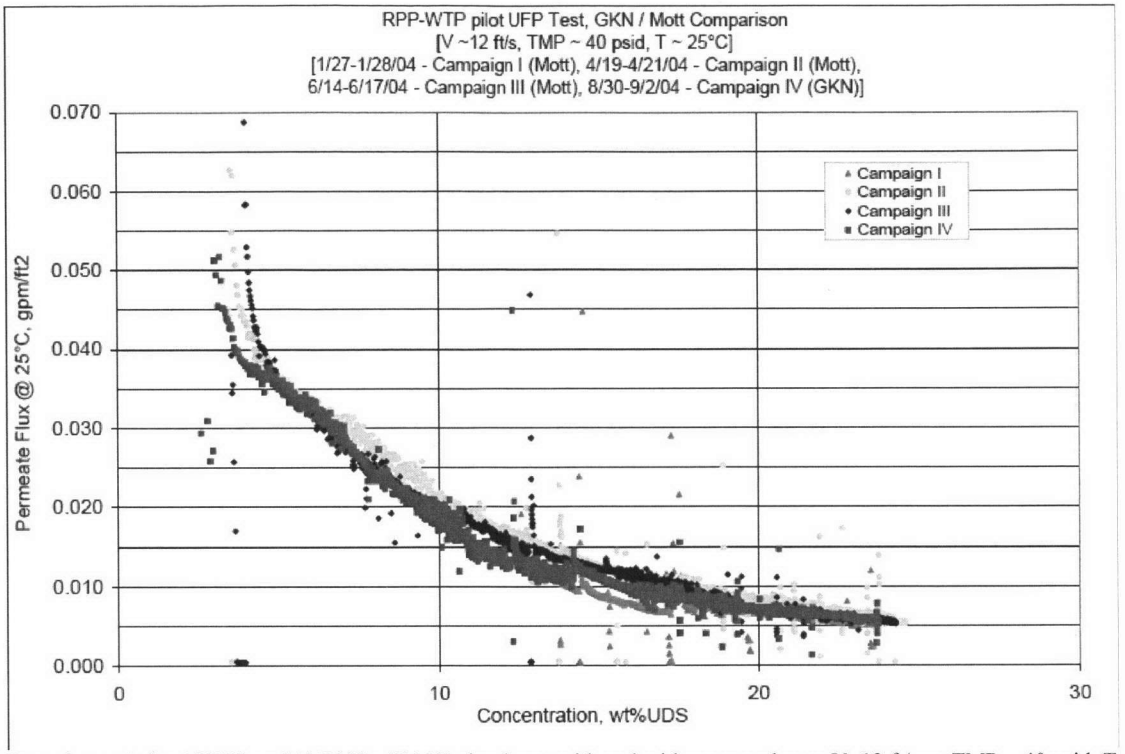


Figure 2.3-17 Semi-Integrated Pilot Plant Flux vs. Percent Solids by Weight



Data shown is for AY102 and (AY102+AP101) simulants, with and without recycles, at V~12 ft/sec, TMP ~ 40 psid, T~25 °C using Mott and GKN filters.

Campaign I contained AY102 simulant only
Campaign II contained (AY102 + AP101) simulant and recycles from Campaign I
Campaign III contained (AY102 + AP101) simulant and recycles from Campaign II
Campaign IV contained (AY102 + AP101) simulant and recycles from Campaign III

Figure 2.3-18 Filter Cleaning During SIPP Tests

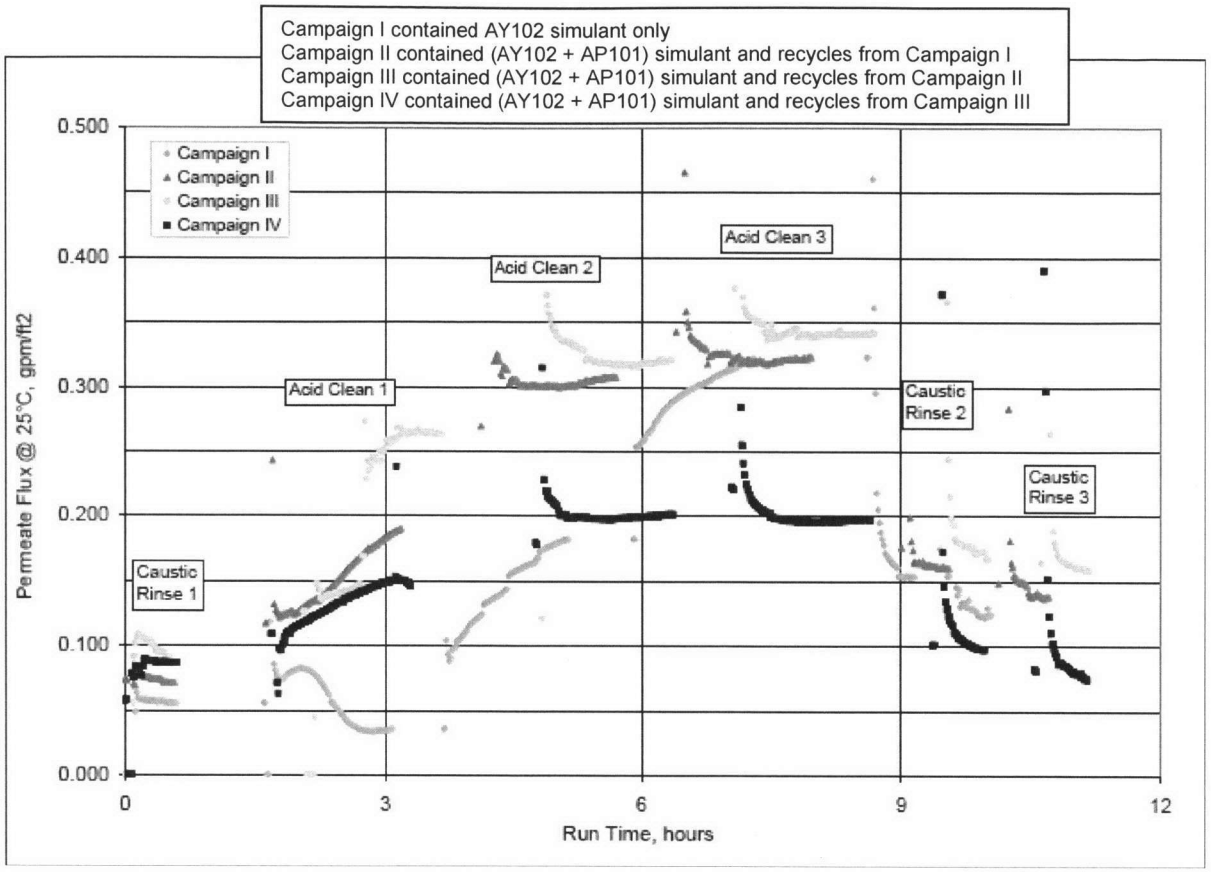


Figure 2.3-19 SIPP Steady State Test AT 25 Wt % UDS

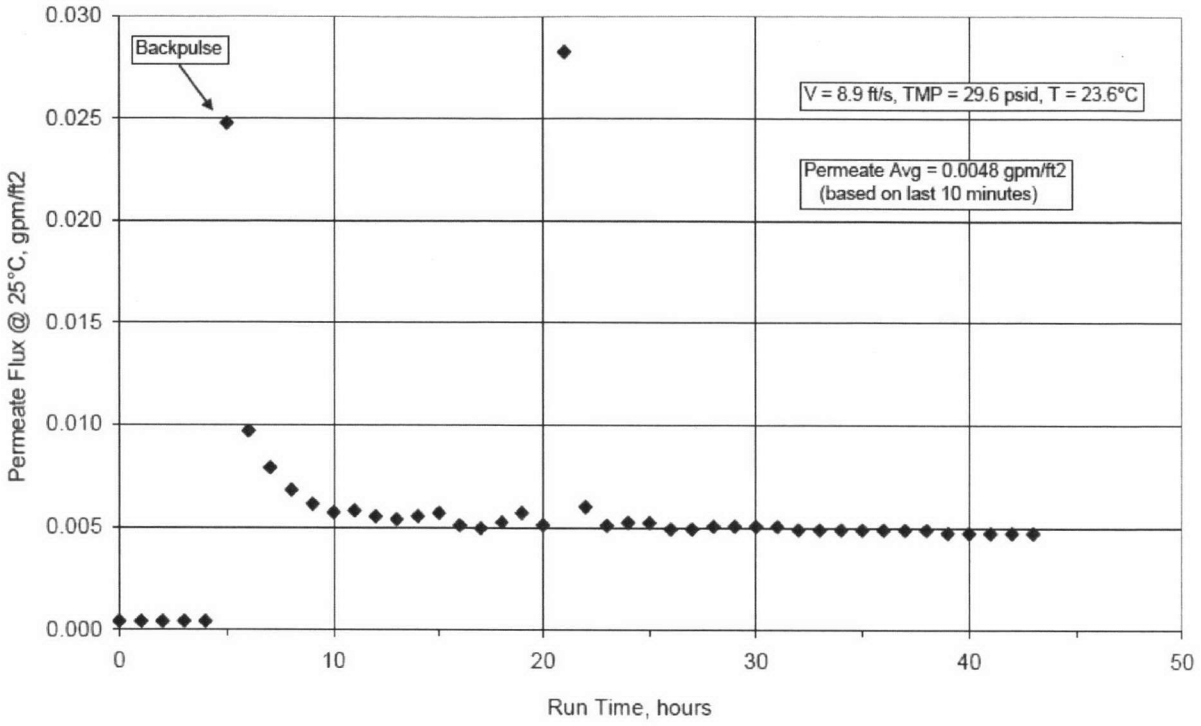
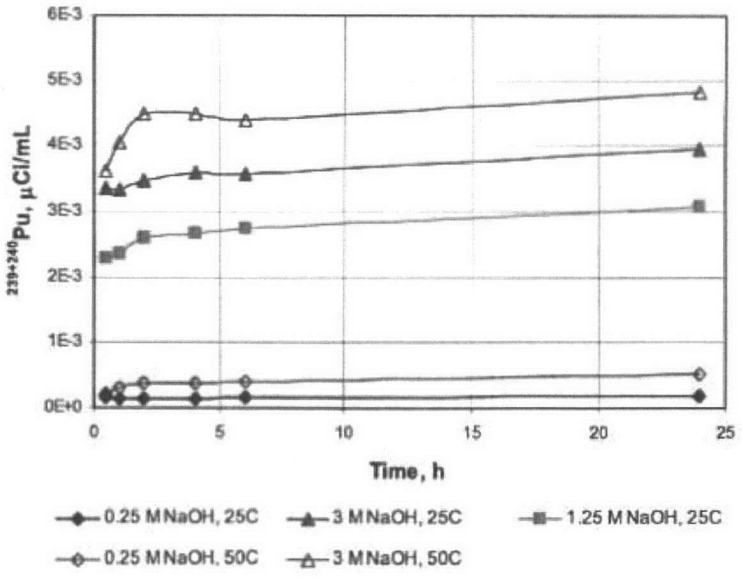


Figure 2.3-20 Concentrations of $Pu^{239+240}$ mobilized as a Function of time



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2.4 System HLP: HLW Lag Storage and Feed Blending Process

2.4.1 Function and Requirements

There are three primary functions of the High-Level Waste (HLW) Lag Storage and Feed Blending Process System (HLP). The first is to receive HLW feed from Hanford Tank Farms. The HLW, once transferred from Hanford Tank Farms to the HLW feed receipt vessel (HLP-VSL-00022), is supplied to the downstream WTP processes. The second function of the HLP system is to receive and stage pretreated process slurries of HLW solids, strontium (Sr), and transuranic (TRU) precipitates from the Ultrafiltration Process System (UFP). The third function is to mix intermediate product streams, such as cesium (Cs) concentrate, with HLW slurries for subsequent vitrification.

All HLP vessels are equipped with pulse jet mixers (PJM) for agitation. Non-Newtonian vessels HLP-VSL-00027A/B and HLP-VSL-00028 are equipped with air spargers in addition to the PJMs. Mixing functions include blending waste, suspending solids, releasing entrained hydrogen gas, and ensuring samples drawn from the vessels are representative (Ref 1). Several enhancements were made to the PJMs for vessel HLP-VSL-00022 in response to External Flowsheet Review Team (EFRT) concerns regarding major issue M3, *Inadequate Design of Mixing Systems*. The number of PJMs in HLP-VSL-00022 was increased from 12 to 18. The discharge nozzles of the PJMs were enlarged and reoriented and the location of the PJMs were revised (Ref 2).

2.4.1.1 Statement of Work Requirements

The WTP *Statement of Work* (SOW) (Ref 3), Operation Specification, Section C.8, Specification 8.2.2.1, states that the composition of the HLW slurry received from Hanford Tank Farms will be a mixture of low-activity waste (LAW) liquid (Envelope A, B, or C) and Envelope D solids. Further, the LAW liquid fraction of the Envelope D waste must comply with Specification 7 (except for Section 7.2.2.2; maximum ^{137}Cs concentration limits do not apply). The chemical and radiological compositional limits for the LAW portion are discussed in Section 2.1, System FRP: Waste Feed Receipt Process. The maximum Envelope D solids composition for the HLW feed is found in Table 2.4-1 and Table 2.4-2. The consolidated SOW values are found in Tables TS-8.1, TS-8.2, and TS-8.4, respectively. The values extracted from Table TS-8.4 are provided for guidance only and will not be used as a basis for determining if the feed meets specification requirements. The SOW (Section C.8, Specification 7.2.2.1) bounds the HLW slurry and other HLW liquids to a sodium molarity between 0.1 and 10 moles per liter. In addition, the HLW feed can range from 10 to 200 g unwashed solids per liter (except for tanks AZ-101 and AZ-102, where minimum solids content does not apply). The feed delivery batch size will be such that, after receipt in WTP and blending with pre-existing receipt tank contents, the concentration will not exceed a linear range of 107 grams of unwashed solids/liter at 0.1 molar sodium up to 144 grams/liter at 7 molar sodium (M183).

The SOW, Section C.7(b)(5) and C.7(b)(6) specifies the following for HLW feed receipt and storage capacity:

> *The Pretreatment Facility shall have the feed-forward capability for a nominal 240,000 gallons of feed lag storage for HLW vitrification facility operations, based upon the facility design capacity, while being capable of receiving without interruption no less than 145,000 gallons of HLW feed per batch. HLW feed batch receipt facilities shall be designed to allow receipt without interruption to waste feed processing.*

The Pretreatment Facility shall have the capability to prepare at least 81,000 gallons of transferable and blended HLW feed within a single vessel for transfer to the HLW Vitrification Facility.

A more comprehensive list of requirements can be found in *System Description for HLW Lag Storage and Feed Blending Process System (HLP)* (Ref 4).

2.4.2 Process Description

The HLP system, which primarily consists of four vessels, is detailed on process flow diagrams in Ref 5 and Ref 6. One vessel receives HLW feed from Hanford tank waste, two receive treated solids from the UFP system, and one blends waste to be sent to HLW vitrification. Figure 2.4-1 shows the equipment and their functions. Volumes and setpoints are available in Appendix B.

The primary function of the HLW feed receipt portion of the HLP system is to receive HLW feed in the HLW feed receipt vessel (HLP-VSL-00022) from the Hanford Tank Farms and supply this feed to the Pretreatment (PT) Facility for processing. If needed, a cooling jacket is used to reduce the vessel contents' temperature to 113 °F or below. The purpose of the PJMs is to agitate the waste and keep the solids suspended for processing and sampling. A sample for criticality safety, feed verification and to set processing parameters is drawn from each batch. A sample hold time of 43.7 hr is applied for this sample in the G2 flowsheet (Ref 8). The vessel vapor space is purged to prevent hydrogen accumulation.

The Tank Farm Contractor (TFC) will provide samples of the staged waste feed batch to the WTP Contractor not less than 180 calendar days prior to the agreed-upon waste transfer date (Ref 9). Prior to an HLW transfer from the Tank Farms, a pre-transfer warming flush may be performed with heated water to mitigate the precipitation of salts. After the waste transfer is complete, the TFC will send a post-transfer pipeline flush of inhibited water (process water containing at least 0.01 M NaOH and 0.011 M sodium nitrite).

HLW will be transferred from the Tank Farms to HLP-VSL-00022 in batches up to 145,000 gal. The maximum temperature of waste transferred from the Tank Farms to HLP-VSL-00022 is 150 °F (Ref 9). Normally, this feed will be transferred from HLP-VSL-00022 via pump HLP-PMP-00021 to the ultrafiltration feed preparation vessels (UFP-VSL-00001A/B). The waste can be returned to the Hanford Tank Farms via pump FRP-PMP-00001, in the FRP system. Following a transfer from HLP-VSL-00022, the transfer pipeline is flushed with plant wash.

Cesium nitric acid concentrate, from the Cesium Nitric Acid Recovery Process System (CNP), is neutralized with 19 M NaOH in vessels HLP-VSL-00027B or HLP-VSL-00028. Thirty thousand, three hundred gallons or greater of slurry must be in HLP-VSL-00027B before receiving and neutralizing CNP concentrate. This minimum volume ensures that the neutralization heat of reaction is dispersed by sufficient slurry to protect the vessel's design temperature of 140 °F, see Ref 10. The maximum operating temperature of HLP-VSL-00027B's discharge pump, HLP-PMP-00017B, is 113 °F. Therefore, a maximum cool down time of 9.7 hours is required for HLP-VSL-00027B before its discharge pump can be operated following the neutralization of CNP concentrate.

HLP-VSL-00028 shall only receive CNP concentrate when its liquid level is 30,700 gallons or greater, to protect the vessel's design temperature of 140 °F. The maximum operating temperature of HLP-VSL-00028's discharge pumps, HLP-PMP-00019A/B is 113 °F. A maximum cool down time of 8.5 hours is required before HLP-VSL-00028 discharge pumps can operate following CNP neutralization, Ref 11.

The lag storage and feed blending portion of the HLP system receives HLW washed solid slurries from the UFP system, provides lag storage of treated HLW solids and Sr/TRU precipitated products, and mixes treated solids with Sr/TRU and Cs concentrate. The HLP system has a high degree of flexibility. Routes are available to allow any transfer between HLP vessels HLP-VSL-00027A, HLP-VSL-00027B, and HLP-VSL-00028. However, all routes are not available simultaneously, as jumper swaps are required for off-normal transfers. Each vessel has PJMs and a cooling jacket to maintain temperature at or below 113 °F. Each vessel also has sampling capability provided. Transfers into and out of HLP-VSL-00027A/B and HLP-VSL-00028 are followed with line flushes.

Normally, the lag storage vessels HLP-VSL-00027A/B receive treated solids from the UFP system; although HLP-VSL-00028 can also receive treated solids directly from the UFP system. HLP-VSL-00027A/B is filled from UFP-VSL-00002A/B as needed to achieve a full batch of up to 82,000 gal, Ref 12. HLP-VSL-00027B and HLP-VSL-00028 can receive concentrated Cs from the CNP system. However, a minimum volume must be in HLP-VSL-00027B or HLP-VSL-00028 prior to the receipt and neutralization of CNP concentrations with caustic. After waste is blended in HLP-VSL-00027A/B, it is transferred to HLP-VSL-00028 for sampling and transfer to the HLW Facility.

Once HLP-VSL-00028 has been filled, the blended contents are held for sampling to determine the composition of the vessel prior to transfer to HLW vitrification. The hold time is 24.8 hr (Ref 8). The contents are then discharged to the HLW feed preparation vessels (HFP-VSL-00001/5) as discrete batches. No new material is received into HLP-VSL-00028 until it is at its heel volume. HLP-VSL-00028 has a normal batch volume of 82,000 gal (Ref 13). This is sufficient volume for approximately 15 HFP-VSL-00001/5 batches.

Cs/Sr slurry from capsules can also be bled into this system (this option will be considered for Balance of Mission waste processing). While the equipment associated with the Technetium Ion Exchange Process System (TXP) and Technetium Eluant Recovery Process System (TEP) has been removed from the WTP design and flowsheets, the process capability exists to receive transfers of concentrated Tc into HLP-VSL-00028 if this equipment is installed in the future.

An alternate HLP-VSL-00027A function is to serve as a lag storage vessel for FEP evaporator concentrate for the scenario of up-front caustic leaching.

Pretreated HLW slurry in HLP-VSL-00027A/B and HLP-VSL-00028 can be transferred back to Hanford Tank Farms via pump FRP-PMP-00001, located within the FRP system.

The overflows of all HLP vessels drain to plant overflow vessel PWD-VSL-00033. However, high level interlocks for vessels HLP-VSL-00027A/B and HLP-VSL-00028 prevent overflows.

2.4.3 Basis

2.4.3.1 Size and Configuration

The SOW storage and feed-forward capacity requirements form the basis for sizing the HLP system vessels.

2.4.3.2 Envelope C Blending

Envelope C solids (Sr/TRU precipitate) have to be blended with Envelope D solids in order to produce immobilized high-level waste (IHLW) that is fully compliant with WTP SOW Specification 1. There is

some evidence that HLW glass with the required durability and crystallization can be made from Sr/TRU precipitate (Envelope C solids) by itself without blending with Envelope D solids (Ref 14). However, glass made solely from Envelope C solids does not meet minimum waste loading requirements mandated by Specification 1 of the WTP SOW. Therefore, to produce a fully compliant IHLW glass, the Envelope C and D solids must be blended.

The waste-loading constituents from the Envelope D solids, as well as the variable, batch-dependent IHLW glass former recipes, drive the quantity of Envelope C solids that can be incorporated into IHLW glass. Incorporation of too much Sr/TRU has the potential to limit the amount of glass formers that can be added to the blend and still make Specification 1 compliant IHLW. Currently, the default Envelope C blending ratio in HLP-VSL-00028 is set at 8 wt % SrO on a total non-volatile oxide basis. This target is based on evaluations of current flowsheet results and may be optimized as the flowsheet develops.

2.4.3.3 Energy Contributions

The steady-state temperature of 113 °F in the HLW feed receipt vessel, *Cooling Requirements for the HLW Feed Receipt Vessel, HLP-VSL-00022* (Ref 15), is required for the FEP system. The steady-state temperature of 113 °F in the HLW lag storage and feed blending vessels is a requirement identified in *Cooling Requirements for HLW Lag Storage Vessels, HLP-VSL-00027A/B* (Ref 10), and *Cooling Requirements for the HLW Feed Blending Vessel, HLP-VSL-00028* (Ref 11). These cooling requirements are satisfied through the use of cooling jackets on all four vessels within the HLP system. These cooling jackets contribute to the chilled water load.

2.4.3.4 Heel Dilution/Cleanout

The partial closure of EFRT issue M3 recommends providing heel dilution/cleanout capability for vessels HLP-VSL-00022, HLP-VSL-00027A/B and HLP-VSL-00028, Ref 2 and Ref 16, *Technology Steering Group - Issue Closure Record - Partial Closure EFRT Issue M3 (Closure Package Volume 3, UFP-VSL-00002A/B, HLP-VSL-00027A/B, HLP-VSL-00028), Inadequate Mixing System Design.* Heel dilution shall be applied to HLP-VSL-00022 as described in Ref 17:

- A temporary positive displacement pump, capable of pumping vessels down to a lower liquid level than the permanently installed pumps, shall be installed for heel dilution.
- HLP-VSL-00022 liquid level will be lowered to 1144 gal by the temporary pump, the temporary pump will discharge to UFP-VSL-00001B.
- Dilution liquid will be added to HLP-VSL-00022 until liquid level is 18,478 gal. The dilution liquid shall be (in order of preference): LAW from FRP-VSL-00002A/B/C/D, process condensate or de-ionized water (DI).
- Fluidize heel solids by operating HLP-VSL-00022 PJMs
- Lower vessel level to 1144 gal by using temporary pump to transfer fluidized heel to UFP-VSL-00001B.
- Flush HLP-VSL-00022 to UFP-VSL-00001B route with 210 gal of flush water after transfer.

Heel cleanout rather than heel dilution shall be used for vessels non-Newtonian vessels HLP-VSL-0027A/B and HLP-VSL-00028 for heel management. Processing of Newtonian solutions in HLP-VSL-00027A/B and HLP-VSL-00028 has been prohibited until further testing can confirm the vessels capability to mix Newtonian solutions, Ref 16. Heel cleanout is envisioned as a recovery process for the off-normal situation where dense solids have settled from a low viscosity slurry into the bottom of a non-

Newtonian vessel. The purpose of heel cleanout is to re-suspend the dense solids in a non-Newtonian slurry/solution so the dense solids can be transferred out of the vessel.

Heel Cleanout Steps

1 The vessel will be drawn down to its normal heel.
2 The PJMs will be turned off and the heel drawn down to an initial low heel liquid level (near the limits of pump operation), using the temporary positive displacement pump. Two jumpers (one suction and one discharge) will be removed and two hoses installed to operate the temporary pump.
3 The vessel will then be filled to a volume that allows any of the vessel's 2 PJMs to operate with a viscous fluid/slurry (viscosity greater than 5 cP) to a sufficient level to operate the PJMs. The viscous material may come from treated HLW feed from UFP-VSL-00002A/B, HLP-VSL-00027A/B, or HLP-VSL-00028.
4 The PJMs will be operated to mix the vessel contents for 1 hour.
5 After mixing, the vessel will then be emptied by the temporary pump back down to the initial low heel liquid level. In general the heel will be transferred forward, i.e. towards the HLW Facility.
6 The temporary pump and hoses will be removed and the jumpers for the vessel's normal discharge pump will be re-installed.

HLP-VSL-00027A

- Slurry source: UFP-VSL-00002A/B or HLP-VSL-00027B
- Intial low heel liquid level: 773 gal
- PJM operation liquid level: 10,642 gallons to 20,000 gal
- Ending heel level: 773 gal
- Heel receipt vessels: HLP-VSL-00027B or HLP-VSL-00028.
- Flush HLP-VSL-00027A to receipt vessel route with 165 gal of flush water after transfer (Ref 18).

HLP-VSL-00027B

- Slurry source: UFP-VSL-00002A/B or HLP-VSL-00027A
- Intial low heel liquid level: 773 gal
- PJM operation liquid level: 10,642 gal to 20,000 gal
- Ending heel level: 773 gal
- Heel receipt vessels: HLP-VSL-00027A or HLP-VSL-00028
- Flush HLP-VSL-00027B to receipt vessel route with 165 gal of flush water after transfer (Ref 18).

HLP-VSL-00028

- Slurry source: HLP-VSL-00027A/B
- Initial low heel liquid level: 770 gal
- Full PJM operation liquid level: 11,556 gal to 20,000 gal
- Ending heel level: 770 gal

- Flush HLP-VSL-00028 to receipt vessel route with 165 gal of flush water after transfer.
- Heel receipt vessels: HFP-VSL-00001/5

To assist heel management two 8-inch diameter visual access ports have been added to vessels HLP-VSL-00022, HLP-VSL-00027A/B and HLP-VSL-00028, Ref 19.

2.4.3.5 Antifoam Agent Addition

To prevent foaming due to spargers, antifoam is added to the non-Newtonian HLP-VSL-00027A/B and HLP-VSL-00028 vessels. Ref 20 is the preferred antifoam agent based on R&T evaluations. The antifoam constituents and composition range quoted from the material safety data sheet (No. 01603183) are listed below:

40 - 70 wt %	Polypropylene glycol
40 - 70 wt %	Polydimethylsiloxane
3 - 7 wt %	Octylphenoxy polyethoxy ethanol
3 - 7 wt %	Treated silica (trade secret)
3 - 7 wt %	Polyether polyol

The target AFA concentration for HLP-VSL-00027A/B and HLP-VSL-00028 is 350 ppm, Ref 21.

2.4.3.6 Line Flushes

The primary basis for the line flushes is found within *ICD 19 - Interface Control Document for Waste Feed* (ICD-19) (Ref 9). However, additional flush requirements were established to prevent the formation of flammable concentrations of hydrogen in piping and ancillary vessels and to decrease the likelihood of plugging in the process lines. The basis for these additional requirements can be found in the report *External Flowsheet Review Team Issue P2 Dynamic Flowsheet Modeling Results* (Ref 22).

Ref 9 specifies the following flush requirements for waste transfers from Hanford Tank Farms to HLP-VSL-00022:

- The pipeline will be flushed before the transfer with heated water, if necessary, to mitigate the precipitation of salts.
- Inhibited water (defined as process water containing 0.01 M NaOH and 0.01 M sodium nitrite) will be used to flush the Hanford Tank Farm transfer lines.
- Immediately following (in less than 120 min) the transfer of feed to the HLP, the TFC will commence flushing the transfer pipeline.
- The pre-transfer and post-transfer combined flush volumes will not exceed three times the transfer pipeline volume and will not exceed 7500 gal total.
- Immediately following a return transfer of waste (in less than 120 min) to the Hanford Tank Farm, the TFC will begin a post-transfer pipeline flush of inhibited water.

Appendix F provides the required frequency and volume for post-HLP transfer flushes within the PT Facility.

Flushing requirements from the HLP system of the PT Facility to the HLW Facility are discussed in Section 4.1.

2.4.4 Ongoing Work and Potential Changes

In March 2006 an External Flowsheet Review Team (EFRT), consisting of experts from industry, national laboratories, and universities, completed a *Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput* (Ref 23).

The EFRT identified 17 major issues and 11 potential issues that could negatively affect WTP throughput. Major issue M3, Inadequate Design of Mixing Systems, can specifically impact the design and operation of the HLP vessels. The HLP vessel concerns were partially addressed in closure packages Ref 2 and Ref 16. However, residual risks were identified in the both these closure packages. Recommendations for further testing and analyses were made in both closure packages. The results of additional testing and analyses could impact the design of HLP vessels.

Project Issue Evaluation report (PIER) 24590-WTP-PIER-MGT-12-0401-C states that several PTF hot cell pump sizing calculations may not adequately account for pump restart at vessel batch levels below the suction piping high point when determine minimum Net Positive Suction Head Available (NPSHa).

Vessels in the PTF black cells were designed such that their pump suction nozzles are located above the lower vessel tangent line. In most cases, the suction nozzle is the suction pipe high point and located above the vessel's minimum operating level. The underlying assumption in pump sizing calculations for determination of NPSHa is fully developed fluid flow has been attained in the pump suction piping. The minimum reported NPSHa does not account for the pump performing any lift at start-up to flood its suction in the event that it drains due to interruption of pump operation when vessel fluid levels are below the suction highpoint. Although the vessel liquid level is typically above the highpoint in the pump suction line when the pump is started, there is possibility of pump interruption during vessel pump-down near the end of a vessel batch. Minimum NPSHa determined for pump sizing should consider all potential operating scenarios (i.e., worst-case conditions). The batch and heel volumes of vessels HLP-VSL-00022, HLP-VSL-00027A/B and HLP-VSL-00028 may require adjustment in response to 24590-WTP-PIER-MGT-12-0401-C.

2.4.5 References

1 24590-WTP-ES-ENG-09-001, Rev 2, *Determination of Mixing Requirements for Pulse-Jet-Mixed Vessels in the Waste Treatment Plant.*

2 CCN 220454, *Technology Steering Group - Issue Closure Record - Partial Closure EFRT Issue M3 (Closure Package Volume 8, HLP-VSL-00022), Inadequate Mixing System Design.* 6 July 2010.

3 DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

4 24590-PTF-3YD-HLP-00001, Rev 2, *System Description for HLW Lag Storage and Feed Blending Process System (HLP).*

5 24590-PTF-M5-V17T-00007, Rev 2, *Process Flow Diagram HLW Feed Receipt System HLP.*

6 24590-PTF-M5-V17T-00008, Rev 3, *Process Flow Diagram-HLW Lag Storage and Feed Blending-System HLP.*

7 24590-WTP-PL-PR-04-0001, Rev 2, *Integrated Sampling and Analysis Requirements Document.*

8 CCN 254099, *Laboratory Sample Turnaround Times (WTP OR Model V7.0) .*

9 24590-WTP-ICD-MG-01-019, Rev 5, *ICD 19 - Interface Control Document for Waste Feed.*

10 24590-PTF-MVC-HLP-00010, Rev F, *Design of Cooling Jacket for HLW Lag Storage Vessels (HLP-VSL-00027A/B).*

11 24590-PTF-MVC-HLP-00011, Rev F, *Design of Cooling Jacket for HLW Feed Blending Vessel (HLP-VSL-00028).*

12 24590-PTF-M6C-HLP-00003, *Vessel Sizing Calculation for HLW Storage Vessels* (HLP-VSL-00027A/B)

13 24590-PTF-M6C-HLP-00004, *Vessel Sizing Calculation for HLW Feed Blending Vessel HLP-VSL-00028.*

14 24590-101-TSA-W000-0010-06-04A, Rev 0, *Final Report: Glass Formulation and Testing with RPP-WTP HLW Simulants.*

15 24590-PTF-MVC-HLP-00006, Rev E, *Design of Cooling Jacket for HLW Feed Receipt Vessel HLP-VSL-00022.*

16 CCN 220456, *Technology Steering Group - Issue Closure Record - Partial Closure EFRT Issue M3 (Closure Package Volume 3, UFP-VSL-00002A/B, HLP-VSL-00027A/B, HLP-VSL-00028), Inadequate Mixing System Design.* 20 August 2010.

17 24590-WTP-RPT-PET-10-013, Rev 0, *Pretreatment Vessel Heel Dilution/Cleanout Feasibility Study.*

18 CCN 141492, *Transmittal of Flush Requirements Following Transfers.* 1 August 2006.

19 24590-PTF-M6N-M80T-00101, *Addition of Access Ports to Selected Vessels in PTF Facility.*

20 DOW Corning. *Q2-3183A Antifoam*, Product Information and Material Safety Data Sheet (MSDS No: 01603183).

21 SCT-M0SRLE60-99-00009, *Ultrafiltration Process (UFP) Caustic Leaching Antifoam Performance.*

22 24590-WTP-RPT-PO-07-001, Rev 0, *External Flowsheet Review Team Issue P2 Dynamic Flowsheet Modeling Results.*

23 CNN 132846, *Report of External Flowsheet Review Team for the Hanford Tank Waste Treatment and Immobilization Plant - Final Report Titled: "Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput."* 17 March 2006.

24 24590-WTP-PIER-MGT-12-0401-C, *Integration of Vessel and Pump Sizing*, 23 March 2012.

Table 2.4-1 Contract Maximum Chemical Content, HLW Unwashed Solids

Component	Maximum (grams/ 100 grams waste oxide)	Source Table	Component	Maximum (grams/ 100 grams waste oxide)	Source Table
Cations			**Cations (continued)**		
Ag	0.55	TS-8.4	Rb	0.19	TS-8.1
Al	14.00	TS-8.4	Rh	0.13	TS-8.4
As	0.16	TS-8.1	Ru	0.35	TS-8.4
B	1.30	TS-8.1	S	0.65	TS-8.4
Ba	4.50	TS-8.4	Sb	0.84	TS-8.1
Be	0.065	TS-8.1	Se	0.52	TS-8.1
Bi	2.80	TS-8.4	Si	19.00	TS-8.4
Ca	7.10	TS-8.4	Sr	0.52	TS-8.1
Cd	4.50	TS-8.4	Ta	0.03	TS-8.1
Ce	0.81	TS-8.1	Tc	0.26	TS-8.1
Co	0.45	TS-8.1	Te	0.13	TS-8.1
Cr	0.68	TS-8.4	Th	5.0	TS-8.4
Cs	0.58	TS-8.1	Ti	1.30	TS-8.4
Cu	0.48	TS-8.1	Tl	0.45	TS-8.1
Fe	29.00	TS-8.4	U	14.00	TS-8.4
Hg	0.10	TS-8.1	V	0.032	TS-8.1
K	1.30	TS-8.4	W	0.24	TS-8.1
La	2.60	TS-8.1	Y	0.16	TS-8.1
Li	0.14	TS-8.1	Zn	0.42	TS-8.1
Mg	2.10	TS-8.4	Zr	15.00	TS-8.4
Mn	6.50	TS-8.1	**Anions**		
Mo	0.65	TS-8.1	Cl	0.33	TS-8.2
Na	19.00	TS-8.4	CN	1.60	TS-8.2
Nd	1.70	TS-8.1	CO_3^{-2}	30.00	TS-8.2
Ni	2.40	TS-8.4	F	3.50	TS-8.4
P	1.70	TS-8.4	NO_2+NO_3	36.00	TS-8.2
Pb	1.10	TS-8.4	**Gases**		
Pd	0.13	TS-8.4	NH_3	1.60	TS-8.2
Pr	0.35	TS-8.1	**Other**		
Pu	0.054	TS-8.1	TOC	11.00	TS-8.2

Source: Ref 3, Spec 8, Table TS-8.1, Table TS-8.2, Table TS-8.4.

Note: Constituents and maximum values associated with source Table TS-8.4 are provided as guidance only and will not be used as a basis for determining if the feed meets specifications requirements.

Table 2.4-2 Contract Maximum Radionuclide Content, HLW Unwashed Solids

Components	Maximum (grams/ 100 grams waste oxide)
^{3}H	6.5 E-05
^{14}C	6.5 E-06
^{60}Co	1.0 E-02
^{90}Sr	1.0 E+01
^{99}Tc	1.5 E-02
^{125}Sb	3.2 E-02
^{126}Sn	1.5 E-04
^{129}I	2.9 E-07
^{137}Cs	1.5 E+00
^{152}Eu	4.8 E-04
^{154}Eu	5.2 E-02
^{233}U (all tanks except AY-101/C-104)	4.5E-06
^{233}U (AY-101/C-104 only)	2.0E-04
^{235}U	2.5 E-07
^{237}Np	7.4 E-05
^{238}Pu	3.5 E-04
^{239}Pu	3.1 E-03
^{241}Pu	2.2 E-02
^{241}Am	9.0 E-02
$^{243}Cm + ^{244}Cm$	3.0 E-03

Source: Ref 3, Spec 8, Table TS-8.3.

Figure 2.4-1 HLP Process System (Upfront Leaching)

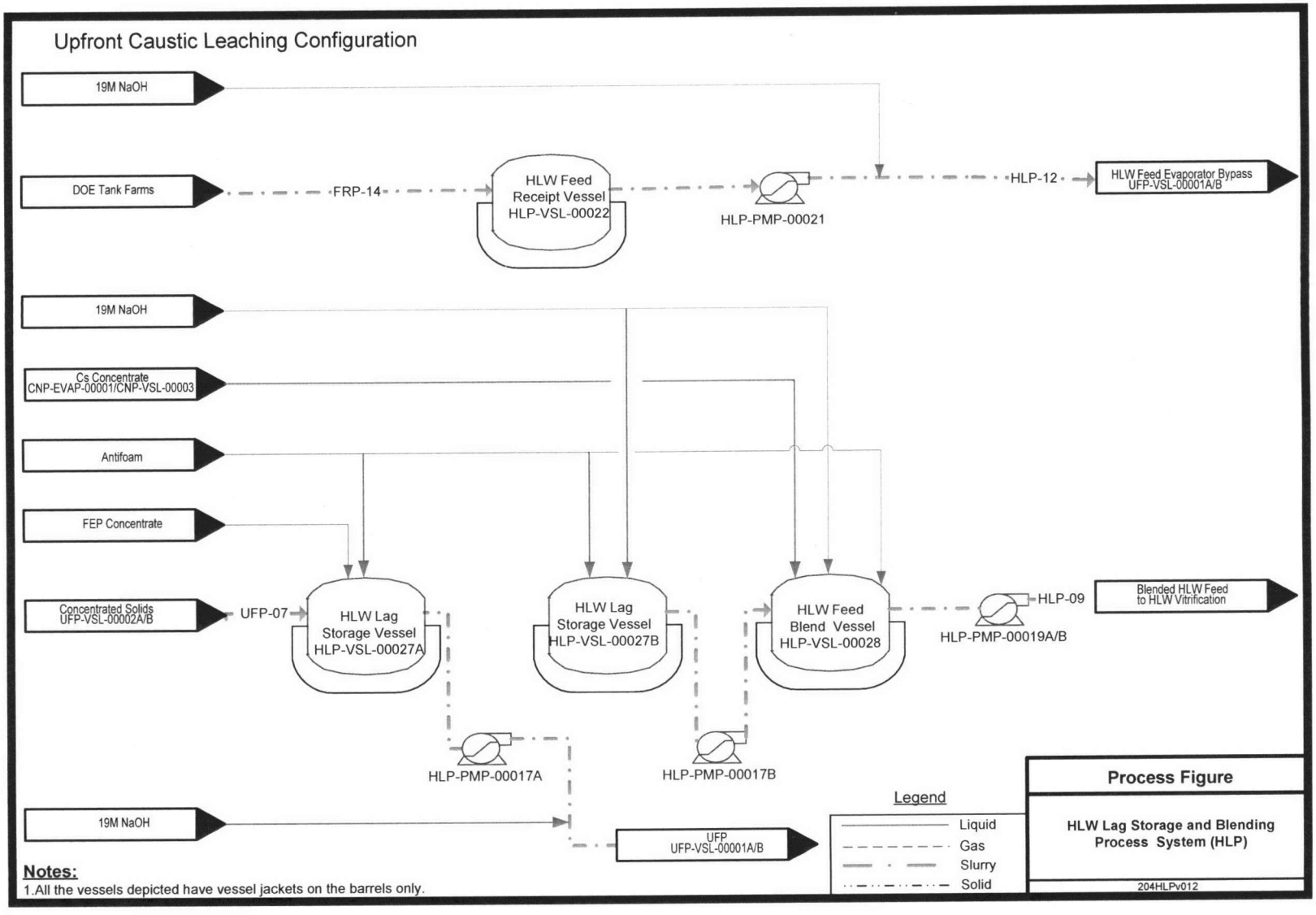
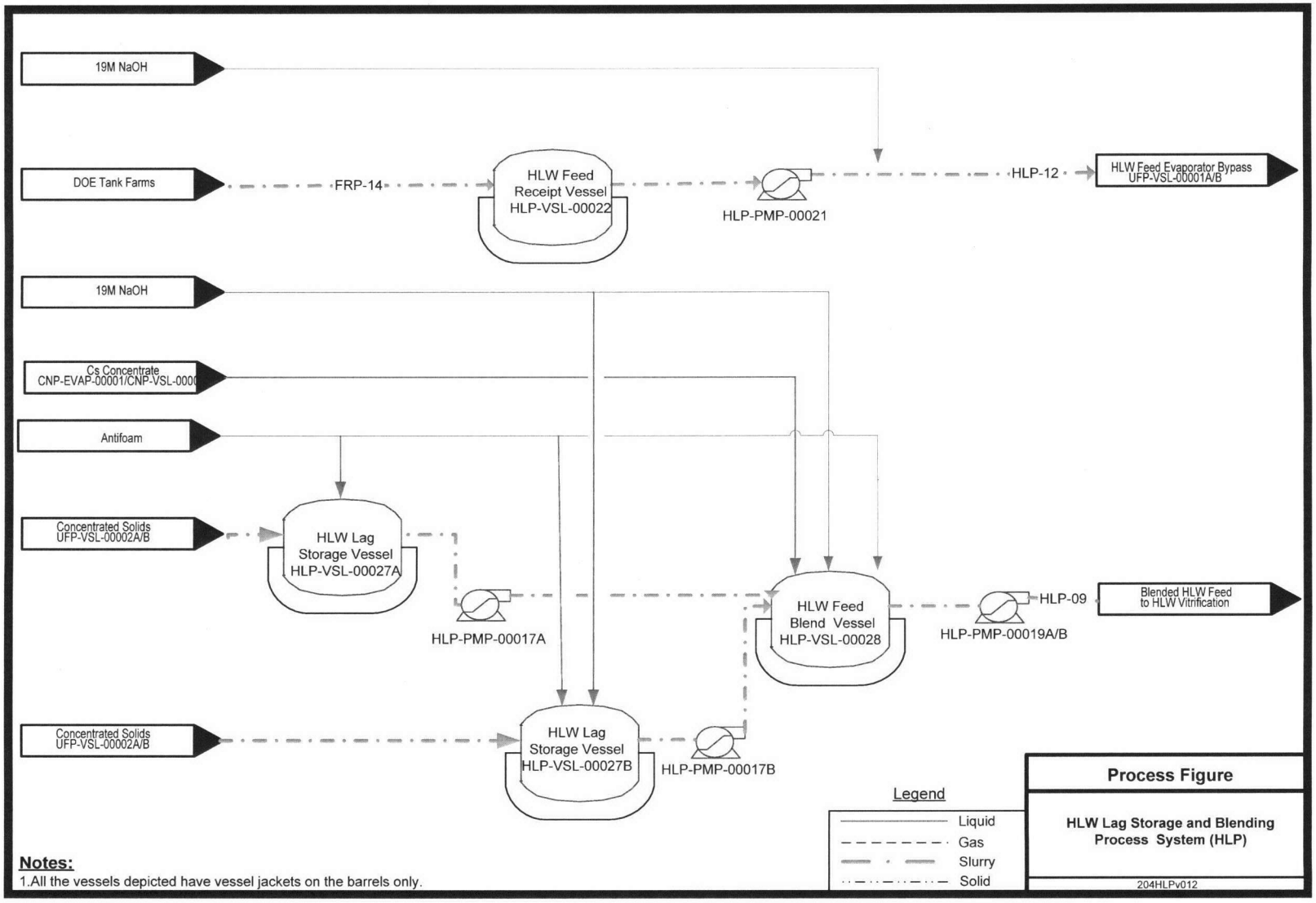


Figure 2.4-2 HLP Process System (Backend Leaching)



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2.5 System CXP: Cesium Removal Using Ion Exchange Process

2.5.1 Function and Requirements

The Cesium ion exchange process system (CXP) removes ^{137}Cs from process liquors disposed of as low-activity waste (LAW) glass. The separated ^{137}Cs is produced as an aqueous stream suitable for concentration, storage, and incorporation in feed to the high-level waste (HLW) melter system. The CXP system receives feed as permeate from the ultrafiltration system.

The CXP system performance directly affects the concentration of ^{137}Cs in immobilized low-activity waste (ILAW). The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136) specifications influence ^{137}Cs removal requirements from LAW liquors. The SOW, Operation Specification Section C.8, Specification 2.2.2.8, limits the average concentration of ^{137}Cs in ILAW such that the radionuclide concentration in LAW glass averages < 3 Ci $^{137}Cs/m^3$. SOW Facility Specification Section C.7 provides a more restrictive limit on the ^{137}Cs concentration in LAW glass to support the selected LAW melter system maintenance concept which reduces the ^{137}Cs concentration for LAW liquors transferred to the LAW melter system such that LAW glass does not exceed 0.3 Ci $^{137}Cs/m^3$.

The SOW Facility Specification, Section C.7 specifies the following Cs removal requirements.

> *C.7(d)(1)(iii) Cs Removal: This operation removes ^{137}Cs from the filtered supernatant to allow for production of an ILAW waste product that meets the Specification 2.2.2.8, Radionuclide Concentration Limitations. In addition, ^{137}Cs will be further removed, to achieve a 0.3 Ci/m^3 in the ILAW product, to facilitate the maintenance concept established for the ILAW melter system.*

The SOW Operations Specification, Section C.8 specifies the following Cs removal requirements.

> *2.2.2.8 Radionuclide Concentration Limitations: The radionuclide concentration of the ILAW form shall not exceed Class C limits as defined in 10 CFR 61.55. In addition, the average glass concentrations of cesium-137 (^{137}Cs) and strontium 90 (^{90}Sr) shall be limited as follows: ^{137}Cs < 3 Ci/m^3 and ^{90}Sr < 20 Ci/m^3. The method used to perform concentration averaging should be identified in the ILAW Product Compliance Plan.*

The Cs removal requirement can be characterized by the acceptable concentration of ^{137}Cs in treated LAW liquors. The higher waste loading in ILAW reduces the amount of ^{137}Cs concentration that is allowed in the ion exchange (IX) product. Figure 2.5-1 indicates how the treated LAW ^{137}Cs concentration that produces glass containing 0.3 Ci $^{137}Cs/m^3$ varies with waste sodium, potassium, and sulfate ion concentration based on current estimates of LAW glass waste loading. Figure 2.5-1 also indicates that the conservative estimates of the ^{137}Cs removal requirements are provided when the potassium ion concentration is assumed to be zero for the purposes of estimating allowable ^{137}Cs concentrations in LAW supernate transferred to the ILAW melter system.

The IX beds remove Cs isotopes from the waste feed supernate. Therefore, the total Cs content of waste feed defines the actual IX column performance. Waste composition analyses indicate that ^{137}Cs generally represents 12 to 25 wt % of the total Cs contained in IX feed solutions. Figure 2.5-2 indicates the estimated variation of the conservative total Cs concentration limit (potassium = 0) for treated LAW supernate producing glass at 0.3 Ci $^{137}Cs/m^3$ with sodium ion, sulfate ion, and ^{137}Cs isotope content.

The SOW Facility Specification (C.7)(b)(7)(vii) sets the design IX system volumetric capacity at 30 gpm. The waste volumetric feed rate required to satisfy the sodium throughput capacity requirement from Table C.7-1.1 varies with sodium concentration in the IX system feed. Figure 2.5-3 indicates the sensitivity of required volumetric feed rate to sodium concentration assuming an instantaneous capacity of 3930 metric tons Na/yr. Higher concentrations of sodium in waste feeds require lower volumetric feed rates to satisfy the facility capacity requirement. Figure 2.5-3 indicates the IX system volumetric capacity will satisfy the facility sodium processing capacity for feed sodium concentrations as low as 3 gmol/L.

The composition of waste fed to the IX system varies as waste is retrieved from different underground storage tanks. Figure 2.5-4 indicates the predicted variation of waste feed characteristics important to the estimate of IX Cs removal performance for a specific waste tank retrieval sequence. Figure 2.5-4 shows that:

- sodium ion concentration can vary from 2.7 to 6.0 gmol/L, with an average of 4.8 gmol/L
- total Cs ion concentration can vary from 3.7×10^{-6} to 1.2×10^{-4} gmol/L, with an average of 1.9×10^{-5} gmol/L
- potassium ion concentration can vary from 0.0034 to 0.38 gmol/L, with an average of 0.03 gmol/L
- hydroxide ion concentration can vary from 1.9 to 4.2 gmol/L, with an average of 3.0 gmol/L
- aluminate ion concentration can vary from 0.17 to 0.46 gmol/L, with an average of 0.3 gmol/L
- the ^{137}Cs/Total Cs mole ratio can vary from 0.12 to 0.25, with an average of 0.15

Actual waste compositions of IX feed will vary with the waste retrieval sequence; any waste blending that occurs before introduction into the WTP; and process activities that occur within the WTP unit operations upstream of the IX system. Therefore, Figure 2.5-4 is included only to provide an indication of the composition ranges that could be encountered during preparation of IX material balances. Future material balance cases and actual operation should not be expected to produce identical variations of the IX feed composition.

2.5.2 Process Description

The CXP system removes Cs ions from LAW by IX, elutes and regenerates IX resin beds by chemical additions and rinse steps, and replaces spent resin with fresh resin. Appendix A references drawings 24590-PTF-M5-V17T-00012 and 24590-PTF-M5-V17T-00013, which show the process flow diagram for the IX system under routine operation, including the loading and restoration cycles.

The CXP system removes Cs from LAW utilizing four IX columns. The four columns are operated in a carousel configuration. Three columns are used in series to process waste during the loading cycle. This provides a lead and lag column arrangement for Cs removal (similar to that used for some column tests), plus a polishing column. The polishing column has been included to address uncertainties in the Cs removal resin performance due to chemical and radiological degradation. The fourth column allows the system to elute and regenerate a column while continuing loading in the remaining three columns. Once the lead column is loaded, valving changes switch the lag column to the lead column function, polishing column to the lag column function, and freshly regenerated column to the polishing column function. Therefore, continuous Cs removal processing can be supported, provided the restoration cycle is shorter than the loading cycle.

The Figure 2.5-65 illustrates the flow of solutions through the cesium ion exchange (CIX) columns during loading and restoration. The Cs removal step loads resin beds with Cs ions. The Cs "breakthrough point"

is defined as the point where the ^{137}Cs concentration in LAW leaving the carousel lead column is 50 % of the ^{137}Cs concentration in feed to the lead column (24590-WTP-RPT-PR-06-001, *Technical Evaluation for Resolution of EFRT Issue P8 Cesium Ion Exchange System Breakthrough Monitoring*, was used as the basis for defining the loading cycle endpoint in this version of the IX material balance. The endpoint basis will be modified as the control philosophy evolves; see Section 2.5.4). Formal confirmation of compliance with ^{137}Cs limits is obtained by analyzing a sample collected from a batch of treated LAW after Cs removal and reviewing the analyses' data to determine if the batch satisfies LAW vitrification feed specifications. Batches that do not comply with LAW vitrification feed specifications are recycled to the CIX feed vessel for removal of additional Cs.

The actual lead column breakthrough point may be modified as operating experience is obtained.

The loaded lead column is eluted and regenerated. Restoration consists of the following column cycles:

- Fluid displacement – displacement of residual LAW feed in the column liquid hold up by rinsing with dilute caustic solution to prevent precipitating aluminum hydroxide
- Pre-elution rinse – displacement of residual dilute caustic solution from the column with demineralized water to minimize acid-base reactions at the start of elution
- Elution – elution of Cs ions from the resin with dilute nitric acid
- Post-elution rinse – displacement of residual acid from the column liquid hold up with demineralized water to minimize acid-base reactions at the start of regeneration
- Regeneration – regeneration of the resin with caustic solution, replacing hydrogen ion on resin IX sites with sodium ion
- Regeneration fluid displacement – displacement of regeneration caustic with treated LAW to minimize the density difference between solutions held in a column and waste introduced at the top of a column during startup as a polishing column in the loading cycle

Loading, fluid displacement, pre-elution rinse, elution, and post-elution rinse cycles are performed using down-flow of solutions through the resin beds. Regeneration and regeneration fluid displacement cycles are performed using up-flow of solutions through the resin bed.

The IX columns are sized to provide sufficient waste solution residence time within the resin beds at the design production rate during the loading cycle such that treated LAW complies with Cs removal requirements. Laboratory tests, described in subsequent sections, obtained acceptable column performance using two columns in series while processing actual waste at a feed rate of 3 resin bed volumes (BV) per hour. The laboratory test experience is combined with the volumetric feed rate requirement from Section 2.5.1 to define an initial estimate of the resin bed volume supporting plant scale operation, shown as Equation 2.5-1.

Equation 2.5-1

$$\frac{(30\,\frac{\text{gal}}{\text{min}})(60\,\frac{\text{min}}{hr})}{(3\,\frac{\text{BV}}{\text{hr}})} = 600\,\frac{\text{gal resin}}{\text{BV}}$$

Duplication of laboratory test conditions would result in a two-column system during loading, with each column containing a 600 gal resin bed. A third column was added to the laboratory testing configuration as a result of allowances for uncertainty in resin test experience, variation in feed composition, resin

loading at the start of a loading cycle, potential system inefficiencies (e.g., channeling), resin degradation, throughput flexibility, and similarity of loading cycle time to elution cycle time.

Table 2.5-23 summarizes the current vessel batch volumes supporting the plant design resin BVs.

2.5.3 Basis

Cs is removed from process liquor using IX technology. An elutable IX media was selected after assessment of five alternatives: IX using a non-elutable media, IX using an elutable media, solvent extraction, ferrocyanide precipitation, and crystallization. Assessment criteria included technical maturity, operability, safety, immobilized waste form requirements, effluent compatibility, throughput, and estimated life-cycle costs. The primary benefit of the elutable IX technology was the ability to meet immobilized waste form product requirements (24590-CM-TSA-HXYG-008401A, *Technical Basis for River Protection Project Waste Treatment Plant Ion Exchange System Design*).

Cs is removed by passing LAW from ultrafiltration permeate through an IX system. SuperLig 644 was selected as the IX material during early phases of the Project design (BNFL 1997). SuperLig 644 was developed and supplied solely by IBC Advanced Technologies, Inc., American Forks, Utah. An investigation was initiated for selecting and testing a resin for Cs removal to provide an alternative to this sole source resin supply. Resorcinol formaldehyde (RF) was selected as the most viable alternative resin for application in the Pretreatment (PT) Facility (24590-PTF-RPT-RT-02-001, *WTP Pretreatment Alternative Resin Selection*). Like SuperLig 644, RF is regenerated using dilute nitric acid to elute Cs captured by the resin during the loading cycle, followed by returning the resin to the sodium form using dilute caustic. Therefore, the basic process steps are similar if use of either resin is required.

The RF resin test program initially evaluated both spherical bead and ground gel resin forms from multiple manufacturing sources. Early test comparisons considered Cs capacity, Cs selectivity, hydraulic, and elution characteristics of the alternative RF resin forms. The early test results are described in the following documents:

- 24590-101-TSA-W000-0004-04-00001, *Comparison Testing of Multiple Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant*
- 24590-101-TSA-W000-0004-91-00003, *Elution Testing of Resorcinol-Formaldehyde Resins with AN-105 Simulant*
- SCT-M0SRLE60-00-110-00021, *Determination of Cesium (Cs^+) Adsorption Kinetics and Equilibrium Isotherms from Hanford Waste Simulants using Resorcinol-Formaldehyde Resins (U)*

The primary result of the comparison testing was selection of a spherical RF resin form for more detailed testing. This selection was driven by the attractive hydraulic characteristics of the spherical resin form when compared to ground gel resin forms. Upon completion of the detailed tests, the spherical RF and SuperLig 644 processing characteristics were compared. The comparison recommended that the spherical RF resin form be considered an approved equivalent to SuperLig 644 (24590-WTP-RPT-RT-06-001, *Basis for Recommendation of Spherical Resorcinol Formaldehyde Resin as the Approved Equivalent to SuperLig 644*). The flowsheet material balance is based on laboratory tests of spherical RF resin performance using both simulated and actual tank waste in laboratory and pilot-scale equipment.

The bases for parameters used in the flowsheet are described below. Much of the basis of development has been guided by the data summary provided in 24590-WTP-RPT-RT-07-005, *Basis of*

Recommendation for Use of Spherical Resorcinol Formaldehyde Resin as the Primary Cesium Ion Exchange Resin in the WTP.

2.5.3.1 Ion Exchange Resin Properties

The RF resin is a polymer that consists of resorcinol units ($C_6H_4(-OH)_2$) linked by methylene ($-CH_2-$) bridges. The various structural units expected within the RF polymer are shown in Figure 2.5-5. Structure type A, which possesses a 1,2,3,4 ring substitution pattern, is believed to represent 85 % of the total repeating units in the RF polymer matrix, at least for base-catalyzed material (spherical RF is produced by an acid catalyzed process). Structures A and B both include tetra-substituted benzene rings containing two hydroxyl and two alkyl substitutions. Structures containing one (Type C) and three (Type D) methylene substitutions, respectively, are also possible. Structure C exists at terminal positions of the polymer chains and may contain methylol ($-CH_2OH$) or hemiformal ($-CH(OH)CH_2OH$) groups in the terminal position (SCT-M0SRLE60-00-221-00001, *Spherical Resorcinol-Formaldehyde Resin Reactivity with Nitric Acid and Other Hanford RPP-WTP Process Solutions*). Overall, it appears that the resin formula weight may be approximated by the repeating unit of $C_7H_6O_2$ (~122 g/gmol) for simple stoichiometry calculations. In the Na-form, the hydrogens in the hydroxyl groups are replaced by Na, resulting in the approximate formula $C_7Na_2H_4O_2$.

The RF resin was considered as an alternative for separating Cs from Hanford wastes in the 1990s (Brown et al. 1995a and Kurath 1994). These early studies were performed using RF as a ground gel. The scoping studies described above resulted in selecting a spherical form of RF for implementation in the PT Facility. Figure 2.5-6 provides a schematic showing the preparation of spherical RF resin beads. Details of the bead formation process are considered confidential. However, the process generally begins with a polystyrene seed structure that is produced by a vendor (e.g., Microbeads, located in Skedsmokorset, Norway). The RF is formed within the seed structure to produce a spherical material that is approximately 0.6 wt % polystyrene and 99.4 wt % RF on a dry basis. Figure 2.5-7 is a photograph of a spherical RF product sample that results from the synthesis process.

Test data were obtained using material from a variety of production lots during development of spherical RF as an alternative for Cs removal. Table 2.5-1 provides a summary of the resin production history. Small resin batches were initially produced using a variety of production parameters to optimize resin characteristics considered important to application in processing Hanford wastes. After the original evaluation of spherical RF resin (24590-101-TSA-W000-0004-04-00001), lots used in testing were manufactured at facilities in Norway and Boulder, Colorado under licensing agreements to demonstrate that the actual RF production was not limited to a single source. These later resin lots were fabricated from seed material produced by Microbeads.

After completion of screening tests, six larger scale resin lots were produced to evaluate resin quality and reproducibility from a scaled-up process. These larger scale resin lots are described as 100 gal batches in some test reports. Resin lots synthesized under similar conditions are summarized by the following groupings:

- BRF-14, 3380-2P-0100, and 5C-370/522
- 5C-370/523 and 5E-370/639
- 5E-370/641, 5J-370/686, 3380-3-0200, 6C-370/745, and 3380-3-0201

The basis for material balances focuses on data obtained using the final five resin lots (in particular, 5E-370/641) as representative of material that would actually be obtained to support processing in the PT Facility.

Assumption 2.5.4. Spherical RF will be supplied in the quantities needed and future production scale resin batch performance is conservatively bounded by the selected benchmark resin properties.

2.5.3.1.1 Resin Density

The specific volume of RF resin beds varies with the pH and ionic strength of contacting salt solutions, with smaller resin volumes observed when resin is in the hydrogen form (H-form) and larger resin volume observed when resin is in the sodium form (Na-form). Since the treated waste contains excess caustic, while the eluant consists of dilute nitric acid, significant resin BV changes are observed during routine IX operating cycles. The mass of resin particles is also modified during process cycles, depending on whether the exchange sites are occupied by sodium or hydrogen ions. Parameters for the IX process during testing and operation are typically defined in terms using the resin BV. The BV definition is frequently identified in test reports based on conditions after contact with the regenerating solution, which approximates the largest BV in the operating cycle (BV swells slightly as regenerating solution replaced with waste).

Resin density estimates are used to determine the mass of IX resin in a bed for loading cycle predictions. Equilibrium and column data have generally been reported for spherical RF testing based on the mass of dry H-form resin. Therefore, density data are frequently reported based on the equivalent mass of dry H-form per unit volume, independent of whether the resin is in the hydrogen or sodium form. The units of values should be clearly understood when applying the density data.

2.5.3.1.1.1 Skeletal Density

Resin skeletal density is defined as the density of solid material (RF) in individual resin beads. Skeletal density measurements were obtained using a pycnometer filled with degassed, de-mineralized water. These results depend on whether the resin is in the hydrogen or sodium form. Table 2.5-2 presents a summary of skeletal density measurements obtained over the course of spherical RF testing. The skeletal density of freshly pretreated hydrogen and sodium form resin was determined to be approximately 1.5 g H-form solid/mL H-form solid and 1.6 g Na-form solid/mL Na-form solid, respectively. Resin skeletal density appears to increase as a resin bed is cycled through multiple loading and elution cycles. Data indicating the observed change in resin skeletal density over 16 cycles during pilot scale testing are provided in Table 2.5-3. No resin buoyancy issues were reported during column tests over the range of process solutions tested.

2.5.3.1.1.2 Bulk Density

Based on laboratory pretreatment experience, as-received spherical RF resin (in the H-form) appears to undergo an irreversible volume expansion during the initial one or two shrink-swell cycles. Table 2.5-4 summarizes volume expansions observed during tests using different resin lots. These data indicate that a resin volume of approximately 1.6 mL Na-form resin/mL as-received H-form resin is anticipated after two shrink-swell cycles have been completed.

The bulk densities of resin beds based on loading pretreated material in 2-cm diameter IX columns or a 25-mL graduated cylinder are reported in 24590-101-TSA-W000-0004-99-00013, Rev 00B, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant*, for each spherical RF resin lot. Table 2.5-5 indicates that the bulk density of resin beds is approximately 0.4 g dry H-form resin/mL wet H-form resin bed. Resin lots manufactured by Boulder

Scientific Corporation appear to have a higher bulk density than resin lots manufactured by Microbeads. Bulk density, on a dry H-form mass basis, decreases when resin is converted to the Na-form. This is indicated by the Na-form bulk densities reported in Table 2.5-5, which estimate the Na-form resin bulk density at approximately 0.3 equivalent g dry H-form resin/mL wet Na-form resin.

The bulk density of spherical RF resin is also reported in 24590-101-TSA-W000-0004-174-00002, *Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins*, based on BV measurements obtained from a 3 in. diameter column with a bed height of ~3.4 in. Spherical RF bulk resin densities reported in this study are shown in Table 2.5-6 and are approximately 10 % lower than those obtained from 2 cm diameter columns. The reference attributes the observed density difference to (1) tapping the 2 cm columns to a constant volume and (2) down-flow regeneration, which was not done for the 3 in. diameter column data in an attempt to reflect plant operating conditions.

Variations in the bulk density on a dry H-form mass basis, shown in Table 2.5-5, indicate that the resin bed volume is projected to change as operations proceed through the loading, elution, and regeneration cycles. Figure 2.5-8 presents typical variations in the relative resin bed volume anticipated during operating cycles observed during spherical RF testing. The test data indicate that a resin bed volume will increase by approximately 25 % during the transition between the H-form resin in contact with nitric acid and the Na-form resin in contact with waste. 24590-101-TSA-W000-0004-174-00002 reported that resin bed heights were 26 % greater in LAW simulant than the height in acid during tests in a 12 in. diameter pilot-scale column. This same reference reported that resin bed heights were 30 % greater in LAW simulant than the height in acid during tests in a 24 in. diameter pilot-scale column.

Conversion of a dry H-form resin mass to a dry Na-form resin mass may be required to support material balance calculations using Equation 2.5-2. SCT-M0SRLE60-00-10-00005, *Radiolytic, Thermal, and Physical Degradation Testing of Spherical Resorcinol-Formaldehyde (RF) Resin (U)*, reports a value for the parameter I_{Na} of 1.2 for spherical RF resin lot BRF-14. Table 3 of 24590-WTP-RPT-RT-06-001 reports values of I_{Na} ranging from 1.22 to 1.25 for spherical RF resin lots. Comparison of the Na-form bulk densities shown in Table 2.5-5 produces an estimate for I_{Na} ranging from 1.17 to 1.31 for spherical RF resin lots. Table 23 of SCT-M0SRLE60-00-110-00029, Rev 00B, *Batch, Kinetics, and Column Data from Spherical Resorcinol Formaldehyde Resin*, reports the I_{Na} value for lot 5E-370/641 as 1.25, while the ratio from densities reported in Table 2.5-5 produces an estimate for I_{Na} of 1.23 for this same resin lot. Therefore, it appears that a value of $I_{Na} = 1.25$ can be used as an approximation to convert the dry mass of H-form resin to dry Na-form resin.

Equation 2.5-2

$$m_{Na} = m_H \times I_{Na}$$

where:

I_{Na} is mass of dry sodium form resin/mass of dry hydrogen form resin

m_H is the dry basis hydrogen form resin mass, g

m_{Na} is the dry basis sodium form resin mass, g

Assumption 2.5.2. The process can accommodate the variations in resin BV indicated by test data over the process cycles.

2.5.3.1.2 Particle Size Distribution

24590-101-TSA-W000-0004-99-00013 reports the results of particle size distribution (PSD) measurements for spherical RF resin lots. As-received resin (in the H-form) was pre-treated by rinsing with water, converted to the Na-form, washed with water, converted to the H-form, and water washed before performing H-form particle size analysis. A portion of the pre-treated H-form resin was then converted to the Na-form prior to performing particle size analysis. The PSDs are reported for both H-form and Na-form resin from each lot using a Microtrac S3000 particle size analyzer. H-form resin particle sizes were determined using water as the dispersion liquid while Na-form resins were dispersed in 0.01 M NaOH. Figure 2.5-9 provides an example of a typical PSD based on the Na-form resin from lot 5E-370/641.

Mean particle diameters can be determined on a volume, number, or surface area basis. The alternative mean diameters are determined by Equation 2.5-3, Equation 2.5-4, or Equation 2.5-5.

Equation 2.5-3

$$m_v = \frac{\sum V_i d_i}{\sum V_i}$$

Equation 2.5-4

$$m_n = \frac{\sum (V_i / d_i^2)}{\sum (V_i / d_i^3)}$$

Equation 2.5-5

$$m_a = \frac{\sum V_i}{\sum (V_i / d_i)}$$

where (using consistent units):

m_v is the volume-based mean particle size
m_n is the number-based mean particle size
m_a is the surface-area-based mean particle size
V_i is the particle volume
d_i is the particle diameter

Table 2.5-7 provides a summary of volume-based, number-based, and surface-area-based PSD characteristics of H-form and Na-form resin beads for different resin lots. These data indicate that the volume-based mean particle size of pre-treated H-form resin ranges from 400 to 450 μm with standard deviation of ~80 μm. Particles with diameter less than 300 μm represent approximately 5 % of the particles, while approximately 10 % of the particles have diameters greater than 500 μm. Similar data indicate the volume-based mean particle size of Na-form resin ranges from 430 to 490 μm.

The as-received resin is provided in the H-form. The PSDs reported for resin lot 5E-370/641 in 24590-101-TSA-W000-0004-174-00002 indicate the volume based mean particle size of the as-received H-form

resin was 389 μm, which increased to 424 μm after cycling through the Na-form (similar to the pretreatment activities for resin lots described above).

The effect of cycling resin through multiple expansion and contraction cycles associated with loading and elution cycles was investigated as part of pilot-scale testing using material from resin lot 5E-370/641 (SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin*). Comparisons of volume-based mean particle sizes from resin samples before and after cycling in a 12 in. diameter column indicate that no significant fines were created over 7 cycles. Data are also reported based on samples from a 24 in. diameter column. The variation of volume-based mean particle sizes for H-form and Na-form resin is summarized in Figure 2.5-10. These data indicate that, after the initial expansion of as-received resin, no significant change in mean particle size was observed over 14 process cycles.

2.5.3.1.3 Resin Radiation Stability

Historical tests investigated the radiation stability of ground gel RF by irradiation in 1 M NaOH and a neutralized current acid waste simulant (Envelope B type waste) at 15 to 20 °C using a ^{60}Co source. Resin samples were exposed at dose rates of 1.6×10^6 rad/hr over several weeks to a total exposure of $\sim 1 \times 10^9$ rad. The resin was found to be stable at total exposures up to 1×10^8 rad (the measured Cs batch distribution coefficient remained constant for exposures ranging from 1×10^6 to 1×10^8 rad). The Cs batch distribution coefficient decreased by 74 % when irradiated to 1×10^9 rad (Brown et al., 1995b).

Project estimates of resin degradation are based on irradiation tests using material from resin lot BRF-14 (SCT-M0SRLE60-00-10-00005). As-received resin was pretreated with a water rinse, converted to the Na-form in 1 M NaOH, washed in water, converted to the H-form in 0.5 M HNO_3, and rinsed in water. The pretreatment sequence was performed a second time before initiating the irradiation tests. Resin samples in AP-101 simulant, 0.5 M HNO_3, or water were exposed to a ^{60}Co source in a stainless steel apparatus which trapped all generated gases. All exposures were 10 days in length and occurred at 25 or 65 °C. Radiolytic exposures of either 34×10^6 or 100×10^6 rad were provided by varying the distance from the source to yield dose rates of 0.135×10^6 or 0.42×10^6 rad/hr, respectively.

Post-exposure liquid analysis found no appreciable semi-volatile organic carbon analytes with a detection limit of 1 mg/L. A post-exposure microscopic examination of resin beads was also conducted to assess changes in color and surface texture. No attrition of the resin beads was observed. However, samples did exhibit a darkening of the resin with increased total dose, which has been observed in other organic IX resins and is attributed to radiolytic degradation. Therefore, unlike the experience with SuperLig 644 irradiation, it does not appear that significant resin mass loss is associated with spherical RF irradiation up to a total dose of 100×10^6 rad.

The effect of irradiation on resin performance was determined by comparing the change in batch equilibrium Cs loading of resin samples after irradiation with Cs loading of unirradiated resin. Data obtained from resin irradiation tests at 25 °C in AP-101 simulant and 0.5 M HNO_3 are summarized in Table 2.5-8 (note that data at 65 °C are also available from the reference, but were not considered applicable to the current process basis). The data from Table 2.5-8 are plotted as a function of liquid-phase Cs concentration on Figure 2.5-11 and Figure 2.5-12 for irradiation in AP-101 simulant and HNO_3, respectively. Interpolation between data points was performed by fitting Langmuir isotherms to the data; the variation of resin loading with dose (relative to unirradiated resin) was characterized by the Cs loading estimated at a liquid-phase Cs concentration of 1×10^{-4} gmol Cs/L. The change in resin Cs loading estimated at a liquid-phase Cs concentration of 1×10^{-4} gmol Cs/L is summarized in Table 2.5-9.

Figure 2.5-13 plots the change in resin capacity, relative to unirradiated capacity, as a function of total absorbed dose indicated by the test data. It is hypothesized that the actual degradation rate of active IX sites is related to the number of active IX sites remaining in a resin bead. This hypothesis produces an exponential relationship between the resin capacity relative to unirradiated resin and absorbed dose. Insufficient test data are available to differentiate between a linear and exponential variation with dose; however, it appears reasonable that the resin capacity must approach zero as an asymptote when the absorbed dose becomes large. Therefore, the exponential relationship shown by Equation 2.5-6 has been used as a basis for predicting the influence of radiation degradation on CIX performance. Figure 2.5-13 indicates that the resin loading capacity is estimated to decrease by approximately 14 % over the first 100×10^6 rad absorbed by the resin when the constant in Equation 2.5-6 is $k_{rad} = 2.98 \times 10^{-9}$ rad^{-1}. Equation 2.5-6 is based on data from irradiation in AP-101 simulant because the loading cycle is expected to dominate contributions to the total resin absorbed dose since it is typically much longer than other IX cycles.

Equation 2.5-6

$$\left.\frac{R}{R_0}\right|_{rad} = e^{-k_{rad} D}$$

where:

$R/R_0|_{rad}$ is the effective resin capacity after irradiation to a specified total dose relative to the initial capacity.

D is the total dose absorbed by resin and solution matrix, rad.

R_0 is the initial Cs capacity of resin, mmol Cs/g dry H-form resin.

k_{rad} is a radiolytic degradation rate constant, 2.98×10^{-9}, rad^{-1}.

Gas generation rates were also measured during irradiation tests described in SCT-M0SRLE60-00-10-00005, Rev 00A. Generated gas compositions obtained from tests, including resin in AP-101 simulant or nitric acid, were compared to solution blanks to estimate component gas generation rates. Constants are provided in the reference estimating generation of H_2, N_2O, CO, O_2, N_2, CH_4, and volatile organic carbon (VOC) for the systems of spherical RF in AP-101 simulant, water, and nitric acid. The results indicate there is no appreciable VOC generation from resin degradation at these exposure conditions. Gas generation from IX columns is not currently included in the flowsheet.

Assumption 2.5.5. The relative impact of radiation degradation on spherical RF performance observed in material used by the PT Facility is assumed to be similar to that determined using material from resin lot BRF-14 (produced using different fabrication parameters than the final reference resin lot).

2.5.3.1.4 Resin Chemical Stability

Resin exposure to dissolved oxygen in process solutions has been found to decrease the Cs loading capacity of spherical RF resin. Earlier investigations had shown that SuperLig 644 was also susceptible to oxidation by dissolved oxygen (see, for example, 24590-101-TSA-W000-0004-114-15, *Chemical Degradation of SuperLig 644 Ion Exchange Resin*). 24590-101-TSA-W000-0004-99-00013 describes a potential mechanism for RF resin oxidation based on Figure 2.5-14. The mechanism implies that one mole of dissolved oxygen is required to destroy one mole of RF (i.e., replace the active hydroxyl group with oxygen). Based on the RF formula weight (122 g/gmol), reaction of 1 mmol dissolved oxygen will

oxidize the active sites on 0.122 g H-form resin. Therefore, 1 mmol dissolved oxygen/g dry H-form resin can potentially reduce the resin capacity by 12.2 %. The mechanism shown on Figure 2.5-14 also indicates that hydrogen peroxide is a possible byproduct of the oxidation reaction, which also can react with the RF active groups. Combining oxygen and hydrogen peroxide oxidation paths results in the potential for 1 mmol dissolved oxygen/g dry H-form resin to reduce the resin capacity by as much as 24.4 %.

Test data from investigation of the effect of dissolved oxygen on resin capacity are summarized in Table 2.5-10. These test data were obtained from Cs breakthrough curves obtained before and after the resin was exposed to dissolved oxygen during the regeneration cycle. Spherical RF oxidation data were obtained using material from resin lots BRF-14, BRF-15, and BRF-17. Elevated oxygen exposure was obtained by regenerating a column with large quantities (e.g., 400 to 600 BV) of recirculating 0.5 M NaOH that was maintained saturated with oxygen by bubbling oxygen in the supply vessel. Additional data were obtained using material from resin lot 5E-370/641 that had been exposed to oxygen during multiple (i.e., 16) loading/elution cycles during hydraulic testing in a 24 in. diameter pilot-scale column.

The effect of oxidation on the effective resin capacity is estimated from the change in loading cycle volume observed at 50 % Cs breakthrough using the same waste feed simulant. This comparison is based on the concept that the column distribution ratio is an approximation of the loading cycle volume at 50 % breakthrough. The relationship between resin Cs loading and loading cycle volume at 50 % from two different tests is derived from combining Equation 2.5-25 with Equation 2.5-26 and is shown as Equation 2.5-7.

Equation 2.5-7

$$\frac{(\text{Cs Loading})_1}{(\text{Cs Loading})_0} = \frac{R}{R_0}\bigg|_{ox} = \left(\frac{\lambda_1}{\lambda_0}\right)\left(\frac{[Cs]_{feed1}}{[Cs]_{feed0}}\right)\left(\frac{\rho_{b0}}{\rho_{b1}}\right)$$

where:

Cs Loading is the resin Cs loading in equilibrium with the feed for tests 0 or 1, mmol Cs/g dry H-form resin

λ is the column distribution ratio for Cs, or loading cycle volume at 50 % breakthrough, for tests 0 or 1, BV

$[Cs]_{feed}$ is the column feed Cs concentration during the loading cycle for tests 0 or 1, gmol/L

ρ_b is the bulk resin density in the column for tests 0 or 1, g resin/mL

$R/R_0|_{ox}$ is the effective resin capacity after exposure to oxygen relative to the initial capacity

Equation 2.5-7 indicates that the ratio of resin Cs loading from two tests can be estimated from the ratio of column distribution ratios if the feed Cs concentration and resin bed bulk densities are approximately equal. The effective resin capacity, relative to that of un-oxidized resin, is calculated for each test listed in Table 2.5-10.

The change in resin capacity relative to un-oxidized resin is plotted as a function of oxygen exposure on Figure 2.5-15. Observed resin oxidation is bounded by the potential variation in resin capacity predicted by the proposed mechanism described in Figure 2.5-14. Therefore, Equation 2.5-8 is used as a

conservative bound describing the change in resin capacity attributed to dissolved oxygen exposure from process solutions.

Equation 2.5-8

$$\left.\frac{R}{R_0}\right|_{ox} = e^{-k_{ox} m_{ox}}$$

where:

k_{ox} is the resin degradation constant from oxygen exposure, 0.2797 g dry H-form resin/mmol O_2
m_{ox} is the cumulative oxygen exposure of a resin bed, mmol O_2/g dry H-form resin

SCT-M0SRLE60-00-221-00001 investigated the reactivity of spherical RF resin in nitric acid, sodium permanganate, and waste simulant solutions. No significant reactions were observed between the resin and 1 M sodium permanganate or waste simulant. The test data indicate that RF resin reactions with nitric acid include low temperature (25 °C) nitration/oxidation and intermediate temperature (55 °C) bulk oxidation involving dissolution and gas generation. Temperature and acid concentrations that initiate detectable reaction rates within 24 hr under stagnant conditions are:

- >75 °C for 0.5 M acid
- <66 °C for 0.625 M acid
- 45-55 °C for 1.0 M acid
- 25-45 °C for 2.0 M acid
- 18-20 °C for 3.0 M acid

Gas generated by the resin-acid reaction in 3 M HNO_3 at 55 °C was primarily composed of CO_2, N_2O, and NO_2. Equations for predicting reaction rates are included in the reference. Agitation of the resin/acid slurry during testing reduced the observed RF reaction rate with nitric acid to the extent that no significant resin reaction was observed at 55 °C in 3 M acid. This observation implies that maintaining liquid flow through a resin bed may stop both the nitration and gas generation from reactions at higher temperatures and acid concentrations; however, flow rates necessary to stop reactions were not determined.

Test data from nitrated/oxidized RF indicate that, although some compounds are produced by the acid-resin reaction which would likely be classified as energetic in a pure form, the bulk material is not significantly energetic. Mass change and elemental analysis indicate that the maximum observed nitration level for RF resin was less than one nitro group per repeating polymer unit. No nitrated RF resin was isolated over the range of potential plant conditions with sufficient stored energy to be considered hazardous with respect to detonation.

Acid decant solutions after contacting spherical RF resin were tested by accelerating rate calorimetry. No significant self-heating of gas generation was observed upon heating the decant solutions. The test results are interpreted as indicating that resin dissolution will not have a significant effect on downstream unit operations. Investigators concluded that the safety risk associated with RF resin reactivity in nitric acid was dominated by the potential for column pressurization from gas generation in resin beds.

2.5.3.1.5 Combined Chemical and Radiolytic Degradation

Actual data measuring the effect of combined chemical and radiolytic degradation on spherical RF resin performance are not available. However, the approach for estimating combined chemical and radiolytic degradation described in 24590-WTP-RPT-PO-04-023, *Resin Degradation Data Reconciliation,* appears to approximate test data for SuperLig 644. The estimate is based on the concept that the resin degradation rate during a particular cycle equals the sum of individual chemical and radiolytic degradation rates, as shown in Equation 2.5-9.

Equation 2.5-9

$$\left(-\frac{dR}{dt}\right) = \left\{\begin{matrix}\text{Rate of effective resin}\\ \text{degradation due to}\\ \text{chemical oxidation}\end{matrix}\right\} + \left\{\begin{matrix}\text{Rate of effective resin}\\ \text{degradation due to}\\ \text{radiolytic degradation}\end{matrix}\right\}$$

Equation 2.5-6 and Equation 2.5-8 are differentiated with respect to time and substituted into Equation 2.5-9 to determine the combined resin degradation rate, as shown in Equation 2.5-10. Note that the degradation rate forms selected effectively assume the rate of chemical and radiolytic resin degradation is proportional to the active resin sites remaining.

Equation 2.5-10

$$\left(-\frac{dR}{dt}\right) = k_{ox} R \frac{dm_{ox}}{dt} + k_{rad} R \frac{dD}{dt}$$

The rate of oxygen exposure per unit mass of resin bed is determined by the process solution flow rate passing through the bed, dissolved oxygen concentration, resin bed volume, and resin bulk density. This is shown by Equation 2.5-11, assuming all dissolved oxygen entering a column reacts with resin in that particular resin bed.

Equation 2.5-11

$$\frac{dm_{ox}}{dt} = \frac{C_{DO}\, v_{solution}}{V_{resin}\, \rho_b}$$

where:

C_{DO} is the dissolved oxygen concentration of a process stream entering the column, mmol O_2/L
$v_{solution}$ is the volumetric flow rate of a process stream entering the column, L/hr
V_{resin} is the resin bed volume, L resin
ρ_b is the resin bulk density, g dry H-form resin/L resin bed

Note that the product $V_{resin} \times \rho_b$ is a constant, independent of the resin form during a process cycle.

This approach assumes that the resin dose (and radiolytic degradation) is dominated by the loading cycle and the radiolytic degradation can be neglected in all other cycles. This approach is not a necessity, but it reduces the number of prediction equations that must be used and tracked during the evaluation of column performance. During column loading, it is assumed that the resin dose rate increases linearly with time as

Cs is captured by the resin. The increasing dose is averaged over the entire resin bed mass. Based on these assumptions, Equation 2.5-12 estimates the change in total dose absorbed by resin and solution for a plant-scale column.

Equation 2.5-12

$$\frac{dD}{dt} = \alpha\, t$$

The parameter α is determined by Equation 2.5-13 and Equation 2.5-14, assuming all ^{137}Cs decay energy is absorbed by the resin and solution mass within the resin bed region of a column during loading.

Equation 2.5-13

$$\alpha = \frac{\left[{}^{137}\text{Cs}, \frac{\text{Ci}}{\text{L}}\right]\left(\text{Loading Flow}, \frac{\text{L}}{\text{hr}}\right)\left(0.00472 \frac{\text{W } {}^{137}\text{Cs}}{\text{Ci}}\right)\left(1 \frac{\text{Joule}}{\text{sec-W}}\right)\left(3600 \frac{\text{sec}}{\text{hr}}\right)}{\left(0.01 \frac{\text{Joule}}{\text{kg-rad}}\right)\left(\text{Mass of Resin + Solution, kg}\right)}$$

$$= 1699.2 \frac{\left[{}^{137}\text{Cs}, \frac{\text{Ci}}{\text{L}}\right]\left(\text{Loading Flow}, \frac{\text{L}}{\text{hr}}\right)}{\left(\text{Mass of Resin + Solution, kg}\right)} \frac{\text{rad}}{\text{hr}^2}$$

Equation 2.5-14

$$\left(\text{Mass of Resin + Solution, kg}\right) = \left[\varepsilon_t\, \rho_{\text{solution}} + (1 - \varepsilon_t)\, \rho_{\text{resin skeleton}}\right]\left(\text{Resin Bed Volume, L}\right)$$

where:

ε_t is the resin void fraction including bed voids and resin pores, 0.75 from Section 2.5.3.1.7.1, dimensionless
$\rho_{solution}$ the solution density, 1.23 kg/L
$\rho_{resin\ skeleton}$ is the resin skeleton density, 1.6 kg/L

Equation 2.5-10 is integrated over an arbitrary process time period assuming the composition of the process stream entering a column is constant during the process time period. This assumption is assumed to apply for each IX process cycle (e.g., loading cycle, elution cycle, regeneration cycle). The integration result is shown by Equation 2.5-15.

Equation 2.5-15

$$-\int_{R_{n-1}}^{R_n} \frac{dR}{R} = \frac{k_{ox} C_{DO} v_{solution}}{V_{resin} \rho_b} \int_0^{T_n} dt + k_{rad} \alpha \int_0^{T_n} t\, dt$$

$$-\text{Ln}\left(\frac{R_n}{R_{n-1}}\right) = \frac{k_{ox} C_{DO} v_{solution}}{V_{resin} \rho_b} T_n + k_{rad} \alpha \frac{T_n^2}{2}$$

$$R_n = R_{n-1}\, e^{-\left(\frac{k_{ox} C_{DO} v_{solution}}{V_{resin} \rho_b} T_n + k_{rad} \alpha \frac{T_n^2}{2}\right)}$$

Solution of Equation 2.5-15 for the first process cycle of a column is shown in Equation 2.5-16.

Equation 2.5-16

$$R_1 = R_0\, e^{-\left(\frac{k_{ox} C_{DO} v_{solution}}{V_{resin}\rho_b} T_1 + k_{rad}\alpha\frac{T_1^2}{2}\right)}$$

$$\frac{R_1}{R_0} = e^{-\left(\frac{k_{ox} C_{DO} v_{solution}}{V_{resin}\rho_b} T_1 + k_{rad}\alpha\frac{T_1^2}{2}\right)}$$

The recursion formula shown by Equation 2.5-15 can be expanded to solve for the effective resin capacity after an arbitrary number of process cycles in terms of the sum of earlier cycles. Also, the product $v_{solution} \times T_n$ is the total volume of solution fed to the column during a particular cycle. These observations result in Equation 2.5-17, which is used to estimate the combined effect of radiolysis and chemical oxidation on the initial resin capacity.

Equation 2.5-17

$$\frac{R_n}{R_0} = e^{-\left(\frac{k_{ox}}{V_{resin}\rho_b}\sum_{i=1}^{n} C_{DO,i}\, V_{cycle\,i} + \frac{k_{rad}}{2}\sum_{i=1}^{n}\alpha_i T_i^2\right)}$$

where:

R_n/R_0 is the effective total Cs resin capacity after n process cycles relative to the initial capacity

k_{ox} is the constant defined by Equation 2.5-8, 0.244 g dry H-form resin/mmol O_2

V_{resin} is the fresh resin BV in a column, L resin

ρ_b is the bulk density of resin in a column, g dry H-form resin/L resin

$C_{DO,i}$ is the oxygen concentration of solution entering a resin bed during the ith cycle, mmol O_2/L

$V_{cycle,i}$ is the process solution volume entering a resin bed during the ith cycle, L

k_{rad} is the constant defined by Equation 2.5-6, 1.46×10^{-9}, rad^{-1}

α_i is defined by Equation 2.5-13 for the ith process cycle, rad/hr^2

T_i is the total duration of the ith process cycle, hr

Resin degradation is evaluated based on exposing a resin bed to a sequence of process cycles during operation. Each cycle (loading, feed displacement, pre-elution rinse, elution, post-elution rinse, and regeneration) can influence resin degradation. The analysis decreases the resin capacity available for removing Cs from waste solution as the number of process steps to which a resin bed is exposed increases.

For plant scale applications, Equation 2.5-17 requires input of the dissolved oxygen concentration of process solutions fed to a column during a particular cycle. 24590-WTP-RPT-RT-07-005 (Appendix A), presents a correlation for dissolved oxygen concentration in waste solutions based on data for 5.2 M Na waste, 0 to 2 M NaOH, and 0 to 2 M NaCl solutions at 25 °C. The correlation result is shown as Equation 2.5-18.

Equation 2.5-18

$$C_{DO} = (0.05905)(P_{sat})\left\{b + \sqrt{b^2 + 4(0.0725)(23.52)}\right\}$$

$$\text{with : } b = 1.207 - [Na^+] - [K^+]$$

where:

C_{DO} is the dissolved oxygen concentration in mmol O_2/L

P_{sat} is the maximum air pressure that potentially equilibriates oxygen in the gas phase with dissolved oxygen in the liquid phase, in atm

$[Na^+]$ is the waste total sodium ion concentration in gmol/L

$[K^+]$ is the waste potassium ion concentration in gmol/L

The air pressure describing the partial pressure of oxygen in equilibrium with process solution is based on an assumed Hanford Site barometric pressure of 14.38 psia, feed tank headspace pressure of –1 psig, and pressurized air from pulse jet mixing equivalent to 12.5 ft of water, gage (5.4 psig). These assumptions result in an assumed air pressure of P_{sat} = 1.22 atm for use in Equation 2.5-18 ([14.38 – 1 +5.4]/14.7). Dissolved oxygen concentrations for feed solutions during other process cycles listed in Table 2.5-11 are calculated from Bunsen coefficients for the solutions at 20 °C. The concentrations are adjusted to reflect the potential for equilibriating with air at pressures that differ from standard atmospheric pressure.

Degradation estimates are evaluated only when a resin bed is in the lead loading position or when process steps are being performed to prepare a column for reuse (feed displacement through regeneration process cycles). Degradation of resin bed in the lag and polishing positions is assumed to be negligible since the lead column captures most of the oxygen and ^{137}Cs in waste feed.

Assumption 2.5.6. The impact of combined radiolytic and chemical degradation rate is assumed to be additive as was observed during testing of SuperLig 644.

2.5.3.1.6 Spent Resin Properties

Spent resin analyses are reported in 24590-101-TSA-W000-0004-114-00020, Rev 00B, *Spherical Resorcinol-Formaldehyde Analysis Following Actual Hanford Tank Waste Processing,* after using the resin in two laboratory-scale columns to process a series of actual waste samples with material from resin lot 5E-370/641. The sequence of wastes processed began with AP-101 simulant, followed by actual wastes from AP-101 and AN-102. A total of three column test runs were performed with varying loading and elution cycle volumes and the two columns swapped between lead and lag positions between test runs. Spent resin dose rates at contact prior to sample analysis for the two resin samples, each with a dry H-form mass of 2.92 g, were <0.5 mR/hr (Column A) and 2.5 mR/hr (Column B).

Both columns were eluted with 30 BV of 0.5 M HNO_3 and rinsed with 3 BV of water before spent resin analysis. Table 2.5-12 summarizes the results of analyzing the two resin samples (an entire laboratory scale resin bed represents a single resin sample). The results summarized in Table 2.5-12 are based on acid digestion of resin samples and should not be confused with toxicity characteristic leaching procedure (TCLP) results. A number of elements were found to have concentrated on the resin, including Ag, As, Ba, Cr, Ni, and Pb. Other elements identified on the spent resin based on information-only results included Co, Cu, Fe, and Zr. The maximum ^{137}Cs concentration reported is 3.68 μCi/g dry H-form resin. Total alpha concentrations ranged from 0.6 to 2.4 nCi/g dry H-form resin.

The isotopic distribution of Cs found in spent resin from Column A is reported to be 69.7 % ^{133}Cs, 12.1 % ^{135}Cs, and 18.2 % ^{137}Cs. For Column B the observed Cs isotopic distribution was 62.9 % ^{133}Cs, 16.2 % ^{135}Cs, and 20.9 % ^{137}Cs. This isotopic abundance for ^{133}Cs is higher than any of the actual waste samples used in column tests, indicating that residual Cs measurements in spent resin may be influenced

by simulant test runs of laboratory equipment typically performed before installation in hot cells for actual waste testing. If the initial waste processed biases the isotopic distribution of Cs in spent resin, ^{137}Cs concentrations experienced during plant operations could be higher than that measured in the laboratory.

Testing to support a preliminary characterization of spent resin is described in SCT-M0SRLE60-00-110-00030, Rev 00B, *Characterization of Spent Spherical Resorcinol-Formaldehyde Resin.* In these tests, a tank waste simulant based on AN-107 was spiked with regulated metals and organic compounds. Two different levels of spike component concentrations in simulant were pumped through separate test columns. Each test column was cycled through three loadings, displacements, pre-elution rinses, elutions, and post-elution rinses. Resin regeneration was performed prior to the second and third loading cycles. A total of 800 BV waste simulant was processed during loading in each column during the tests. The resin beds were sampled and analyzed by an independent laboratory. Analysis results indicated that TCLP leachate from spent resin is below characteristic hazardous levels for Resource Conservation and Recovery Act of 1976 (RCRA) metals. The TCLP leachate was also found to be below criteria for regulated and total organics.

2.5.3.1.7 Resin Hydraulic Properties

2.5.3.1.7.1 Resin Bed Porosity

A discussion of the relationship between porosity and resin density, which is summarized below to clarify the basis for reported porosity values, is provided in SCT-M0SRLE60-00-05-00004, Rev 00A, *Ion Exchange Modeling of Cesium Removal from Hanford Waste using Spherical Resorcinol-Formaldehyde Resin.* Equation 2.5-19 summarizes the definition of three different porosities that may be encountered during the consideration of an IX resin bed. Note that the volume basis for porosity is constructed around the resin bed itself and does not consider ends of an IX column that contain no resin.

Equation 2.5-19

$$\varepsilon_t = \varepsilon_b + (1 - \varepsilon_b)\varepsilon_p$$

with :

$$\varepsilon_b = \frac{V_{void} - V_{pore}}{V_{bed}};\ \varepsilon_p = \frac{V_{pore}}{V_{part}};\ \varepsilon_t = \frac{V_{void}}{V_{bed}} = \frac{V_{bed} - V_{sld}}{V_{bed}}$$

where:

ε_t is the total porosity of a resin bed. This is the volume fraction of a resin bed that contains liquid. Liquid volume (V_{void}) between resin beads and within the pores of resin beads is included. The total porosity is defined by the bed volume (V_{bed}) less the volume of actual solid material (V_{sld}) relative to the bed volume.

ε_b is the resin bed porosity. This is the volume fraction of a resin bed that contains liquid between the resin beads. The liquid volume between resin beads would be considered to approximate the drainable liquid in a resin bed. The bed porosity is defined by the total bed void volume (V_{void}) less the volume of pores within resin beads (V_{pore}) relative to the bed volume.

ε_p is the porosity of a resin particle. This is the volume fraction of a resin bead that contains liquid. The particle porosity is defined as the volume of pores (V_{pore}) relative to the volume of resin beads as if they had no pores (V_{part}).

Equation 2.5-20 indicates the relationship between bulk resin bed density and resin skeletal based on the definitions associated with Equation 2.5-19.

Equation 2.5-20

$$\rho_b = \rho_s(1-\varepsilon_t) = \rho_s(1-\varepsilon_b)(1-\varepsilon_p)$$

where:

ρ_b is the mass of resin solid per unit volume of resin bed

ρ_s is the skeletal resin density, or mass of resin solid per unit volume of resin solid

Skeletal density and bulk density of a resin bed are discussed in Section 2.5.3.1.1. The available data indicate the bulk density of an H-form spherical RF resin bed is approximately 0.4 g dry H-form resin/mL resin bed, while the skeletal density of H-form spherical RF resin is approximately 1.5 g dry H-form resin/mL dry H-form resin. Equation 2.5-20 indicates that the total porosity of a resin bed is estimated to be 0.73 based on these inputs ($\varepsilon_t = 1-\rho_b/\rho_s$). Similarly, the total porosity of a Na-form resin bed is estimated to be 0.75 from the data reported in Section 2.5.3.1.1.

The porosity of spherical RF resin beds was measured as part of hydraulic testing using material from resin lot 5E-370/741. 24590-101-TSA-W000-0004-174-00002 summarizes bed porosity estimates from hydraulic tests performed using 3 in., 12 in., and 24 in. diameter resin beds. The resin bed porosity was determined based on the Ergun equation for flow through a packed bed, shown as Equation 2.5-21.

Equation 2.5-21

$$\frac{(\Delta P)}{Z} = \frac{150(1-\varepsilon_b)^2 \mu V_0}{\varepsilon_b^3 D_p^2} + \frac{1.75(1-\varepsilon_b)\rho_l V_0^2}{D_p \varepsilon_b^3}$$

where:

(ΔP) is the differential pressure across the resin bed when fluid is passing through the resin bed

Z is the resin bed height

ε_b is the resin bed porosity

μ is the fluid viscosity flowing through the resin bed

D_p is the resin particle diameter

V_0 is the superficial velocity of fluid passing through the IX column

ρ_l is the fluid density

Test data determined the pressure drop across a resin bed with known bed height, fluid viscosity, mean particle diameter, fluid superficial velocity, and fluid density. Based on these measured quantities, Equation 2.5-21 is used to solve for the resin bed porosity. The resin beds were subjected to multiple loading, elution, and regeneration cycles during hydraulic testing. Figure 2.5-16 indicates that the observed porosity of a spherical RF resin bed during the down-flow load cycle, after up-flow simulated waste introduction, remains approximately constant at 0.42 over multiple cycles.

The porosity of a resin particle (or bead) can be estimated from Equation 2.5-20 based on the Na-form bulk density, Na-form skeletal density, and bed porosity. The currently available data indicates the porosity of a spherical RF resin bead from resin lot 5E-370/641 is estimated to be approximately 0.61.

2.5.3.1.7.2 Resin Bed Permeability

Fluid pressure drops across the resin bed are not included as part of the current material balance calculations. Therefore, resin bed permeability is not a specific input to the material balances. However, unexpected pressure drop behavior was observed during initial pilot-scale tests of the Cs IX column using the SuperLig 644 IX resin. Higher-than-anticipated pressure drops were observed in 2 in., 4 in., and 6 in. diameter test beds. CCN 046316, *Pressure Drop Excursion in Ion Exchange Columns using SuperLig 644 Resins for Cesium Removal,* summarizes the various test observations, indicating:

- Pressure drops for SuperLig at the design basis superficial velocity (scaled flow rate) may exceed the plant system pressure drop design allowance during regeneration, and
- Pressure drops observed in each process cycle for SuperLig (i.e., loading, rinses, elution, and regeneration) appeared to generally increase as the resin is reused for multiple loading cycles.

Pressure drops exceeding the allocation included in the plant design for SuperLig resin beds were encountered in as few as three loading cycles, causing concern that the baseline plan to reuse a resin 10 times cannot be achieved.

Larger scale testing was performed using the SuperLig 644 resin to further investigate the hydraulic issue. Testing was completed operating a 1/2-scale IX column through multiple chemical cycles. The design basis calls for 10 load/elute cycles to be performed before each resin change. Testing completed 11 load/elute cycles, maintaining an acceptable pressure drop across the resin bed for all 11 cycles. Some degradation in hydraulic performance was observed over the test cycles, but pressure drops remained within plant design allowances. Other key observations include the need for care in the introduction of waste (because of large liquid density differences) to avoid excessive disturbance of the resin bed and the need for periodic up-flow through the bed (SCT-M0SRLE60-00-30-00003, *Ion Exchange Testing with SuperLig 644 Resin (U)*). The poor hydraulic performance observed was ultimately attributed to the compressible nature of the ground gel material, which reduced the resin bed permeability as the resin swelled during regeneration. Therefore, successful hydraulic testing was considered an important factor in demonstrating that spherical RF is an acceptable alternate resin for Cs removal.

Spherical RF resin bed hydraulic tests using a 3 in. diameter column are reported in 24590-101-TSA-W000-0004-174-00002. Initial tests conducted with resin samples from early resin lots (BRF-14, BRF-15, and BRF-18) indicated operating procedure modifications were needed to allow relief of residual bed stresses that occur when the bed expands during regeneration and introduction of LAW into a regenerated bed. The procedure was modified to include up-flow of the caustic solution during regeneration and a short initial phase of up-flow during the introduction of LAW to fluidize the bed and displace the low-density caustic before initiating down-flow of LAW during the loading cycle. Once the modified procedure was implemented, tests using material from resin lot 5E-370/641 were performed. No significant changes to the resin bed hydraulic characteristics were observed after 14 chemical cycles (i.e., processing the resin bed through loading, rinse, elution, and regeneration cycles).

Additional hydraulic test data, using spherical RF from resin lot 5E-370/641 in 12- and 24-in. diameter columns, are reported in SCT-M0SRLE60-00-110-00028. Seven chemical cycles were completed in the 12 in. diameter column and 16 cycles were completed in the 24 in. diameter column. No trend of increasing or decreasing bed permeability was observed during tests at either scale when up-flow

regeneration, followed by up-flow waste simulant introduction, was used prior to the down-flow loading cycle.

Hydraulic test data were evaluated using the Darcy flow equation for fluid flow through a porous bed (Equation 2.5-22) and Ergun equation for friction factor in a porous bed (Equation 2.5-23). The average spherical RF bed permeability measured using the pilot-scale columns ranged from 2.8 to 3.3×10^{-6} cm^2. A permeability greater than 1.17×10^{-6} cm^2 is predicted to allow processing 22 gpm of solution, with viscosity of 5 cP, through a 600-gal resin bed (53 in. diameter) and produce a differential pressure less than 9.7 psi (design basis limiting flow conditions). Therefore, the test data indicate flow rates that are a factor of 2 to 3 greater than 22 gpm can be achieved through a spherical RF resin bed at the design basis limiting differential pressure.

Equation 2.5-22

$$K_p = \frac{V_0 \mu Z}{(\Delta P)}$$

where:

K_p is the resin bed permeability (typical units of cm^2)

Equation 2.5-23

$$f = \frac{(\Delta P)}{\rho_l V_0^2}\frac{D_p}{Z}\frac{\varepsilon_b}{(1-\varepsilon_b)} = \frac{150}{Re_p} + 1.75$$

where:

$$Re_p = \frac{D_p \rho_l V_0}{\mu (1-\varepsilon_b)}$$

2.5.3.1.7.3 Resin Bed Fluidization

Resin bed fluidization was studied as part of hydraulic studies using 3 in., 12 in., and 24 in. diameter columns reported in 24590-101-TSA-W000-0004-174-00002 and SCT-M0SRLE60-00-110-00028. Fluidization was evaluated to support performing the regeneration and regenerant displacement cycles using up-flow of the liquid phase through the resin bed. The up-flow liquid phase flow pattern during regeneration and regenerant displacement cycles allows resin expansion to occur when the bed is in an unconstrained configuration, which minimizes the potential for stresses to build in a resin bed that could result in reduced permeability. The resin bed expands during fluidization as the effective bed porosity increases. Data were obtained during pilot scale tests to determine the resin bed volume variation with fluid superficial velocity. Figure 2.5-17 summarizes the observed variation in bed volume with superficial velocity when the resin is fluidized by an up-flow of 0.5 M NaOH. Figure 2.5-18 summarizes the observed variation in bed volume with superficial velocity when the resin is fluidized by an up-flow of waste simulant. Bed fluidization and expansion is a function of fluid and resin properties. 24590-WTP-RPT-RT-07-005 describes a basis for predicting fluidizing conditions as these properties change.

2.5.3.1.8 Resin Thermal Properties

Thermal property information specific to spherical RF is currently limited to heat capacity data presented in SCT-M0SRLE60-00-221-00001. The observed variation in heat capacity of damp H-form and Na-

form spherical RF resin with temperatures ranging from 50 to 80 °C is shown in Figure 2.5-19. Data were obtained using material from resin lot BRF-14. The mass basis used to determine the heat capacity of samples contained 30 wt% dry H-form resin with the remaining mass contributed by the contacting liquid. Contacting liquid for the H-form resin was water, while the Na-form resin was in contact with AN-107 simulant.

The heat capacity of Na-form resin varied linearly from 0.75 to 0.85 cal/g-°C over the temperature range of 50 to 80 °C. Based on these data, the reference concluded that the heat capacity of the resin/simulant slurry was near that of the supernate alone and the resin does not greatly affect the heat capacity in a system where the liquid phase is the dominant material.

The heat capacity of H-form resin varied linearly from 0.45 to 0.82 cal/g-°C over the temperature range of 50 to 80 °C. Investigators anticipated that the heat capacity of this system would be approximately constant at 0.75 cal/g-°C and the observed heat capacity variation with temperature is not understood.

2.5.3.1.9 Effect of Organics on Resin Performance

No tests for the potential effect of organic materials on IX performance have been performed using spherical RF resin. However, SCT-M0SRLE60-00-96-03, *Evaluating the Effects of Tri-Butyl Phosphate (TBP) and Normal Paraffin Hydrocarbon (NPH) in Simulated Low-Activity Waste Solution on Ion Exchange,* investigated the potential effect of organic materials on resin performance using SuperLig 644. These tests were performed using AZ-101 waste simulant and compared batch equilibrium distribution coefficients, column loading cycle breakthrough curves, and elution curves while processing simulant with and without an organic spike in the waste feed material. Waste simulants were spiked with 2500 µg/mL tributyl phosphate (TBP) and 2500 µg/mL dodecane (NPH) before filtration, but filtrate analysis found that TBP and NPH concentrations were below the detection limits of 0.12 µg/mL. A second spike solution was also created for testing where the filtrate was spiked with 0.7 µg/mL TBP. Batch equilibrium experiments indicated no significant difference in Cs sorption because of addition of the organics to waste for SuperLig 644. Column loading tests did not achieve a significant breakthrough after processing 86 BVs of waste. However, the column breakthrough curves with and without organics in the simulant feed were the same over the volume of waste processed. In addition, no discernible effects from the presence of organics in the waste feed were observed on the Cs elution process. Since the presence of organics in waste feed did not appear to affect SuperLig 644 performance, it has been assumed that spherical RF performance will not be influenced by the presence of organics.

Assumption 2.5.7. The presence of organics in waste is assumed to have no measurable impact on spherical RF loading or elution performance, since testing performed using organic spiked material did not impact the loading and elution performance of SuperLig 644.

2.5.3.2 Batch Contact Data

Batch contact data describe the projected resin performance in the form of equilibrium distribution coefficients. The equilibrium distribution coefficient is a measure of the concentration of Cs in the resin that is in equilibrium with a particular concentration of Cs in solution. Batch distribution coefficients are measured by contacting a known mass of resin with a known volume of solution, and comparing the initial solution Cs concentration with the solution Cs concentration after an extended contact period. The distribution coefficient is calculated as shown by Equation 2.5-24.

Equation 2.5-24

$$K_d = \frac{[Cs]_s}{[Cs]_l} = \frac{\left(\frac{C_i - C_f}{C_f}\right)V}{MF}$$

where:

K_d is the equilibrium distribution coefficient, mL/g dry H-form resin
$[Cs]_s$ is the concentration of Cs in resin at equilibrium, gmol/g dry H-form resin
$[Cs]_l$ is the concentration of Cs in solution at equilibrium, gmol/mL
C_i is the measured initial Cs concentration of test solution, consistent units
C_f is the measured final Cs concentration of test solution, consistent units
V is the volume of solution used in test, ml
M is the mass of resin used in test, g dry H-form resin
F is a weight correction constant measured as part of a test to convert resin mass to a dry basis

The equilibrium distribution coefficient can be used to estimate the volume of feed that can be treated by a column during the loading cycle. This is indicated by the Cs column distribution ratio, which is determined by Equation 2.5-25.

Equation 2.5-25

$$\lambda_{Cs} = K_d \rho_b$$

where:

λ_{Cs} is the column distribution ratio for Cs, volume of liquid per volume of resin
ρ_b is the bulk resin density, g dry H-form resin/mL Na-form resin bed

The Cs column distribution ratio estimates the number of resin BV of feed solution expected to be treated before observing 50 % breakthrough (typically used to indicate that the loading cycle is complete and the column elution cycle should be initiated). However, operation of the lead column to 50 % breakthrough is not necessarily consistent with operating to satisfy a defined Cs concentration in the treated LAW IX product for a particular waste feed composition.

Batch distribution data can also estimate the expected equilibrium column loading variation with feed composition. The Cs loading is determined by Equation 2.5-26.

Equation 2.5-26

$$Q_{Cs} = K_d C_f$$

where:

Q_{Cs} is the quantity of Cs loaded on the resin when in contact with a particular concentration of Cs in solution, mmol Cs/g resin

Resin Cs loading is influenced by the concentration of competing ions in LAW fed to the resin bed. Current data indicate that five monovalent cations compete with the active exchange sites with the following estimated order for resin affinity: $H^+ > Cs^+ > Rb^+ > K^+ > Na^+$ (SCT-M0SRLE60-00-05-00004). Column test data reported in SCT-M0SRLE60-00-110-00029 support the concept that Rb is captured by spherical RF resin beds. However, available batch equilibrium data are insufficient to predict the influence of this ion on Cs loading, and the Rb concentration in waste is small compared to that of other competing ions. Therefore, the evaluation of Cs loading isotherms omitted Rb and was simplified to the remaining four monovalent cations.

2.5.3.2.1 Total Ion Capacity

The capacity of ion-specific sites available for the exchange ion to attach to the resin is the number of active exchange sites measured in milli-moles divided by the resin mass measured in grams. While modeling of spherical RF resin in the past has found Cs-selective site capacities that are less than 1 mmol/g dry H-form resin, literature and elution data indicate the presence of a higher total site population. Total capacity reported for earlier forms of RF range from 1.5 to 6.83 meq/g and a total capacity of 6 ± 0.8 meq/g dry H-form resin has been recommended for spherical RF from resin lot 5E-370/641 (SCT-M0SRLE60-00-110-00029. A total resin capacity of 6.8 meq/g dry H-form resin (or 6.8 mmol/g dry H-form resin) has been used to evaluate batch equilibrium data for spherical RF.

The apparent capacity of spherical RF to exchange hydrogen ions with waste ions of interest for evaluating IX column performance (e.g., Cs^+, Na^+, K^+) has been found to vary with hydroxide ion concentration of the solution contacting the resin. 24590-WTP-RPT-RT-06-001 describes an equation for estimating how the apparent resin capacity (fraction of total resin capacity that captures Cs^+, Na^+, and K^+) is influenced by hydroxide ion concentration. The estimate is based on a resin unit containing two active IX sites that can be described by the disassociation constants shown in Equation 2.5-27.

Equation 2.5-27

$$RH_2 \leftrightarrow RH^- + H^+ \quad K_{a1} = \frac{[RH^-][H^+]}{[RH_2]}$$

$$RH^- \leftrightarrow R^{-2} + H^+ \quad K_{a2} = \frac{[R^{-2}][H^+]}{[RH^-]}$$

$$H_2O \leftrightarrow H^+ + OH^- \quad K_w = [H^+][OH^-]$$

Assuming a molar quantity of r_0 H-form resin is placed in a unit volume of solution in the form of RH_2, x is the molar quantity of RH^- formed, and y is the molar quantity of R^{-2} formed, the disassociation constants can be described by Equation 2.5-28. The unit RH^- is available to capture one monovalent cation and the unit R^{-2} is available to capture two monovalent cations.

Equation 2.5-28

$$K_{a1} = \frac{x\left(\frac{K_w}{[OH^-]}\right)}{(r_0 - x - y)} \text{ or } K_{a1}(r_0 - x - y) = x\left(\frac{K_w}{[OH^-]}\right)$$

$$K_{a2} = \frac{y\left(\frac{K_w}{[OH^-]}\right)}{x} \text{ or } y = \frac{K_{a2}\, x}{\left(\frac{K_w}{[OH^-]}\right)}$$

Equation 2.5-28 can be solved for the fraction of total resin present in the solution volume as RH^- at equilibrium as shown by Equation 2.5-29.

Equation 2.5-29

$$K_{a1}(r_0 - x - \frac{K_{a2}\, x}{\left(\frac{K_w}{[OH^-]}\right)}) = x\left(\frac{K_w}{[OH^-]}\right)$$

$$K_{a1} r_0 - K_{a1} x - \frac{K_{a1} K_{a2}\, x}{\left(\frac{K_w}{[OH^-]}\right)} = x\left(\frac{K_w}{[OH^-]}\right)$$

$$K_{a1} r_0 = \left[K_{a1} + \frac{K_{a1} K_{a2}}{\left(\frac{K_w}{[OH^-]}\right)} + \left(\frac{K_w}{[OH^-]}\right)\right] x$$

$$\frac{x}{r_0} = \frac{K_{a1}}{\left[K_{a1} + \frac{K_{a1} K_{a2}}{\left(\frac{K_w}{[OH^-]}\right)} + \left(\frac{K_w}{[OH^-]}\right)\right]}$$

$$\frac{x}{r_0} = F_{NaHR} = \frac{\left(\frac{K_w}{[OH^-]}\right)\left(\frac{1}{K_{a2}}\right)}{\left[1 + \left(\frac{K_w}{[OH^-]}\right)\left(\frac{1}{K_{a2}}\right) + \left(\frac{K_w}{[OH^-]}\right)^2\left(\frac{1}{K_{a1} K_{a2}}\right)\right]}$$

The relationship for y from Equation 2.5-28 can be combined with the result from Equation 2.5-29 to produce an estimate for the fraction of total resin present in the solution volume as R^{-2} at equilibrium, which is shown as Equation 2.5-30.

Equation 2.5-30

$$\frac{y}{r_0} = F_{Na2R} = \frac{1}{\left[1+\left(\frac{K_w}{[OH^-]}\right)\left(\frac{1}{K_{a2}}\right)+\left(\frac{K_w}{[OH^-]}\right)^2\left(\frac{1}{K_{a1}K_{a2}}\right)\right]}$$

The total number of potential resin site available in the unit solution volume is equal to $2 \times r_0$. Therefore, the variation in fraction of total potential site available for IX with hydroxide ion concentration is estimated by Equation 2.5-31.

Equation 2.5-31

$$\frac{\text{Sites Available}}{\text{Total Sites}} = F_{sa} = \frac{x+2y}{2r_0} = \frac{\left(\frac{x}{r_0}\right)+2\left(\frac{y}{r_0}\right)}{2} \text{ or}$$

$$F_{sa} = \frac{\left(\frac{K_{a1}K_{a2}}{K_w^2}\right)[OH]^2 + \left(\frac{1}{2}\right)\left(\frac{K_{a1}}{K_w}\right)[OH]}{\left(\frac{K_{a1}K_{a2}}{K_w^2}\right)[OH]^2 + \left(\frac{K_{a1}}{K_w}\right)[OH]+1}$$

The apparent resin capacity is then estimated as $F_{sa} \times 6.8$ mmol/g dry H-form resin. 24590-WTP-RPT-RT-06-001 uses the data shown in Table 2.5-13 to estimate values for spherical RF disassociation constants that are shown by Equation 2.5-32. Figure 2.5-20 provides a comparison of values for F_{sa} calculated from data with predictions of F_{sa} calculated using Equation 2.5-29, Equation 2.5-30, Equation 2.5-31, and Equation 2.5-32 indicating that the prediction is consistent with the experimental observations.

Equation 2.5-32

$$K_{a1} = 10^{-10.6} \quad \frac{\text{gmol}}{\text{L}}$$

$$K_{a2} = 10^{-13.2} \quad \frac{\text{gmol}}{\text{L}}$$

$$K_w = 10^{-14} \quad \left(\frac{\text{gmol}}{\text{L}}\right)^2$$

Figure 2.5-21 indicates the predicted apparent resin capacity ranges from approximately 2.5 to 6.6 mmol/g dry H-form resin when the hydroxide ion concentration varies from 0.001 to 3 gmol/L. Apparent resin capacity determined from column tests using material from different resin lots are compared to the prediction on Figure 2.5-21.

2.5.3.2.2 Resin Cs Loading

Spherical RF resin Cs batch equilibrium loading data obtained using material from resin batch 5E-370/641 at 15 °C, 25 °C, and 45 °C are summarized in Table 2.5-14, Table 2.5-15, and Table 2.5-17,

respectively. These data were supplemented by data obtained from column loading tests performed at approximately 25 °C and summarized in Table 2.5-16. Addition batch equilibrium data are available from testing using material from resin lot BRF-14 in SCT-M0SRLE60-00-110-00021, 24590-101-TSA-W000-0004-91-00003, and 24590-101-TSA-W000-0004-174-00002. Data from resin lot BRF-14 were not used as part of the basis for material balances since BRF-14 was produced using a different formulation from the large scale resin lots.

Two correlations of the batch equilibrium data are described below. The first correlation (designated Prediction Method 1) is presented as Equation 12 in 24590-WTP-RPT-RT-07-005 and provided below as Equation 2.5-33. Figure 2.5-22 provides a comparison of observed equilibrium Cs loading with Cs loading predicted using Equation 2.5-33 and indicates that Prediction Method 1 describes the data from tests over the following range of conditions:

- Temperature – 15 to 45 °C,
- [Na+] – 3.93 to 5.96 gmol/L,
- [K+] – 0 to 0.69 gmol/L,
- [OH-] – 0.038 to 1.933 gmol/L, and
- [Cs+] – 4.29×10^{-9} to 5.39×10^{-3} gmol/L.

Equation 2.5-33

$$A_1 = (0.41553)F_{sa} - 0.13244\left([Na^+]+[K^+]\right) - 3.5191\left(\frac{[K^+]}{[Na^+]}\right) - 1.07633$$

$$T_{DF} = (251.4)[K^+] + (116.06)[OH^-] + 476.1$$

$$A_2 = T_{DF}\left(\frac{1}{T} - 0.003354\right) + A_1$$

$$A_3 = \text{Minimum}\left\{1,\ (0.3592)[K^+] - 0.0951\frac{\log_{10}[Cs^+]-4.52}{2} - \frac{255.13}{T} + 1.0009 + (0.013643)[OH^-]\right\}$$

$$A_4 = A_3\left(\log_{10}[Cs^+]+4.52\right) + A_2$$

$$A_5 = A_4 + 0.15497 - \frac{(0.13015)[K^+]}{(0.690985)}$$

$$Q_{Cs} = 10^{A_5}$$

where:

Q_{Cs} is in mmol Cs/g dry H-form resin
F_{sa} is calculated from Equation 2.5-29, Equation 2.5-30, Equation 2.5-31, and Equation 2.5-32
$[Cs^+]$ is the liquid phase Cs ion concentration, gmol/L
$[Na^+]$ is the liquid phase sodium ion concentration, gmol/L
$[K^+]$ is the liquid phase potassium ion concentration, gmol/L

$[OH^-]$ is the liquid phase hydroxide ion concentration, gmol/L

T is the solution absolute temperature, K

Prediction Method 1 (Equation 2.5-33) is an empirical fit of the test data using a Freundlich isotherm that allows the exponent on Cs concentration (A_3) to vary with conditions and approach one (Langmuir isotherm) at infinite dilution. Predicted equilibrium resin loading based on Prediction Method 1 is compared to measured values on Table 2.5-14, Table 2.5-15, and Table 2.5-17. Table A-1 of 24590-WTP-RPT-RT-07-005 indicates that Equation 2.5-33 predicts resin loading that is generally within ±20 % of test data, with a standard deviation for predicted/measured values of 8.8 %. Figure 2.5-23(a) provides a qualitative comparison of the batch equilibrium resin Cs loading as a function of liquid phase Cs concentration predicted by Equation 2.5-33 for temperatures of 15 °C, 25 °C, and 45 °C with test data where the $[K^+] = 0.69$ M. Note that the test data $[Na^+]$ varied from 3.93 to 5.96 gmol/L and the $[OH^-]$ varied from 0.038 to 1.933 gmol/L. The comparison curves shown on Figure 2.5-23(a) were determined at a single concentration of Na^+ (5 gmol/L) and OH^- (1.88 gmol/L) to simplify the figure. Therefore, Figure 2.5-23(a) should only be considered a qualitative comparison between data and predictions. Figure 2.5-23(b) provides a similar comparison between predictions using Equation 2.5-33 and test data where the $[K^+] = 0$ gmol/L.

While Prediction Method 1 (Equation 2.5-33) appears to be a good representation of the experimental data over a wide range of temperatures and liquid phase compositions, its utility is generally limited to use during the loading cycle of an IX column. Indeterminate results are produced by the equation form when $[Na^+]$ or $[Cs^+]$ are zero. Therefore, Prediction Method 1 cannot support modeling of the restoration cycles where feed materials contain no Cs and, in some cases, no sodium ions.

Estimates based on Prediction Method 1 that extrapolate to Cs ion concentrations greater than 0.01 gmol/L can produce anomalous results. However, no waste at Hanford is projected to exceed a Cs ion concentration of 5.4×10^{-3} gmol/L. Therefore, Prediction Method 1 is considered applicable to the loading cycle for waste compositions anticipated in the IX column feed in the WTP.

Modeling of the IX carousel requires a form for the resin Cs loading that can function when column feed solutions contain no Cs or sodium ion during rinse, elution, and regeneration cycles. Therefore, an alternate equation form for representing the batch equilibrium test data was developed. SCT-M0SRLE60-00-05-00004 describes efforts to develop a detailed thermodynamic model for the spherical RF data shown in Table 2.5-14, Table 2.5-15, and Table 2.5-17. The detailed thermodynamic model relies on estimated activity coefficients for ions in the liquid phase and non-idealities on the solid surface of the resin. For application to loading cycle modeling studies, SCT-M0SRLE60-00-05-00004 simplified the prediction of resin Cs loading based on the Freundlich/Langmuir equation form shown as Equation 2.5-34. This simplification was primarily used to reduce computation time for the IX model used for loading cycle models; the constants were determined for each feed composition investigated.

Equation 2.5-34

$$Q_{Cs} = \frac{Q_{Cs\,tot}[Cs^+]^{maCs}}{\beta + [Cs^+]^{mbCs}}$$

where:

$Q_{Cs\,tot}$ is the total CIX capacity of resin

β, maCs, and mbCs are constants determined from curve fitting to test data for each loading cycle feed composition

An alternative method (designated Prediction Method 2) for describing spherical RF equilibrium data based on the Freundlich/Langmuir equation form shown as Equation 2.5-35 was developed for the material balance basis as an adaptation of the work described in SCT-M0SRLE60-00-05-00004. Prediction Method 2 was developed because:

- Unlike Equation 2.5-33, resin loading is defined for all values of $[Cs^+]$ and $[Na^+]$ that may be encountered during the rinse, elution, and regeneration cycles, and
- Unlike Equation 2.5-34, a separate calculation is not required to determine the constants for each column feed composition

Equation 2.5-35

$$Q_{Cs} = \frac{F_{sa} Q_{Cs\,tot} \left[Cs^+\right]^{ma1}}{Cnst + \left[Cs^+\right]^{mb1} + K_{12}\left[K^+\right]^{m2} + K_{13}\left[Na^+\right]^{m3}}$$

with:

$$Q_{Cs} = 0 \text{ when } \left[Cs^+\right] = \left[Na^+\right] = \left[K^+\right] = 0$$

$$\left[OH^-\right] = 10^{-7} \text{ gmol/L when } [OH^-] - [H^+] = 0$$

$$\left[OH^-\right] = [OH^-] - [H^+] \text{ when } [OH^-] - [H^+] > 0$$

$$\left[OH^-\right] = \frac{K_w}{[H^+] - [OH^-]} \text{ when } [OH^-] - [H^+] < 0$$

F_{sa} is determined by Equation 2.5-31 and represents a description of the resin Cs loading capacity variation with liquid phase hydroxide ion (or hydrogen ion) concentration. This implies that the total Cs capacity is assumed to be proportional to the total resin cation capacity as the liquid phase hydroxide concentration is varied. The parameters $Q_{Cs\,tot}$, ma1, Cnst, mb1, K_{12}, m2, K_{13}, and m3 are constants that can be determined by a curve fit to test data.

Constraints were imposed to estimate parameters for Equation 2.5-35 from test data. To simplify the analysis, Equation 2.5-35 parameters were determined using data at 25 °C. Therefore, Prediction Method 2 is only applicable to a single operating temperature. The simplification was considered justified since current plans do not include IX column operation at different temperatures. Data correlation also fixed the total resin Cs capacity of resin lot 5E-370/641, $Q_{Cs\,tot}$, at 1 mmol Cs/g dry H-form resin based on prior results for a variety of feed compositions, summarized in Table 4-11 of SCT-M0SRLE60-00-05-00004. Data were then fit to find the remaining parameters in Equation 2.5-35 based on minimizing the relationship shown as Equation 2.5-36.

Equation 2.5-36

$$\Delta^2 = \sum \left(\frac{Q_{Cs,measured} - Q_{Cs,predicted}}{Q_{Cs,measured}} \right)^2$$

The curve fit calculation is summarized in Table 2.5-18 and results in the parameter values listed by Equation 2.5-37, where the parameter units are consistent to produce Q_{Cs} in mmol Cs/g dry H-form resin when liquid phase concentrations are input in gmol/L. Figure 2.5-24 provides a comparison of observed equilibrium Cs loading with Cs loading predicted using Equation 2.5-35 and Equation 2.5-37. Figure 2.5-25(b) provides a qualitative comparison of the batch equilibrium resin Cs loading as a function of liquid phase Cs concentration predicted by Prediction Method 2 and indicates that predictions are generally within ±20 % of the test data. The comparison provided by Figure 2.5-25(b) should only be considered approximate, since curves were determined based on $[Na^+]$ = 5 gmol/L and $[OH^-]$ = 1.88 M, while the data are based on sodium ion concentrations ranging from 3.93 to 5.95 gmol/L and hydroxide ion concentration ranging from 0.038 to 1.933 gmol/L.

Equation 2.5-37

$$Q_{Cs\,tot} = 1$$
$$ma1 = 0.866$$
$$Cnst = 2.89 \times 10^{-4}$$
$$mb1 = 0.841$$
$$K_{12} = 1.11 \times 10^{-2}$$
$$m2 = 0.807$$
$$K_{13} = 5.20 \times 10^{-6}$$
$$m3 = 2.877$$

Figure 2.5-25(a) and Figure 2.5-25(b) indicate that the two prediction methods do not produce identical estimates of resin Cs loading at 25 °C for liquid phase Cs concentrations ranging from 2×10^{-6} to 5×10^{3} gmol/L when the $[K^+]$ is less than 0.69 gmol/L. The difference results from a lack of data in this liquid phase composition region. Figure 2.5-26 provides a direct comparison of resin Cs loading produced by the two prediction methods, indicating the differences on the order of a factor of 2 to 3 may be observed for some liquid phase compositions.

The correlation of batch equilibrium data can also be used to indicate the predicted sensitivity of resin Cs loading to changes in hydroxide and sodium ion concentrations of waste during the loading cycle. Based on Equation 2.5-35, Figure 2.5-27 indicates that resin Cs loading is predicted to vary by ±10 % over the range of waste hydroxide concentrations projected in Section 2.5.1. Figure 2.5-28 indicates that resin Cs loading is predicted to vary by ±10 % over the range of waste sodium ion concentration projected in Section 2.5.1 when the waste potassium ion concentration is relatively high. However, increased sodium ion concentration can significantly decrease the resin Cs loading when the waste potassium ion concentration is low.

2.5.3.3 Resin Preconditioning Experience

Spherical RF resin samples were generally pretreated using the same protocol before beginning a specific laboratory-scale test. The protocol began with an as-received resin, which is in the H-form. The resin

was converted to the Na-form and back to the H-form in an unconstrained vessel (i.e., a beaker or tank) with agitation before initiating a test. The resulting H-form resin was converted back to the Na-form prior to introducing resin into a test column. Table 2.5-19 provides a summary of the typical steps used to precondition resin per protocol before laboratory-scale testing.

24590-101-TSA-W000-0004-99-00013 evaluated the effect of alternate resin preconditioning steps on the resin Cs removal performance using material from resin lot 6C-370/745. The two pretreatment modifications evaluated by testing are indicated in Table 2.5-19. Cs breakthrough curves using laboratory scale test columns were compared using AP-101 simulant as the loading cycle feed. Comparison of the breakthrough curves resulted in the conclusion that minimal resin pretreatment (swell step only, as indicated by Modification 1 on Table 2.5-19) will provide effective CIX loading performance and no in-column cycling is required. Subsequent loading cycle volumes after pretreatment by Modification 1 are expected to be similar to that of pretreatment by Protocol P1-RF and Modification 2 at 50 % Cs breakthrough based on the test results shown in Table 14.14 and Figure 14.13 of 24590-101-TSA-W000-0004-99-00013. In addition, Modification 1 is expected to reduce resin damage from dissolved oxygen exposure in pretreatment chemical solutions prior to actual waste processing as indicated in Figure 14.10 of 24590-101-TSA-W000-0004-99-00013.

Larger scale testing was generally focused on hydraulic issues and does not provide data on the effects of pretreatment procedures on Cs removal performance. Resin pretreatment for the larger scale tests can be described as follows:

- 3 in. test column – As-received resin was soaked in 3 BV of 1 gmol/L NaOH overnight. The NaOH was decanted and replaced with water when the slurry was transferred to the test column (24590-101-TSA-W000-0004-174-00002).
- 12 in. test column – As-received resin from resin lot 5E-370/641 (~5 gal) was pretreated in a 20 L carboy by washing three times in a caustic solution until the solution molarity was 0.22 gmol/L. The following morning, the resin was observed to have swollen to 7.75 gal and the solution molarity had decreased to 0.06 gmol/L. The soak solution was replaced with 0.5 gmol/L NaOH solution and mixed. After a total of 48 hr, the resin volume increased to 8.25 gal. The Na-form resin was then added to the test column (SCT-M0SRLE60-00-110-00028).
- 24 in. test column – As-received resin from resin lot 5E-370/641 was sluiced into a pretreatment tank with water. Water from the transfer operation was decanted, 4 BV 0.5 gmol/L NaOH (based on the resin volume in the pretreatment tank) was added, and the slurry agitated to achieve suspension of the resin. The slurry was allowed to sit overnight and then re-agitated before determining the liquid phase NaOH concentration. The process was repeated once to obtain a final liquid phase NaOH concentration of 0.5 ± 0.05 gmol/L. The Na-form resin was then transferred to the test column (SCT-M0SRLE60-00-110-00028).

2.5.3.4 Column Loading Performance

2.5.3.4.1 Cs Removal Column Test Data Summary

Column tests evaluating Cs removal during the loading cycle have been performed by passing waste solution through small-scale (0.01 to 0.02 L BV) and pilot-scale (20 to 200 L BV) columns to investigate resin performance. Tests were performed using single columns and lead-lag column arrangements to investigate Cs breakthrough curves under a variety of conditions. Test data have been developed using waste simulants and actual waste samples as feed to the IX columns. Periodic samples of the column effluents produced a profile of the column breakthrough curves observed during each test.

Table 2.5-1 indicates that 21 small-scale resin lots were tested as part of the development of spherical RF resin for the Cs removal system. Column test data from small resin lots (for example, data reported in 24590-101-TSA-W000-0004-04-00001, or data reported for Waves 1, 1b, 2, 2a, and 2b in 24590-101-TSA-W000-0004-99-00013) have not been included as part of the material balance basis to focus on testing results using resin that was fabricated at batch scales of approximately 100 gal. Table 2.5-20 provides a summary of the column loading cycle tests using scaled-up RF resin production lots currently available in project documentation. A total of 27 column tests with scaled-up RF resin production lots have been performed to provide Cs breakthrough data at different operating conditions, including the effects of varying resin batch, waste feed temperature, and waste feed composition. New resin beds were not necessarily used for each test in order to investigate the effect of resin degradation on observed column breakthrough curves.

Minimal performance variations have been observed in column loading cycle tests for the 100-gallon resin lots. Figure 2.5-29 provides a comparison of the variations in resin performance observed in single column tests from different resin lots at similar operating conditions using a waste simulant based on AP-101 (waste material with highest projected potassium ion concentration). The comparison indicates that loading cycle volumes varied by approximately 10 BV at 50 % breakthrough for the 100-gallon resin lots. Therefore, performance data obtained using samples from any of these resin lots were assumed to be comparable.

Test data evaluating the influence of waste feed flow rate on Cs breakthrough using similar waste feed compositions are not available for spherical RF resin over the range of 1.4 to 3.1 BV/hr with superficial velocities of 0.15 to 1.81 cm/min (Table 8 of 24590-WTP-RPT-RT-07-005). However, SCT-M0SRLE60-00-05-00004 presents a comparison of the predicted variation in Cs breakthrough with feed flow rate over a range of 7.2 to 30.0 gpm based on loading cycle computer modeling. Figure 2.5-30 indicates that the predicted loading cycle volume is independent of waste feed flow rate when the lead column of a carousel is operated until Cs breakthrough reaches 50 %.

A single column test using a resin bed of approximately 11 mL from resin lot 5E-370/641 was used to investigate waste loading at 45 °C (SCT-M0SRLE60-00-110-00029). The observed Cs breakthrough curves are compared with similar data reported in 24590-101-TSA-W000-0004-99-00013 obtained at ~20 °C on Figure 2.5-31. These tests indicated that the resin breakthrough capacity (i.e., the quantity of Cs captured per unit mass of resin in column before detecting Cs in the column effluent) decreases when the column operating temperature is raised from 25 to 45 °C. The loading curve comparison indicates that the IX loading cycle volume can be reduced by approximately 50 % if operated at 45 °C as compared to operation at 20 °C. Applying Equation 2.5-33 to a waste composition similar to the wastes compared on Figure 2.5-31 ([Na] = 4.5 M, [K] = 0.7 M, [OH] = 1.9 M, and [Cs] = 4.5E-05 M) indicates the resin capacity is expected to decrease by approximately 40 % if column operating temperature is increased from 20 to 45 °C. This implies that resin performance improves by performing the loading cycle at lower temperature, and an operating temperature at or below 25 °C is preferred. In-line heat exchangers are installed between the LAW feed tank, CXP-VSL-00004, and the IX columns to control the feed temperature. These feed coolers, which cool a maximum of 30 gpm of feed from a maximum of 44 to 25 °C, are the main energy users in the CXP system.

Potassium competes with Cs for IX sites on the resin bed. This attribute results in decreasing the volume of waste that can be processed during the loading cycle when the waste feed potassium concentration increases. The influence of feed potassium concentration on the Cs breakthrough curve is compared on Figure 2.5-32, obtained from tests using 11 to 20 mL resin beds from 100 gal resin lots. These data were obtained from an actual waste test (24590-101-TSA-W000-0004-174-00001, *Spherical Resorcinol-*

Formaldehyde Resin Testing for ^{137}Cs Removal from Simulated and Actual Hanford Waste Tank 241-AP-101 Diluted Feed (Envelope A) Using Small Column Ion Exchange) and waste simulant tests (24590-101-TSA-W000-0004-99-00013). Feed flow rates, feed hydroxide ion concentration, and feed Cs ion concentrations are not the same for the group of tests shown on Figure 2.5-32. However, the comparison provides a qualitative indication that increased potassium feed concentration will decrease the loading cycle volume.

Test data indicate that monovalent cations, such as potassium and rubidium, rapidly achieve equilibrium resin loadings during the loading cycle. Figure 2.5-33 and Figure 2.5-34 provide comparisons of rubidium and potassium breakthrough curves with comparable Cs breakthrough curves during column tests reported in SCT-M0SRLE60-00-110-00029. These data support the assumption that dominant cations in waste can be assumed to be at equilibrium with resin for loading cycle volumes of interest to Cs removal and allows simplification of IX modeling to consideration of Cs ions alone throughout the loading cycle. This issue is discussed in more detail in SCT-M0SRLE60-00-05-00004.

The effects of chemical degradation are discussed in Section 2.5.3.1.5. Cs breakthrough curves obtained using similar operating conditions and waste feed compositions after loading and elution cycles 1, 2, and 17 are shown on Figure 2.5-35. The breakthrough curves were obtained from single-column tests using 20 mL resin beds from a 100-gallon resin lot (24590-101-TSA-W000-0004-99-00013). Data after 17 cycles were obtained using samples from a pilot-scale resin bed (200 L) that had been cycled through 16 cycles as part of hydraulic testing. The performance tests were completed in a laboratory-scale column. Hydraulic testing focused on investigating the effect of shrink-swell cycles on resin bed permeability. Therefore, while each cycle in the hydraulic testing is expected to approximate chemical degradation from the feed displacement, rinse, elution, and regeneration cycles, loading cycles for some tests were shorter than that expected during plant operation. The observed breakthrough curves shown on Figure 2.5-35 indicate the deterioration of resin performance (loading cycle volume decreased by 10 to 20 BV at 50 % breakthrough) as resin is degraded. However, the data may underestimate the change in loading cycle volume observed after 17 complete loading cycles.

A sequence of three tests using two columns in series (lead/lag configuration) were performed to demonstrate adequate ^{137}Cs decontamination can be achieved at design basis loading cycle volumes. These tests used two columns with approximately 11 mL resin beds from resin batch 5E-370/641 for waste processing. The test sequence consisted of processing a waste feed, fluid displacement, and pre-elution rinse through the lead/lag column configuration; disconnecting the lead column to perform elution, post-elution rinse, and regeneration steps; revising the test apparatus to place the lag column in the lead position and eluted lead column in the lag position; and processing the next waste batch. This was repeated, switching the columns from the lead to lag position between each waste feed tested.

The test sequence began by processing a simulant representing the waste composition in tank AP-101. The remaining two test sequences were performed using actual waste samples. The test results (in order of waste processed) are summarized in the following Project documents:

- AP-101 simulant (24590-101-TSA-W000-0004-174-00001
- AP-101 actual waste (24590-101-TSA-W000-0004-174-00001
- AN-102 actual waste (24590-101-TSA-W000-0004-72-00017, *Small Column Ion Exchange Testing of Spherical Resorcinol-Formaldehyde Resin for ^{137}Cs Removal from Pre-Treated Hanford Tank 241-AN-102 Waste (Envelope C)*)

Figure 2.5-36 and Figure 2.5-37 summarize the lead and lag column Cs breakthrough curves observed during actual waste tests in the above sequence. The first test using AP-101 simulant is omitted from the breakthrough comparisons.

Six column tests were performed to support investigation of resin storage conditions as reported in 24590-QL-HC9-WA49-00001-03-00001, *Storage and Aging Effects on Spherical Resorcinol-Formaldehyde Resin Ion Exchange Performance*. Resin samples from production scale lots 5J-370/686 and 6C-370/745 were sampled and stored for a period of 1 year before column testing. The resin samples were stored in either the wet or dry form at temperatures ranging from ambient (~22 °C) to 45 °C. The column tests indicated that the resin can be stored without significant adverse effects on the CIX loading and eluting characteristics for at least 1 year in an environment rendered inert with nitrogen at temperatures ranging from 22 to 45 °C. Both wet and dry storage conditions are tolerated.

2.5.3.4.2 Loading Cycle Prediction Basis for Material Balances

Loading cycle volume predictions are currently determined using an analytical solution to a simplified dynamic material balance for fixed bed adsorption and IX processes shown as Equation 13 in 24590-WTP-RPT-RT-07-005. The modeling equation performs a one-dimensional transient material balance for Cs. The analytical equation was benchmarked to column test data, combined with the isotherm relationship from batch distribution data described Equation 2.5-33.

The modeling equation is currently benchmarked to loading data obtained from the lead column breakthrough curve during processing of actual waste from AP-101 using resin lot 5E-370/641. The column test identified as test RF2 on Table 2.5-20 was used as the benchmark test for regression analysis. Figure 2.5-38 provides a comparison between the prediction and test data for the benchmark case. The effect of resin degradation on loading cycle volume predictions was incorporated in the loading cycle volume prediction based on Equation 2.5-17, Equation 2.5-18, and Table 2.5-11.

Actual loading cycle predictions implemented in the material balances are based on an algebraic equation described in Section 2.5.3.8.

2.5.3.4.3 Trace Ion Removal Data

While the RF resin is highly specific to removal of cesium ion from waste solutions, evidence exists from test data that additional ions are captured by the IX process during the loading cycle and transmitted to the column eluate. Figure 2.5-39 provides a summary of the potential for separation of trace cations from waste by the IX process based on column test data from actual waste and simulant tests. The summary indicates the percent of cation mass feed in a column test (based on total waste volume feed and sample composition analysis) that was found in the column eluate (based on total eluate volume and composite sample analysis). Test mass balance closure for many of these trace ions is poor due to uncertainty in the sample analysis results for components present at low concentrations, and results are not necessarily consistent among all tests. The concentration of a number of cations in the column feed was below the detection limit. Values for these cations were not included on Figure 2.5-39. However, the comparison does indicate the potential for the IX process to partially remove the following trace ions from waste feed, which are subsequently eluted: B, Ba, Ca, Cd, Cr, Cu, Fe, Mo, Ni, Pb, Sr, U, and Zn. Boron and silicon are also indicated as cations transmitted to the eluate, but uncertainty exists in these results because of the potential for sample contamination by laboratory equipment.

Figure 2.5-40 provides an alternative description of the cations observed in eluates from column testing based on the resin bed mass, eluate composition, and eluate volume. This presentation of the data is not limited by detection limits for the feed composition.

Figure 2.5-41 provides a similar comparison for anions and radionuclides, indicating that measurable portions of the feed chloride, phosphate, sulfate, and actinides were transmitted from waste to the eluate. The mechanism for transfer of trace ions to the eluate is not clearly understood at this time. The comparisons provided in Figure 2.5-39, Figure 2.5-40, and Figure 2.5-41 cannot differentiate between ions captured by IX with the resin and effects of trace ion precipitation. It would seem more likely that the transfer of anions to eluate involves a precipitation process.

It should be noted that trace ion compositions of eluate observed during testing can be influenced by the volume of rinses (feed displacement plus pre-elution rinse) performed between loading and elution cycles. These rinses reduce the quantity of trace ions remaining in the column liquid phase prior to starting elution. Trace ions from residual waste in the liquid phase cannot be differentiated from trace ions that are actually adsorbed by the resin. Tests identified as RF2 and RF3 used a total rinse volume of 17 to 20 BV, while tests identified as RF17 and RF18 used a total rinse volume of 5 to 6 BV before performing the acid elution. Figure 2.5-40 does not indicate a bias toward the apparent cation loading observed during tests RF17 and RF18 being larger than that of tests RF2 and RF3. Therefore, it has been assumed that residual trace ions in the liquid phase were small compared to that adsorbed on resin for these test data.

2.5.3.5 Column Elution

2.5.3.5.1 Column Elution Test Data Summary

Resin bed elution cycles were performed during the column tests described in Section 2.5.3.4.1. The actual elution cycle was preceded by a fluid displacement cycle and pre-elution rinse cycle in each test. Table 2.5-21 provides a summary of the conditions used for elution during each column test. Figure 2.5-42 shows a summary of the available elution curves obtained from column testing indicating that the volume of eluant required to achieve an effluent Cs concentration (relative to the feed Cs concentration). Elution curves were not reported for all column tests performed (Column test IDs RF19 to RF21) and are not shown of Figure 2.5-42. The concentration profile shown in Figure 2.5-42 compares the eluate Cs concentration to the original column feed concentration as a function of eluate volume generated during elution. The elution concentration profile data indicate that Cs concentrations can be expected to peak at a factor of 100 greater than the original feed Cs concentration.

Figure 2.5-43 describes the variation of resin Cs loading with increasing eluate volume over the course of an elution cycle. This provides an alternative method of describing elution progress and is generally produced by integrating the Cs concentration profiles shown on Figure 2.5-42 and adding the mass of Cs in the eluate to the resin Cs loading at the end of the loading cycle. Figure 2.5-43 indicates that initial Cs loading has some, but not a large, influence on resin elution. Increasing the initial resin Cs loading by a factor of 10 appears to have the potential to increase the eluate volume by a factor of 2 to achieve a similar resin Cs loading at the conclusion of an elution cycle.

Figure 2.5-44 provides a comparison between elution curves from column tests performed at similar conditions using the six different 100-gallon resin lots. Elution volume varied by 1 to 2 BV to achieve a particular resin Cs loading when resin loading is similar at the start of elution and supports a conclusion that resin performance during elution is independent of the resin lot used during testing.

Eluant flow rate used in column tests, where eluate composition data are available, was approximately constant at 1.4 to 1.5 BV/hr. Therefore, data are not available to determine if elution performance varies with flow rate. However, tests with SuperLig 644 have indicated that the total volume is more important than flow rate in determining the extent of Cs removal during the elution cycle, and it is assumed that spherical RF elution is also relatively insensitive to eluate flow rate.

Figure 2.5-45 provides a comparison of resin Cs loading observed during elution at 20 and 45 °C. The comparison indicates that resin Cs loading is reduced more efficiently at higher temperatures.

Figure 2.5-46 compares elution tests performed using 0.25, 0.40, and 0.50 M HNO_3 as the column eluant. Figure 2.5-46 indicates that increasing nitric acid concentration reduces the volume of eluant added to a column before initiating significant Cs removal from the resin bed. Once the Cs begins eluting from the resin bed, eluant nitric acid concentration does not appear to have a significant influence on the eluate volume required to produce a specific Cs resin loading at the end of elution.

Figure 2.5-47 indicates the influence of resin degradation on elution observed during testing. In general, the eluate volume required to obtain a specified resin Cs loading was largest during the first elution cycle of fresh resin. Subsequent shrink-swell cycles associated with resin re-use for Cs loading and elution appears to reduce the required eluate volume. An explanation for this observation has not been supported by experimental studies. However, the observations do support the concept that benchmarking models to fresh resin elution test data should provide a conservative prediction of the change in resin Cs loading during elution.

Figure 2.5-48 provides a summary of elution profiles observed from two tests performed to compare up-flow and down-flow elution (all elution testing was performed using liquid phase down-flow except for one specific test). Up-flow elution resulted in Cs elution peak concentration broadening, which is attributed to uneven flow through the resin bed and solution mixing in the solution above the resin bed. The residual Cs concentration in the resin bed was higher than the Cs concentration associated with down-flow processing.

Table 2.5-21 indicates the total sodium and potassium concentration and the observed potassium-to-sodium ion mole ratio in eluate solutions where composition data are available. The resulting potassium to sodium [K]/[Na] mole ratio is used in Section 2.5.3.6 to support a simplified description of stoichiometry for the IX column material balance. Figure 2.5-49 indicates that the simple power function relationship, shown as Equation 2.5-38, approximates the variation in [K]/[Na] observed in eluate from tests performed at 25 °C with [K]/[Na] in loading cycle waste feed. The actual resin potassium loading is more complex than the approximation shown by Equation 2.5-38 and would be expected to be modeled by an equation form similar to that used for describing Cs equilibrium data. However, the potassium mass removed from treated LAW and transferred to the HLW glass by IX is small compared to the total mass flow of potassium into the WTP. In addition, data are not available to support a more complex description of the resin potassium loading. Therefore, Equation 2.5-38 was considered sufficient to support the IX column material balance.

Equation 2.5-38

$$\left.\frac{[K]}{[Na]}\right|_{Eluate} = (1.52)\left(\left.\frac{[K]}{[Na]}\right|_{Waste}\right)^{0.696}$$

24590-WTP-RPT-RT-07-005 developed a correlation for the observed [K/Na] mole ratio in eluate solutions based on limiting the selectivity coefficient for potassium and sodium cations. This correlation is shown as Equation 2.5-39 and is compared to the empirical correlation on Figure 2.5-49.

Equation 2.5-39

$$\left.\frac{[K]}{[Na]}\right|_{Eluate} = \left[1 + 5.887\, e^{-9.843 \left.\frac{[K]}{[Na]}\right|_{Waste}}\right] \left(\left.\frac{[K]}{[Na]}\right|_{Waste}\right)$$

The evaluation of eluate compositions has generally been based on the composite, or average, concentration of ions observed during column testing. However, it should be noted that the actual concentration of all cations peaks during early phases of the elution cycle, similar to the concentration profile indicated for Cs. Solute cations are dominated by sodium and potassium ions. The variation of sodium, potassium, and Cs ion concentrations observed during elution for two column tests are shown on Figure 2.5-50. Similar variations for elution of trace ions are indicated on Figure 2.5-51. However, it is noted that complete elution of chromium and iron ions was not observed during these tests.

Identification of the appropriate endpoint for elution became an issue during investigation of the SuperLig 644 resin. The experience derived from that earlier test program has been applied to determine a basis for defining the spherical RF elution endpoint. The elution endpoint is influenced by the carousel operation, where an eluted column is placed in a polishing position. When activated as part of the loading cycle, the freshly eluted column receives waste from the lag column, which has been depleted of Cs. Therefore, the Cs concentration in waste entering a freshly eluted column in the polishing position can increase if the resin Cs loading has not been reduced to an appropriate level during elution.

The elution endpoint has been defined based on preventing the Cs concentration of treated LAW exiting a polishing column from exceeding the criterion for producing LAW glass at 0.3 Ci $^{137}Cs/m^3$. Figure 2.5-2 indicates the variation in the treated LAW [Cs/Na] ion mole ratio that satisfies the LAW glass criterion as waste sulfate ion concentration is increased. A lower bound for the treated LAW Cs concentration occurs when the sulfate ion concentration is zero. Assuming the LAW sulfate ion concentration is zero, the LAW sodium ion concentration is 5 gmol/L, and ^{137}Cs represents 25 wt % of the total Cs, Figure 2.5-2 estimates that treated LAW will produce glass that is less than 0.3 Ci $^{137}Cs/m^3$ when the total Cs concentration in treated LAW is less than 2.8×10^{-8} gmol/L.

Figure 2.5-52(a) indicates conversion of the limiting liquid phase Cs concentration to a resin Cs loading based on the Cs batch equilibrium diagram for resin in waste solutions. The equilibrium diagram for waste solutions is used since the freshly eluted column will be processing waste as the liquid phase when placed in the polishing position. Figure 2.5-52(a) indicates that the resin Cs loading in equilibrium with a liquid phase at 2.8×10^{-8} gmol Cs/L varies with the waste potassium ion concentration (and actually varies with sodium and hydroxide concentration in addition to potassium). Increasing potassium ion concentrations in waste decreases the resin Cs loading that can produce acceptable treated LAW from a freshly eluted column in the polishing position. Therefore, the maximum waste potassium ion concentration ($[K^+] = 0.69$ M for AP-101 waste) produces a conservative estimate of resin Cs loading to be obtained at the end of the elution cycle. Figure 2.5-52(a) indicates that a resin Cs loading of less than 3×10^{-5} mmol Cs/g dry H-form resin at the end of the elution cycle is projected to limit the treated LAW Cs concentration to less than 2.8×10^{-8} gmol Cs/L for waste solution containing less than 0.69 gmol K/L.

Figure 2.5-52(b) compares the resin Cs loading limit from Figure 2.5-52(a) with a range of column elution test data. Based on Figure 2.5-52(b), it is estimated that 15 BV of eluate will produce a resin Cs

loading at the end of the elution cycle that prevents treated LAW from exceeding a Cs concentration that produces LAW glass at 0.3 Ci $^{137}Cs/m^3$. It should be noted that the selected elution cycle volume does not necessarily prevent the Cs concentration of waste leaving the polishing column from exceeding the Cs concentration of waste leaving the lag column for time periods during the carousel operation (sometimes known as Cs bleed). However, treated LAW is expected to comply with the 0.3 Ci $^{137}Cs/m^3$ criterion for LAW glass even if this were to be observed.

Elution test data have been obtained using ~0.5 M HNO_3 as the eluant. However, the correlation of batch equilibrium data suggests that it may be possible to obtain adequate elution with lower acid concentrations, once the resin is converted to the H-form and residual hydroxide ion in the column liquid holdup has been neutralized. Figure 2.5-53 indicates the sensitivity of resin Cs loading to hydroxide ion concentration at elution conditions based on Equation 2.5-35, indicating that, neglecting kinetics, it is theoretically possible to reduce the equilibrium Cs loading of resin to allow reuse of a loaded column in the polishing position with water as the eluant. Therefore, it may be feasible to reduce the acid concentration of eluant in the later stages of the elution cycle, if necessary. This modification would require some confirmation testing before its inclusion in the IX system process basis.

2.5.3.5.2 Elution Cycle Prediction Basis for Material Balances

Residual Cs on resin at the end of the elution cycle influences the apparent IX system Cs removal efficiency for a carousel operation as eluted columns are returned to the polishing position. Development of an estimate for the residual Cs on resin after elution is described in 24590-WTP-MCR-PO-08-0012, *Incorporate Spherical Resorcinol-Formaldehyde Data in Dynamic Material Balances*.

Normalizing the elution data shown on Figure 2.5-43 to the resin Cs loading at the start of elution suggests that the Cs mass transfer rate from resin to liquid phase during elution is related to the change in resin loading observed during testing. Four elution tests, with resin Cs loadings at the start of elution that vary over two orders of magnitude, were used to approximate the variation of Cs transferred to the liquid phase with elution volume (Column test IDs RF2, RF3 Lead Column, RF3 Lag Column, and RF16). These four tests were used as a single set of data to describe elution performance.

The fraction of initial resin Cs loading transferred to the liquid phase as a function of elution volume has the form of a normal distribution with an extended tail. Levenspiel (1972) indicates that this type of effluent concentration variation is characteristic of a vessel containing dead zones for fluid mixing. One method of modeling this mixing pattern is the sum of exit age distributions, where each distribution is multiplied by a fraction and the sum of these fractions is one. Data fitting was performed to estimate the observed variation in Cs transferred to the liquid phase by a sum of three distributions. Data in the tail are approximated by an exponential distribution. Reasonable approximations of the remaining observations were obtained by combining a log-normal and normal distribution with the exponential distribution. Regression of the data results in the Equation 2.5-40 as an approximation of the fraction of initial resin Cs loading removed in each eluate volume increment.

Equation 2.5-40

$$E(V) = f_2 e^{-\lambda_2 V} + f_1\left(\frac{1}{\sqrt{2\pi}\,\sigma_1 V} e^{-\left[\frac{(\mathrm{Ln}V-\mu_1)^2}{2\sigma_1^2}\right]}\right) + f_0\left(\frac{1}{\sqrt{2\pi}\,s_0} e^{-\left[\frac{(V-m_0)^2}{2s_0^2}\right]}\right)$$

where:

$f_2 = 6.613\times10^{-4}$

$\lambda_2 = 6.658\times10^{-2}$

$f_1 = 0.02736$

$\mu_1 = 1.42$

$\sigma_1 = 0.3965$

$f_0 = 1 - f_1 - f_2$

$m_0 = 4.899$

$s_0 = 0.7914$

Figure 2.5-54 provides a comparison between the elution approximation and the composite test data from four tests. The residual Cs loading on a column after elution is estimated by Equation 2.5-41.

Equation 2.5-41

$$\text{Resdual Cesium (Elution Volume)} = R_{0,\text{elute}} \int_0^{\text{Elution Volume}} E(V)dV$$

where $R_{0,\text{elute}}$ is the resin cesium loading at the start of elution in gmol Cs/kg dry H - form Resin

2.5.3.6 Stoichiometry and Liquid Phase Mixing Between Cycles

Material balances for the IX column carousel can become complex, depending on the column cycle under consideration. During the loading cycle, ions from the LAW feed are actually being transferred from the liquid phase to resin in all three columns (lead, lag, and polishing). Cs partially loads on a lag column before switching the lag column to the lead position. Ions, such as potassium or rubidium, that reach equilibrium resin loadings after a relatively short time period in a loading cycle, are actually transferred from waste to the resin of a column in the polishing position. To simplify calculations, the material flow associated with ion transfers is approximated by assuming they all occur in a single column as it passes through loading, rinse, elution, and regeneration cycles. This is equivalent to modeling the carousel in a quasi-steady state.

Liquid mixing in the column void space (particularly in the column headspace) influences the composition of column effluents during the different cycles. A conservative model of liquid mixing has been assumed to describe liquid mixing as column feed compositions are changed with cycle. The model assumes the headspace mixing pattern resembles a continuous stirred tank, followed by a plug flow pattern through the resin bed void space. The mixing assumption influences the column inventory of ions in the liquid phase at the end of a cycle that are available to be removed in column effluents during the next cycle.

Waste feed solutions are expected to be essentially free of solids after the ultrafiltration unit operation upstream of IX. However, small quantities of solids may be present in the waste feed from filtration inefficiency or post-filtration precipitation. The path of these solids through the IX system is defined on a simplified basis in order to close material balances.

The basis for estimating the influence of ion transfer to the resin, liquid mixing between cycles and waste feed solids on the material balances is described in the following sections.

2.5.3.6.1 Stoichiometry of Ions Transferred between Resin and Liquid Phase

Removal of Cs from the LAW supernate is based on transfer of Cs ions from the LAW to the solid resin during the loading cycle, elution of the captured ions from the solid resin into the aqueous eluant, and regeneration of the solid resin bed before reuse in the loading cycle. The total resin ion capacity is discussed in Section 2.5.3.2.1. While the total ion capacity remains constant, the fraction of resin ion capacity that adsorbs waste cations, such as sodium, potassium, and Cs, varies with the hydroxide ion concentration of the liquid phase. Therefore, the equilibrium resin capacity for waste cations varies during IX cycles as the liquid phase hydroxide ion concentration changes. To simplify the analysis, ion transfer between the resin and liquid phase is assumed to be negligible during the feed displacement, pre-elution rinse, and post-elution rinse cycles.

Figure 2.5-55 indicates the primary ion transfers that occur during each IX cycle. The ion transfers involved in each cycle are described by the following stoichiometry, where R denotes a unit of resin. The stoichiometry has been simplified by assuming only sodium, potassium, Cs, and hydrogen ions transfer between the liquid phase and resin IX sites.

2.5.3.6.1.1 Loading Cycle

The effective stoichiometry across a loading cycle is described by Equation 2.5-42. The stoichiometry is based on assuming resin at the start of a loading cycle is in equilibrium with a liquid phase that is at the same hydroxide concentration as the waste feed (as a result of a regenerant displacement cycle). Ions adsorbed on resin sites were limited to sodium and hydrogen ions at the start of a loading cycle to simplify the stoichiometry. In actual operation, a portion of the resin exchange sites will also be occupied by potassium ions, depending on the waste composition. However, the quantity of potassium adsorbed by resin during the loading cycle is small relative to the potassium mass flow in waste.

Equation 2.5-42

$$(a + b + c)\,RNa(s) + d\,RH(s) + b\,K^{+}(aq) + c\,Cs^{+}(aq) \rightarrow$$

$$a\,RNa(s) + b\,RK(s) + c\,RCs(s) + d\,RH(s) + (b + c)Na^{+}(aq)$$

Based on the disassociation constant analysis described in Section 2.5.3.2.1, a small fraction of the resin exchange sites are occupied by hydrogen ions throughout the loading cycle. This fraction remains constant throughout the loading cycle since the resin is assumed to be at equilibrium with liquid at the waste hydroxide ion concentration at the start of the loading cycle. Potassium and Cs ions from the liquid phase replace sodium ions on the resin, releasing sodium to the liquid phase. The stoichiometry coefficients in Equation 2.5-42 are determined by the waste composition, loading cycle volume, resin properties described in prior sections, and Cs recovery efficiency obtained over the loading cycle. Calculation of the loading cycle stoichiometry coefficients is shown by Equation 2.5-43.

Equation 2.5-43

$$Q_{bed} = \left(6.8 \frac{\text{gmol ions}}{\text{kg dry H-form resin}}\right) \rho_b \; V_{bed}$$

$$Q_{bed} = a + b + c + d$$

$$Q_{bed} \; F_{sa}([OH]_{waste}) = a + b + c$$

$$c = \xi_{Cs} \; [Cs]_{waste} \; V_{Load}$$

$$\frac{b}{a} = 1.24 \left(\frac{[K]_{waste}}{[Na]_{waste}} \right)^{0.657}$$

$$a = \frac{(Q_{bed} \; F_{sa}([OH]_{waste}) - c)}{\left(1 + \frac{b}{a}\right)}$$

$$b = \left(\frac{b}{a}\right) a$$

$$d = Q_{bed} - (a + b + c)$$

where:

Q_{bed} is the total resin ion capacity, gmol ions
ρ_b is the bulk resin bed density, 0.3 kg dry H-form resin/L wet Na-form resin from Table 2.5-5
V_{bed} is the resin bed volume used for a plant-scale column, L
$F_{sa}([OH]_{waste})$ is determined by Equation 2.5-31 and Equation 2.5-32 at the waste $[OH^-]$
ξ_{Cs} is the fraction of feed Cs removed by resin during the loading cycle
V_{Load} is the waste volume fed to a column during the loading cycle, L
b/a is the potassium to sodium ratio determined by Equation 2.5-38
a, b, c, and d are molar quantities of Na, K, Cs, and H on resin bed at end of loading, gmol

2.5.3.6.1.2 Elution Cycle

The effective stoichiometry over the elution cycle is shown by Equation 2.5-44. Resin loading at the start of the elution cycle is assumed to be identical to resin loading at the end of the loading cycle. Sodium, potassium, and Cs ions are replaced by hydrogen ions on the resin and the cations are transferred to the liquid phase.

Equation 2.5-44

$$a\,RNa(s) + b\,RK(s) + c\,RCs(s) + d\,RH(s) + (a + b + c)\,H^+(aq) \rightarrow$$
$$(a + b + c + d)\,RH(s) + a\,Na^+(aq) + b\,K^+(aq) + c\,Cs^+(aq)$$

2.5.3.6.1.3 Regeneration Cycle

The effective stoichiometry over the regeneration cycle is shown by Equation 2.5-45. Resin loading at the start of the regeneration cycle is assumed to be identical to resin loading at the end of the elution cycle. Regeneration is performed using a solution of NaOH. Therefore, a portion of the hydrogen ions on resin exchange sites are replaced with sodium ions, transferring hydrogen ions to the liquid phase.

Hydrogen ions released from the resin are neutralized by hydroxide ions and add to the liquid phase water.

Equation 2.5-45

$$(a+b+c+d)\,RH(s)+e\,Na^{+}(aq)+e\,OH^{-}(aq)\rightarrow(a+b+c+d-e)\,RH(s)+e\,RNa(s)+e\,H_2O$$

The quantity of sodium ions exchanged with hydrogen ions on the resin depends on the concentration of hydroxide ions in the regenerant solution. This quantity is determined by Equation 2.5-31 and Equation 2.5-32, and the resulting stoichiometry coefficients are shown by Equation 2.5-46.

Equation 2.5-46

$$e = F_{sa}([OH]_{regenerant})\,Q_{tot}$$
$$(a+b+c+d-e) = \left(1-F_{sa}([OH]_{regenerant})\right)Q_{tot}$$

2.5.3.6.1.4 Regenerant Displacement Cycle

Regenerant solution in the column void regions is displaced by treated LAW during the regenerant displacement cycle and the effective stoichiometry is shown by Equation 2.5-47. Resin loading at the start of the regenerant displacement cycle is assumed to be identical to resin loading at the end of the regeneration cycle. Resin loading is returned to the loading that is assumed for the start of the loading cycle.

Ion transfer between the resin and liquid phase during the regenerant displacement cycle is dependent on the regenerant hydroxide ion concentration relative to the waste hydroxide concentration. If the waste hydroxide ion concentration is greater than the regenerant hydroxide ion concentration (the most common condition), additional sodium ions are transferred to resin exchange sites and displaced hydrogen ions combine with hydroxide ions in the liquid phase to increase the liquid phase water mass. If the waste hydroxide ion concentration is less than the regenerant hydroxide ion concentration, additional hydrogen ions are transferred to resin exchange sites and displaced sodium ions increase the liquid phase sodium mass. Water disassociation increases the hydroxide ions and decreases the water mass of the liquid phase as hydrogen ions are adsorbed by the resin IX sites.

Equation 2.5-47

$$\text{For}\,[OH^{-}]_{waste} \geq [OH^{-}]_{regenerant} \quad \{(a+b+c) \geq e\}:$$
$$(a+b+c+d-e)RH(s)+eRNa(s)+(a+b+c-e)Na^{+}(aq)+(a+b+c-e)OH^{-}(aq)\rightarrow$$
$$(a+b+c)RNa(s)+dRH(s)+(a+b+c-e)H_2O$$

$$\text{For}\,[OH^{-}]_{waste} < [OH^{-}]_{regenerant} \quad \{(a+b+c) < e\}:$$
$$(a+b+c+d-e)RH(s)+eRNa(s)+(e-[a+b+c])H_2O\rightarrow$$
$$(a+b+c)RNa(s)+dRH(s)+(e-[a+b+c])Na^{+}(aq)+(e-[a+b+c])OH^{-}(aq)$$

2.5.3.6.1.5 Overall Regeneration plus Regenerant Displacement Cycles

The stoichiometry described by Equation 2.5-45 and Equation 2.5-47 can be simplified if the regeneration and regenerant displacement cycles can be combined to form a single process step. The combination of these cycles could be justified since column effluents are directed to the same plant vessel during both cycles. The advantage of combining the regeneration and regenerant displacement cycles for material balance purposes is that the stoichiometry simplifies to Equation 2.5-48, which is independent of the regenerant hydroxide ion concentration relative to the waste hydroxide ion concentration. The effect of combining the two process steps is a loss of detail in the composition difference between column effluents during the regeneration cycle versus column effluents during the regenerant displacement cycle. A composite composition of column effluents during the combined cycles is predicted by the material balance.

Equation 2.5-48

$$(a + b + c + d)RH(s) + (a + b + c)Na^{+}(aq) + (a + b + c)OH^{-}(aq) \rightarrow$$
$$(a + b + c)RNa(s) + dRH(s) + (a + b + c)H_2O$$

2.5.3.6.2 Liquid Phase Mixing Between Cycles

Mixing of liquid holdup in columns can reduce the effectiveness of rinse solutions as the column transitions from the loading cycle to elution cycle and back, depending on the liquid holdup of the plant scale columns. The current flowsheet basis estimates this inefficiency by modeling liquid holdup in the head space (480 gal) above a resin bed as a continuously stirred tank mixing pattern followed by a plug flow region for the void volume of the resin bed for solutions processed by down-flow through a column. All solutes in the column liquid phase inventory are assumed to be affected by the mixing of liquid holdup. However, mass balances for components that transfer between the resin and liquid phase must be adjusted by the stoichiometry described in Section 2.5.3.6.1 to account for interaction with the resin. An estimate of solute composition change in the liquid phase with cycle feed volume is developed in 24590-WTP-MCR-PT-02-103, *Ion Exchange Solution Mixing Between Cycles*. The predicted variation in solute concentrations within the head space is described by Equation 2.5-49.

Equation 2.5-49

$$C^{i}_{\text{Head Space}}(V_c) = C^{i}_{F} - (C^{i}_{F} - C^{i}_{0})\, e^{-\left(\frac{V_c}{V_l}\right)}$$

where:

$C^{i}_{\text{Head Space}}$ is the head space concentration variation of component i with cycle volume, gmol/L
V_c is the solution volume fed to the column during a cycle, L
C^{i}_{F} is the concentration of component i in the solution fed to a column during the cycle, gmol/L
C^{i}_{0} is the concentration of component i in the liquid phase at the start of a cycle, gmol/L
V_l is the liquid head space volume, L

Solute concentrations in the column effluent are shifted in time by the plug flow region that represents the resin bed void volume. This results in estimating column effluent solute concentrations by Equation 2.5-50.

Equation 2.5-50

$$C^i_{Effluent}(V_c) = C^i_0 \qquad \text{for } 0 \le V_c \le V_r$$

$$= C^i_F - (C^i_F - C^i_0)\, e^{-\left(\frac{V_c - V_r}{V_l}\right)} \qquad \text{for } V_c > V_r$$

where:

$C^i_{Effluent}$ is the column effluent concentration variation of component i with cycle volume, gmol/L
V_r is the resin bed void volume (resin bed volume × ε_T), L

Cycle volumes of interest in the Cs removal process exceed the resin bed void volume ($V_c > V_r$). Integration of Equation 2.5-50 produces an estimate for the component mass leaving a column in the effluent stream that varies with the cycle volume as shown by Equation 2.5-51.

Equation 2.5-51

$$E^i(V_c) = C^i_0 V_r + C^i_F (V_c - V_r) + (C^i_F - C^i_0)\, V_l \left[e^{-\left(\frac{V_c - V_r}{V_l}\right)} - 1 \right] \qquad \text{for } V_c > V_r$$

where:

E^i is the variation in mass of component i that exits the column with cycle volume, gmol

The component mass remaining in the liquid phase column inventory at the end of a cycle is shown as Equation 2.5-52. It is noted that, as the cycle volume becomes large, the exponential term in Equation 2.5-52 approaches zero and the column liquid phase inventory at the end of a cycle is described by the product of the feed concentration and total column liquid volume. Loading and elution cycle volumes are large enough to produce this result.

Equation 2.5-52

$$I^i(V_c) = C^i_F (V_r + V_l) - (C^i_F - C^i_0)\, V_l\, e^{-\left(\frac{V_c - V_r}{V_l}\right)} \qquad \text{for } V_c > V_r$$

where:

I^i is the variation in column liquid phase mass inventory of component i with cycle volume, gmol

Composition changes associated with liquid phase mixing during rinse cycles have not been specifically studied as part of laboratory tests to verify the assumed mixing model. In fact, visual observations of the column head space indicate the mixing model may not be applicable to the feed displacement cycle, where liquid phase density differences appear to result in the feed displacement solution (0.1 M NaOH) floating on top of waste simulant with the displacement/waste fluid interface traveling down through the head space liquid volume in an apparent plug flow pattern.

Data reported in SCT-M0SRLE60-00-110-00029 for the concentration change in column effluents for a range of cations, including Al, Ca, Cr, Cu, K, Na, Pb, and Sr, during displacement were reviewed in an

attempt to provide quantitative support for the feed displacement visual observations. The data were obtained from laboratory-scale test columns directed at investigating the resin's affinity for elements other than Cs. The concentrations of the elements listed above were above detection limits in column effluent samples obtained in 10 mL increments. Figure 2.5-56 and Figure 2.5-57 present the concentration data from displacement samples (and early phases of elution) as a function of column effluent volume for the tests using AP-101 and AN-107 waste simulant, respectively. The comparable waste feed concentration is shown on each figure at Volume = 0, indicating that the column effluent concentration of each element in the first displacement sample is similar to that of the waste feed. No discontinuities in the element concentrations were observed (indicative of a plug flow mixing pattern) as the displacement volume increased. The apparent mixing volume during displacement, indicated by column effluent changes, was determined based on Equation 2.5-50 and found to be approximately 80 % of the liquid head space volume maintained above the resin bed.

The quantitative data shown on Figure 2.5-56 and Figure 2.5-57 appear to conflict with the visual observations of feed displacement mixing patterns in the column head space and confirm the applicability of the mixing model. However, since the data were obtained for a different purpose, a number of data interpretation difficulties were encountered. These issues are summarized below.

- Evaluation of the displacement samples using Equation 2.5-50 assumes that interaction between the liquid phase and resin are negligible during displacement. Elution samples for each element obtained subsequent to the displacement samples indicate that all the elements listed, except Al and Ni, may have some affinity to the resin. Therefore, the observed concentration changes could be influenced by interactions with the resin and the similarity between apparent mixing volume and column head space could be a coincidence.
- The difference between laboratory scale and plant liquid introduction at the top of the column could be sufficient enough that feed displacement mixing is observed at the laboratory scale that would not be observed at a larger scale.
- The laboratory scale equipment is reported to contain a "dead" volume that is two to three times larger than the column head space volume. In addition, the volume of the collection funnel and tubing before the automatic sampler is similar to the column head space volume. Therefore, the calculated apparent mixing volume could reflect column effluent mixing that occurs after solution exits the resin bed rather than in the column head space. The apparent mixing volume calculated from the concentration data is approximately 30 % of the "dead" volume, which would imply that displacement mixing patterns might be closer to plug flow.
- Concentration changes observed during displacement could be influenced by the liquid phase concentration of components in resin pores diffusing into the bulk liquid flow such that the similarity between apparent mixing volume and column head space volume is a coincidence.

In spite of these data interpretation issues, it appears prudent to assume the mixing model applies to all IX cycles performed down-flow since this assumption produces a conservative estimate of transmitting residual ions in the liquid phase from one cycle to the next.

Material balances determining the mass of each component leaving the carousel during a cycle operating in down-flow are estimated by Equation 2.5-53.

Equation 2.5-53

$$\left\{\begin{matrix}\text{Mass leaving}\\ \text{Column during}\\ \text{a cycle}\end{matrix}\right\} = \left\{\begin{matrix}\text{Mass entering}\\ \text{column with}\\ \text{feed during}\\ \text{a cycle}\end{matrix}\right\} - \left[\left\{\begin{matrix}\text{Resin}\\ \text{inventory}\\ \text{at end}\\ \text{of cycle}\end{matrix}\right\} - \left\{\begin{matrix}\text{Resin}\\ \text{inventory}\\ \text{at start}\\ \text{of cycle}\end{matrix}\right\}\right] - \left[\left\{\begin{matrix}\text{Liquid phase}\\ \text{inventory}\\ \text{at end}\\ \text{of cycle}\end{matrix}\right\} - \left\{\begin{matrix}\text{Liquid phase}\\ \text{inventory}\\ \text{at start}\\ \text{of cycle}\end{matrix}\right\}\right]$$

$$= C_F^i V_c - \left[\left\{\begin{matrix}\text{Resin}\\ \text{inventory}\\ \text{at end}\\ \text{of cycle}\end{matrix}\right\} - \left\{\begin{matrix}\text{Resin}\\ \text{inventory}\\ \text{at start}\\ \text{of cycle}\end{matrix}\right\}\right] - \left[I^i(V_c) - C_0^i(V_l + V_r)\right]$$

Liquid phase concentrations are reset at the beginning of each cycle using Equation 2.5-54 to ensure that the material balance is closed across multiple cycles.

Equation 2.5-54

$$C_{0,n}^i = \frac{I_{n-1}^i(V_{c,n-1})}{(V_l + V_r)}$$

Regeneration and regenerant displacement cycles are performed using up-flow in the IX column. Under actual operating conditions, fluid flow patterns through the column should be well mixed during portions of the regeneration and regenerant displacement cycles, since the up-flow superficial velocity is sufficient to fluidize the resin bed.

Assumption 2.5.8. A model based on ideal stirred tank mixing of the column head space liquid volume is assumed to be applicable to all cycles processed down-flow as a conservative estimate of transmitting residual ions in the liquid phase from one cycle to the next.

2.5.3.6.3 Solid Phase Feed Components

Waste feed to the IX columns is processed by the ultrafiltration system before transfer to the IX feed tank. Therefore, the potential for observing solids in the IX system is considered low, unless post-filtration precipitates are formed. Aluminum is the most likely component to form solids after filtration. It is assumed that post-filtration precipitates will be captured on the IX columns to be dissolved by the acid eluant and transferred out of the IX system in the eluate. The current material balances are based on controlling the post-filtration supernate chemistry to avoid formation of precipitates in the IX feed vessel.

2.5.3.7 LAW Displacement, Rinse, and Regeneration Cycles

The current flowsheet basis adopts feed solution compositions and flows during LAW displacement, rinse, and regeneration cycles similar to those used in testing. The following discussion describes the current basis for each rinse cycle volume, and potential variations that may occur during operation.

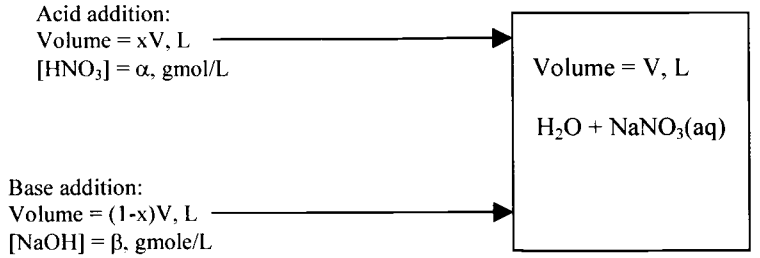
2.5.3.7.1 LAW Displacement

The composition of LAW displacement feed solution fed to the column liquid holdup must avoid precipitation of waste constituents in the column. Further, the column effluent composition during LAW displacement must avoid formation of precipitates when recycled to the CIX feed tank. A nominal LAW displacement feed composition of 0.1 M NaOH is used as the current flowsheet basis based on successful completion of laboratory scale tests. However, the composition may be modified in the future based on a detailed thermodynamic analysis of the waste composition ranges expected to be processed during plant operation and NaOH concentrations greater than 0.1 M will also create conditions precluding aluminum precipitates. It may also be desirable to vary the LAW displacement composition, depending on the waste composition in process. The current flowsheet is based on a total LAW displacement volume of 3 BV, consistent with the volume used in column tests. A minimum LAW displacement volume based on waste composition, which avoids precipitation upon introduction of the pre-elution rinse water, has not yet been established. The current flowsheet is based on a LAW displacement flow rate equivalent to the maximum waste processing flow rate. The flow rate is not an important parameter with respect to creating chemical process conditions as long as the liquid flow patterns in the actual column design effectively displace residual waste solution from the column liquid holdup. Variation in the LAW displacement flow rate must balance the time required to perform the LAW displacement cycle with column pressure drop.

2.5.3.7.2 Pre-Elution Rinse

Water is used as the column feed during the pre-elution rinse. The combined volume of the LAW displacement and pre-elution rinse cycles controls the mass of residual waste ions in liquid holdup that are removed from the column during each elution. (This does not apply to ions that interact with the IX resin.) In addition, the pre-elution rinse water reduces the hydroxide concentration in residual liquid holdup to minimize neutralization heat generated upon introduction of eluant to the column. The current flowsheet is based on a pre-elution rinse volume of 2 BV at a flow rate equivalent to the maximum waste processing flow rate. As with the LAW displacement, the pre-elution rinse flow rate must be sufficient to effectively mix with the column liquid holdup, as well as balance cycle time with pressure drop in the actual column design.

Specific criteria have not been established for limiting the quantity of trace ions (such as Cl^- and F^-) in eluate in the flowsheet basis at this time. Trace ion concentrations in eluate could be adjusted by increasing the combined volume of LAW displacement and pre-elution rinse water. Criteria have also not been defined for the maximum allowable heat of neutralization that defines the concentration of hydroxide ions that can remain in liquid holdup at the end of the pre-elution rinse. A simplified estimate of the maximum allowable hydroxide ion concentration can be determined from a heat balance that precludes generating a significant heat of reaction when adding nitric acid to basic solutions at the start of the elution cycle (or caustic to acidic solutions at the start of the regeneration cycle). A conservative method of evaluating this potential is to limit the adiabatic temperature rise associated with neutralization reactions on a unit volume of solution basis, neglecting heats of reaction with other residual waste ions. The estimate is based on the configuration shown by the following sketch, neglecting variations due to changes in solution density.



The adiabatic temperature rise for a unit volume of solution is found by heat balance shown as Equation 2.5-55.

Equation 2.5-55

$$\frac{Q_r}{V} = \rho C_P \Delta T$$

where

Q_r = the heat of the neutraliztion reaction (kcal)
ρ = solution density (base on water at 1000 g/L since solutions of interest are relatively dilute)
C_P = solution specific heat (base on water at 0.001 kcal/g-°C since solutions of interest are relatively dilute)
ΔT = temperature rise for unit volume of solution (°C)
V = the total mixture volume (L)
x = fraction of total mixture volume that was originally acid.

The neutralization reaction of interest is shown as Equation 2.5-56.

Equation 2.5-56

$$HNO_3\,(aq) + NaOH\,(aq) \rightarrow NaNO_3\,(aq) + H_2O\,(l)$$

The heat of reaction for the acid-base neutralization is estimated from heats of formation at 25 °C listed in Equation 2.5-57 from Perry, Green, and Maloney (1997).

Equation 2.5-57

HNO_3 (aq)	ΔH_f = -49.21 kcal/mole
NaOH (aq)	ΔH_f = -112.193 kcal/mole
$NaNO_3$ (aq)	ΔH_f = -106.88 kcal/mole
H_2O (l)	ΔH_f = -68.3174 kcal/mole

This results in the estimate for heat evolved by the neutralization reaction shown as Equation 2.5-58.

Equation 2.5-58

$$\Delta H_r = (-68.3174) + (-106.88) - (-49.21) - (-112.193) = -13.8 \text{ kcal/mole} OH^-$$

The moles of reactants available to generate heat per unit volume of mixture are dependent on the relative volumes and concentrations of reactants mixed. The total moles of reactants available per unit volume of mixture are shown by Equation 2.5-59.

Equation 2.5-59

$$\text{gmole}\,HNO_3 = \frac{\alpha\, x\, V}{V} = \alpha\, x \quad \text{gmole/L}$$

$$\text{gmol}\,NaOH = \frac{\beta(1-x)\,V}{V} = \beta(1-x) \quad \text{gmole/L}$$

The quantity of reactants, on a unit volume basis, is maximized when the moles of each reactant are equal, such that $\alpha\, x = \beta\,(1\text{-}x)$. This produces the maximum quantity of heat in the mixure mass and occurs when Equation 2.5-60 is satisfied.

Equation 2.5-60

$$x = \frac{\beta}{\alpha+\beta} \quad \text{or}$$

$$(1-x) = \frac{\alpha}{\alpha+\beta}$$

Therefore, the maximum heat generation on a unit volume of solution basis is estimated by Equation 2.5-61.

Equation 2.5-61

$$\frac{Q_r}{V} = (\Delta H_r\, \beta)\left(\frac{\alpha}{\alpha+\beta}\right) \text{ kcal/L}$$

Substitution and rearrangement to find an acid concentration that results in a particular adiabatic temperature rise in a unit volume of mixture is found by Equation 2.5-62.

Equation 2.5-62

$$\frac{Q_r}{V} = (\Delta H_r\, \beta)\left(\frac{\alpha}{\alpha+\beta}\right) = \rho C_P\, \Delta T$$

$$\left(\frac{\Delta H_r\, \beta}{\rho C_P\, \Delta T}\right)\alpha = \alpha + \beta$$

$$\left(\frac{\Delta H_r\, \beta}{\rho C_P\, \Delta T} - 1\right)\alpha = \beta$$

$$\alpha = \frac{\beta}{\left[\dfrac{\Delta H_r\, \beta}{\rho C_P\, \Delta T} - 1\right]}$$

Alternatively, Equation 2.5-62 can be rearranged to find a base concentration that results in a particular adiabatic temperature rise as shown by Equation 2.5-63.

Equation 2.5-63

$$\beta = \frac{\alpha}{\left(\frac{\Delta H_r \alpha}{\rho C_p \Delta T} - 1\right)}$$

Using ρ = 1000 g/L and C_P = 0.001 kcal/g-°C results in an estimate of the acid or base concentration that can remain in the column and produce a specified maximum temperature rise in a unit volume of solution when solution from the next cycle is added to the column. As an example, assume that the acid-base neutralization reaction is limited to produce a maximum solution temperature rise of 1 °C (ΔT = 1 °C). The eluant added after the pre-elution rinse is 0.45 gmol/L HNO_3 (α = 0.45 gmol/L). The estimate results in β = 0.086 gmole OH^-/L. Therefore, the adiabatic temperature rise of a unit volume of mixture will be limited to no more than 1 °C if the $[OH^-] \leq 0.086$ gmol/L at the conclusion of the pre-elution rinse.

Figure 2.5-59 provides a description of the plant-scale resin bed and liquid phase holdup in a column when the resin is in the Na-form based on properties described in the previous sections. Figure 2.5-59 indicates that the head space liquid phase volume is estimated at 480 gal and the liquid phase volume within the resin bed is estimated at 450 gal (including liquid in resin pores). Hand calculations using Equation 2.5-52 and Equation 2.5-54 (with an initial waste liquid holdup $[OH^-]$ of 4.2 M and liquid phase volumes from Figure 2.5-59) estimate that the LAW displacement and pre-elution rinse volumes indicated in Table 2.5-22 will reduce the liquid holdup $[OH^-]$ to less than 0.024 gmol/L. Therefore, the rinse volumes indicated in Table 2.5-22 are projected to result in liquid temperature increases from neutralization reactions of less than 1 °C in the plant scale equipment.

2.5.3.7.3 Post-Elution Rinse

Water is also used as the column feed for the post-elution rinse cycle. Like the pre-elution rinse, the post-elution rinse water reduces the acid concentration in residual liquid holdup to minimize neutralization heat generated upon introduction of regenerant to the column. The current flowsheet is based on a post-elution rinse volume of 1500 gal. However, the post-elution rinse feed rate is limited by the capacity of the Cs eluant evaporator to process the column effluent. Therefore, the post-elution rinse flow rate is the same as that used for eluant.

The adiabatic heat balance described above can be repeated for the case where 0.5 gmol/L NaOH regenerant (β = 0.5 gmol/L) is added to column liquid holdup at the end of the post-elution rinse. The estimate results in α = 0.085 gmol H^+/L. Therefore, the adiabatic temperature rise of a unit volume of solution mixture will be limited to no more than 1 °C if the $[H^+] \leq 0.085$ gmol/L at the conclusion of the post-elution rinse. Figure 2.5-59 indicates that the head space liquid phase volume is estimated at 600 gal and the liquid phase volume within the resin bed is estimated at 360 gal (including liquid in resin pores) for a plant scale resin bed in the H-form. Hand calculations using Equation 2.5-52 and Equation 2.5-54 (with an initial eluate liquid holdup $[H^+]$ of 0.45 gmol/L and liquid phase volumes from Figure 2.5-59) estimate that the post-elution rinse volume indicated in Table 2.5-22 will reduce the liquid holdup $[H^+]$ to less than 0.026 gmol/L. Therefore, the flowsheet basis is projected to result in liquid temperature increases from neutralization reactions of less than 1 °C in plant scale equipment.

2.5.3.7.4 Regeneration

The composition of regenerant fed to the column must be suitable to avoid precipitation in column head space when waste is reintroduced into the column during the loading cycle and provide a suitable caustic solution for reuse as the LAW displacement feed. In addition, the combined volume and composition must provide sufficient sodium to convert the resin bed from the hydrogen to sodium form. A nominal regeneration feed composition of 0.5 gmol/L NaOH is used as the current flowsheet basis based on successful completion of laboratory scale tests. This composition may be modified in the future based on a detailed thermodynamic analysis of the waste composition ranges expected to be processed during plant operation. It may also be desirable to vary the regenerant composition, depending on the waste composition in process, to support modification of the LAW displacement composition. The current flowsheet is based on a total regenerant volume of 2000 gal as recommended in 24590-WTP-RPT-RT-07-005.

The regeneration solution does not convert all the resin IX sites to the sodium form due to the variation of resin disassociation with hydroxide ion concentration. Figure 2.5-61 indicates that the molar quantity of sodium ion adsorbed on a resin bed increases as the regenerant volume is increased for a fixed regenerant NaOH concentration of 0.5 M. The hydroxide ion concentration in the liquid phase also increases as the regenerant volume is increased. For the recommended regenerant volume, Figure 2.5-61 predicts that the resin will contain ~4.9 mmol Na/g dry H-form resin and the liquid phase will be at ~0.12 gmol OH/L at the end of the regeneration cycle. This indicates that approximately 70 % of the theoretical adsorption sites will be converted to the sodium form during regeneration. Increasing the regenerant caustic volume or caustic concentration increases the fraction of adsorption sites converted to the sodium form during regeneration.

Regeneration is performed using a fluid flow up through the resin bed to fluidize the resin beads as they expand during conversion from the H-form to the Na-form. A three-step regeneration procedure is recommended in 24590-WTP-RPT-RT-07-005, based on test experience in the pilot scale (24-inch diameter) IX column. The procedure consists of an up-flow rate of 47 gpm for 1800 gal of the regenerant volume, followed by a 10 min settling period, and concluding with an up-flow rate of 7.4 gpm for 200 gal of regenerant. The selected fluidizing flow rate produces a superficial fluid velocity of ~12.5 cm/min in the column during the period when most of the resin bead expansion occurs and was selected to produce a uniformly fluidized bed for efficient conversion of resin to the Na-form without formation of bead-to-bead pressure. This superficial velocity results in a bed expansion equivalent to 140 % of the stationary bed height (Figure 2.5-17).

2.5.3.7.5 Regeneration Fluid Displacement

Pilot-scale testing indicated that introduction of waste solutions into a regenerated column with dilute caustic in the column head space has the potential to disturb the resin bed due to liquid phase density differences. The effect of the denser waste liquid falling through the column head space onto the leading edge of the resin bed results in an uneven resin bed height across the column. This effect would be projected to result in fluid channeling through the resin bed during loading cycles and reduce column performance.

A procedure was developed during pilot scale testing to mitigate this potential issue by displacing the dilute caustic in the liquid phase at the end of regeneration with treated LAW. The treated LAW has a higher hydroxide ion concentration and ionic strength than the residual regenerant solution. Therefore, the treated LAW is passed through the column in an up-flow direction since further bead expansion is expected to occur.

A three-step regeneration fluid displacement procedure is recommended in 24590-WTP-RPT-RT-07-005, based on test experience in the pilot scale (24-inch diameter) IX column. The procedure consists of an up-flow rate of 9.4 gpm for 1100 gal of the regenerant displacement volume, followed by an up-flow rate of 15 gpm for 150 gal of regenerant displacement and concluding with a 30 min settling time period. The selected fluidizing flow rate produces a superficial fluid velocity of ~2.5 cm/min in the column during the period when most of the resin bead expansion occurs and was selected to produce a bed expansion equivalent to 130 to 140 % of the stationary bed height from Figure 2.5-18.

The fluidizing flow rate varies with waste viscosity, waste density, bead diameter, and bead density. The regeneration fluid displacement flow rate required to produce the goal bed expansion will vary with these properties. Section 8 of 24590-WTP-RPT-RT-07-005 provides a methodology for estimating the required flow rate for target bed expansions as properties vary.

2.5.3.8 Cs Removal Process Basis

Waste will not be moved forward from the LAW collection vessels (CXP-VSL-00026A/B/C) to LAW vitrification if IX product does not comply with Cs removal requirements. Out-of-specification material is recycled until adequate Cs removal is observed based on sample analyses. Therefore, as long as the polishing column effluent complies with LAW vitrification feed criteria, the description of Cs removal performance reduces to a prediction of the loading cycle volume that can be processed before the lead column ^{137}Cs effluent concentration reaches 50 % of the waste feed ^{137}Cs concentration.

An alternative constraint is imposed on the loading cycle volume by safety analysis considerations. This constraint incorporates an administrative control limiting the total ^{137}Cs on a resin bed that supports safety analysis related calculations (e.g., hydrogen generation estimates). The technical safety limit imposed on total ^{137}Cs loaded on a resin bed is 150,000 Ci, with a Limiting Condition for Operation limit of 125,000 Ci, and LAW loading limit of 75,000 Ci (CCN 035290, *Determine the Method for Measuring Compliance with a Technical Safety Requirement on Cesium-137 Loading on an Ion Exchange Column (Second Meeting)*).

The analytical model, benchmarked to column loading and elution cycle test data described in earlier sections, is used as the basis for estimating the variation in loading cycle volume with IX feed composition. Prediction of resin performance is supported by the estimate of combined radiolytic and chemical degradation described in Section 2.5.3.1.5. The effective resin Cs capacity in each column is reduced to approximate the effects of resin degradation on the carousel loading cycle performance estimate.

2.5.3.8.1 Loading Cycle Volume

At the beginning of each loading cycle, the CXP system works in recycle mode, where treated LAW waste is sent back to the feed vessels (24590-WTP-RPT-PR-06-001). Monitors on the line ensure that the treated LAW meets specifications before it is rerouted to CXP-VSL-00026A/B/C for the remainder of the loading cycle. In order to ensure that at least an entire column volume is recycled back, the models assume that the CXP system will operate in recycle mode until 1500 gallons have passed through. An algebraic equation for estimating the IX carousel-loading cycle volume was developed by performing multiple loading cycle volume estimates for assumed waste feed compositions using the analytical model described in Section 2.5.3.4.2. Column feed compositions varied the Cs ion concentration from 1×10^{-6} to 1×10^{-3} gmol Cs/L and potassium ion concentration from 0 to 0.6 gmol K/L. Waste sodium ion concentration was held constant at 5 gmol Na/L and hydroxide ion concentration at 3 gmol OH/L for

development of the algebraic loading cycle volume equation. Resin degradation was based on the effective resin capacity after 20 cycles as an approximation of the average capacity observed over reusing a resin bed for 40 cycles before replacement with fresh resin.

The loading cycle volume calculation is documented in 24590-WTP-MCR-PO-08-0012. Results from the waste composition variation indicate that the loading cycle volume can be approximated by Equation 2.5-64 and Equation 2.5-65.

Equation 2.5-64

$$V_{load} = -A \, Ln([Cs^+]) - B$$

where:

V_{load} is the loading cycle volume, gal
$[Cs^+]$ is the waste feed Cs concentration in gmol/L

Equation 2.5-65

$$A = 55214 - 80312[K^+]$$
$$B = 342375 - 553228[K^+]$$

where:

$[K^+]$ is the waste feed potassium concentration in gmol/L

The predicted loading cycle volume is independent of the processing flow rate. This is the result of selecting a definition for the loading cycle endpoint based on reaching $C/C_0 = 0.5$ in the lead column effluent. Figure 2.5-30 indicates that the loading cycle volume to reach a column effluent concentration equivalent to $C/C_0 = 0.5$ is independent of the waste feed rate.

2.5.3.8.2 Cs Removal

Estimates of the carousel Cs removal performance are included in the mass balance based on the conservative assumption that all residual Cs in a column at the conclusion of elution is transmitted to the treated LAW product. This neglects Cs removed from the column during the post-elution rinse and regeneration cycles. Based on calculations shown in 24590-WTP-MCR-PO-08-0012, Cs transmitted to the treated LAW is dominated by residual Cs in the polishing column at the end of regeneration. The calculated overall decontamination factors for Cs from the carousel over a wide range of feed Cs and potassium concentrations are shown in Table 2.5-24. These values are plotted on Figure 2.5-62. This indicates that the Cs decontamination factor can be estimated as approximately constant at 4270 for a fraction of feed Cs removed from waste during a loading cycle of 0.999766.

2.5.3.8.3 Waste Cs Blending Criteria

The IX system loading cycle volume varies with waste feed composition, while the volume and flow rate of rinse, elution, and regeneration cycles are constant. Therefore, it is possible for the restoration cycle time to limit the IX processing rate as the loading cycle volume becomes small. The loading cycle volume is generally reduced as the waste Cs or potassium ion concentration increases. The loading cycle

volume also is reduced by resin degradation. When the restoration cycle time limits throughput, the IX carousel loading cycle can theoretically be performed:

- At the maximum volumetric feed rate, followed by a time period where a loaded column is held waiting for another column to complete the restoration cycles. (This option is unlikely to be used as an operating basis due to activation of the hydrogen vent system.)
- The carousel loading cycle volumetric feed rate can be reduced such that the loading cycle time is consistent with the combined restoration cycle time.

In either case, the average volumetric processing rate of waste feed through the IX carousel is reduced to the same value.

Figure 2.5-63 indicates the variation in loading cycle flow rate with loading cycle volume that produces a loading cycle time greater than or equal to the restoration cycle time based on values in Table 2.5-22 (total restoration cycle time ~ 23 hr). This indicates that the effective loading cycle feed rate decreases for loading cycle volumes less than 41,400 gal. The lower limit for the loading cycle volume is independent of the feed composition and depends only on the maximum desired IX system waste processing rate and time required to perform the rinse, elution, and regeneration cycles [for this case, (30 gal/min)(60 min/hr)(23 hr) = 41,400 gal].

One approach for maintaining the IX system waste feed volumetric throughput at maximum capacity is provided by blending waste before its introduction into the WTP to produce waste Cs concentrations that have a loading cycle volume such that carousel operation is not limited by the combined restoration cycle time. The mass of Cs contained in the loading cycle volume depends on one of the following factors:

1. The quantity of Cs that can be captured by the resin, or resin capacity, while producing a treated LAW waste stream that complies with the LAW glass concentration criterion for ^{137}Cs. The resin Cs capacity is dependent on the concentration of Cs, potassium, and sodium ion in the waste feed to IX.
2. The quantity of ^{137}Cs that can be fed to an IX column as limited by the facility safety basis. The current technical safety limit imposed on total ^{137}Cs loaded on a resin bed in 150,000 Ci, with a Limiting Condition for Operation limit of 125,000 Ci, and LAW loading limit of 75,000 Ci. Therefore, routine operation is expected to limit the loading cycle to 75,000 Ci ^{137}Cs.

Waste blending limits for Cs imposed by these two factors are considered in the following sections.

The waste blending criterion for ^{137}Cs imposed by the resin capacity was evaluated by rearranging Equation 2.5-64 to solve for the IX waste feed Cs concentration as shown in Equation 2.5-66.

Equation 2.5-66

$$V_{load} = -A\,Ln[Cs_{Waste}] - B$$

$$[Cs_{Waste}] = e^{-\left(\frac{V_{load}+B}{A}\right)}$$

Conversion of the total Cs ion concentration to a ^{137}Cs concentration depends on the mass ratio of ^{137}Cs to total Cs in a particular waste stream. Waste tanks characterized to date have generally found this ratio to be approximately 0.25 g ^{137}Cs/g total Cs in waste tanks other than the AZ-101 and AZ-102. AZ-101 and AZ-102 waste has generally been characterized with a Cs composition that is 0.3 g ^{137}Cs/g total Cs.

Figure 2.5-4(f) indicates the Cs limit for IX feed that would be imposed by the resin capacity after conversion to a ^{137}Cs per mole of sodium basis assuming 0.25 g ^{137}Cs/g total Cs.

The WTP safety analysis has been based on a maximum inventory of 150,000 Ci ^{137}Cs loaded on an IX column. Conservative implementation of the safety basis is currently based on limiting ^{137}Cs loaded on an IX column during the loading cycle to 75,000 Ci ^{137}Cs. The safety basis limit provides an alternative method for determining a Cs blending criteria by constraining the maximum quantity of ^{137}Cs in the minimum loading cycle volume that can be processed without experiencing cycle time limits by the rinse/restoration cycles. Equation 2.5-67 provides a generalized relationship for the ^{137}Cs concentration in IX waste feed that satisfies constraints imposed by the safety basis.

Equation 2.5-67

$$\left[{}^{137}Cs_{waste}\ \frac{Ci}{L}\right] = \frac{\left(\text{Safety Basis } {}^{137}\text{Cs Loading Limit, Ci}\right)}{\left(t_{rer}, \text{hr}\right)\left(60\ \frac{\text{min}}{\text{hr}}\right)\left(\dot{v}_{\text{design load}}, \frac{\text{gal}}{\text{min}}\right)\left(3.785\ \frac{L}{\text{gal}}\right)}$$

where:

t_{rer} = Total time to complete the combined rinse, elution, and regeneration cycles, hr

$\dot{v}_{design\ load}$ = Design loading cycle waste feed flow rate, gpm

Equation 2.5-68 provides an example calculation of the ^{137}Cs blending criterion imposed by the WTP safety basis for inputs used in previous sections of this draft, indicating the IX feed must be less than 0.478 Ci ^{137}Cs/L for the loading cycle volume to exceed 41,400 gal.

Equation 2.5-68

$$\left[{}^{137}Cs_{waste}\ \frac{Ci}{L}\right] = \frac{\left(75{,}000\ \text{Ci } {}^{137}\text{Cs}\right)}{\left(23\ \text{hr}\right)\left(60\ \frac{\text{min}}{\text{hr}}\right)\left(30\ \frac{\text{gal}}{\text{min}}\right)\left(3.785\ \frac{L}{\text{gal}}\right)} = 0.478\ \frac{\text{Ci } {}^{137}\text{Cs}}{\text{L}}$$

Figure 2.5-64 compares the projected Cs blending limit based on resin capacity with a blending limit based on the safety basis loading limit constraint. The comparison indicates that current modeling predicts that a waste blending limit of 0.478 Ci ^{137}Cs/L will allow the IX system to process waste without being constrained by the operational time to perform restoration process cycles.

2.5.3.8.4 Cs Removal Process Streams

Table 2.5-22 describes the nominal Cs removal cycles and time the column is in each cycle. The general equipment configuration is based on the process flow diagram presented in Section 2.5.2. The equipment arrangement consists of four columns operated in a carousel, with each column capable of performing in the lead, lag, polishing, or elution operating position. During the loading cycle, treated LAW supernate is fed through three columns in series (lead, lag, and polishing) and transferred to the LAW collection vessels. After loading a lead column using the indicated volume of LAW (Cycle [1] on Figure 2.5-65), LAW feed is switched to the former lag column (becoming the lead column), polishing column switched to the lag column position, and freshly eluted column switched to the polishing column position. Restoration cycles (Cycles [2] to [7] on Figure 2.5-65) are then performed on the loaded column.

Key inputs to complete the IX material balances are summarized as follows:

- Waste composition
- Volume and composition of rinse, elution, and regeneration cycles
- Liquid phase flow rate of each cycle
- Resin bed volume during loading cycle

The basis for each cycle is described below.

Loading Cycle - This cycle treats the LAW for removal of Cs. The LAW flow rate is based on bounding design requirements discussed in Section 2.5.1, and can vary from 5 gpm to 30 gpm in order to avoid ion exchange feed inventory buildup and to preserve a buffering volume. The loading cycle volume and fraction of waste feed Cs removed by IX with the resin is dependent on the waste composition being processed, as described in Section 2.5.3.8.1 and Section 2.5.3.8.2, respectively.

LAW Fluid Displacement Cycle - This cycle displaces residual LAW feed from the column with a dilute caustic solution to prevent the potential precipitation of aluminum hydroxide during introduction of the water rinse. The fluid displacement composition and volume are consistent with the fluid displacement step used during laboratory column tests. The volume is based on providing 3 BV of displacement fluid feed to the column based on the nominal initial resin bed volume (3 × 600 gal ~ 1800 gal), as recommended in 24590-WTP-RPT-RT-07-005. Flow rate is the same as the maximum waste processing rate as an estimate of the balance between cycle time and column pressure drop (see Section 2.5.3.7.1). A resin outlet flush of 21 gal of demineralized water follows the displacement cycle. During resin outlet flushes, the liquid flows up through the resin outlet nozzle to ensure it remains unobstructed.

Pre-elution Rinse Cycle - This cycle displaces residual dilute caustic from the column to prevent an acid-base reaction from occurring within the IX bed during introduction of the eluant, and combined with the LAW fluid displacement, limit the trace ions transferred to eluate. The volume is based on providing approximately 1 column volume (1200 gal) of rinse fluid, as recommended in 24590-WTP-RPT-RT-07-005. Section 2.5.3.7.2 indicates that the selected rinse volume is generally expected to limit the adiabatic temperature rise of liquid to less than 1 °C when eluant is introduced during the elution cycle. Flow rate is the same as the maximum waste processing rate as an estimate of the balance between cycle time and column pressure drop.

Elution Cycle - This cycle removes Cs from the IX bed using dilute nitric acid. The nitric acid composition (0.45 M HNO_3), cycle volume (9000 gal) and flow rate (10 gpm) are recommended in 24590-WTP-RPT-RT-07-005. Elution test data were primarily obtained using nitric acid concentrations of 0.5 M HNO_3. However, variation of the eluant acid concentration over a range of 0.25 to 0.5 M HNO_3 does not appear to have a significant influence on the eluate volume required to produce a specific Cs resin loading at the end of elution once the resin is converted to the H-form and residual hydroxide ion in the column liquid phase has been neutralized (Section 2.5.3.5.1). Resin reactivity tests indicate that no significant reactions were observed in 0.5 M HNO_3 at temperatures up to 77 °C (Section 2.5.3.1.4). Therefore, an eluant acid concentration of 0.45 M HNO_3 was selected to provide some margin between the flowsheet eluant composition and composition where resin reactivity data have been obtained with minimal effect on the elution cycle volume.

The basis for eluant volume is described in Section 2.5.3.5.1 and is based on reducing residual Cs on resin to produce treated LAW that complies with the ^{137}Cs concentration criterion when an eluted column is placed in the polishing position. Figure 2.5-52 indicates that this goal is achieved with an elution volume

of 15 BV. Application to the nominal initial resin bed volume of 600 gal results in a total elution cycle feed volume of 9000 gal (15 × 600 gal ~ 9000 gal). The eluant flow rate (10 gpm) is based on the capacity of the eluate concentrator. A resin outlet flush of 21 gal of 0.45 M HNO_3 follows the elution cycle.

Post-elution Rinse Cycle - This cycle displaces residual acid from the column after elution to prevent an acid-base reaction from occurring within the IX bed during introduction of the regenerant. The volume is based on providing approximately 1.3 column volumes of rinse fluid (1500 gal), as recommended in 24590-WTP-RPT-RT-07-005. Section 2.5.3.7.2 indicates that the selected rinse volume is generally expected to limit the adiabatic temperature rise of liquid to less than 1 °C when eluant is introduced during the elution cycle. The post-elution rinse flow rate (10 gpm) is based on the capacity of the eluate concentrator. A resin outlet flush of 21 gal of 0.5 M NaOH follows the post-elution rinse cycle.

Regeneration Cycle - This cycle converts the IX resin from the hydrogen form (converted during elution) to the sodium form in preparation for reuse of the resin for LAW solution processing. The regenerant composition is consistent with the regenerant step used in laboratory column tests. The volume is based on providing a total of 3.3 BV (2000 gal) of 0.5 M NaOH regenerant fluid, as recommended in 24590-WTP-RPT-RT-07-005.

Section 2.5.3.7.4 describes the effect of regenerant volume variations and the basis for regenerant flow rate. Actual regenerant flow rates are varied during the cycle to produce a resin bed of uniform height over the column cross section. Material balances are based on a time average of the flow rates.

Regeneration Fluid Displacement Cycle - This cycle displaces spent regenerant (dilute caustic solution) from the column liquid hold up prior to introduction of waste when a column is returned to the carousel polishing column position. The volume is based on providing a total of 1.03 column volumes (1250 gal) of regenerant displacement fluid, as recommended in 24590-WTP-RPT-RT-07-005. Section 2.5.3.7.5 describes the basis for regeneration displacement fluid flow rate. Actual fluid flow rates are varied during the cycle to produce a resin bed of uniform height over the column cross section. The resin outlet flush of 54 gal of treated LAW follows this cycle.

2.5.4 Ongoing Work and Potential Changes

24590-WTP-PL-PET-07-0003, *Issue Response Plan to Mature WTP Radioactive Cesium Removal to Technical Readiness Level 6,* provides a description of planned future work that has the potential to change the basis for IX system material balances. The plan describes a combination of engineering studies and prototypic tests.

Resin bulk density has been based on a rounded approximation of density data from all six production scale resin lots summarized in Section 2.5.3.1.1.2 and Table 2.5-5 (0.4 g dry H-form resin/mL wet H-form resin bed). It is expected that future revisions will focus resin properties on resin lots 5E-370/641, 5J-370/686, and 6C-370/745 in anticipation that Microbeads will be the primary source of resin. This will reduce the bulk resin density estimate in Section 2.5.3.1.1.2 to 0.36 g dry H-form resin/mL wet H-form resin bed, 0.3 g dry H-form resin/mL wet Na-form resin bed, and 0.37 g dry Na-form resin/mL wet Na-form resin bed. The modified bulk density estimates increase the resin bed porosity estimated in Section 2.5.3.1.7.1 from ~0.75 to ~0.77. These modified parameters could decrease resin loading cycle volumes by ~10 %.

The current elution volume indicated is 9000 gal (15 BV) of 0.45 M HNO_3, as indicated by Figure 11 of 24590-WTP-RPT-RT-07-005. It is expected that this will be updated to 9150 gal (15.25 BV) of eluant in future revisions to be consistent with Table 5 of 24590-WTP-RPT-RT-07-005. In addition, alternative elution methods that reduce the eluant nitric acid concentration during later phases of the elution cycle may be considered in the future to reduce nitric acid that must be neutralized when concentrated Cs eluate is transferred to the HLW Facility.

The control philosophy used as a basis for this version of the IX material balance is based on defining the end of a loading cycle by the point in time where the lead column effluent Cs concentration reaches 50 % of the waste feed Cs concentration based on 24590-WTP-RPT-PR-06-001. The control philosophy influences the predicted waste volume processed during a loading cycle and the Cs removal performance of the IX system. An alternative control philosophy is also under consideration where a loading cycle is continued until the polishing column effluent reaches a Cs concentration equal to the criteria for treated LAW waste acceptance by the LAW Facility on an instantaneous basis. Note that the composite Cs concentration of treated LAW for this alternate approach would still be well below the Cs concentration allowed for processing by the LAW Facility. The alternative control philosophy is generally expected to produce larger loading cycle volumes and a slightly reduced Cs removal performance compared to the control basis used for the current material balance. This alternative approach may be considered in a future material balance revision.

Liquid phase mixing in the column headspace has been modeled using a continuous stirred tank mixing pattern despite visual indications that the flow pattern may be closer to a plug flow mixing pattern when column addition solution densities, added down-flow to the column, are less than the resident solution density. The primary reason for maintaining the mixing flow pattern is to indicate that ions other than sodium, potassium, and Cs should be present in column eluate. A similar result could be obtained by modifying the mixing pattern to plug flow, combined with estimates of the apparent resin loading of other ions (see Figure 2.5-39 and Figure 2.5-40). This alternative approach may be considered in a future material balance revision.

2.5.5 References

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24590-101-TSA-W000-0004-04-00003, Rev 00A, *Pre-conditioning and Regeneration Requirements of Ground Gel Resorcinol Formaldehyde Ion Exchange Resin* (WTP-RPT-104, Rev 0).

24590-101-TSA-W000-0004-72-00017, Rev 00C, *Small Column Ion Exchange Testing of Spherical Resorcinol-Formaldehyde Resin for ^{137}Cs Removal from Pre-Treated Hanford Tank 241-AN-102 Waste (Envelope C)* (WTP-RPT-135, Rev 1).

24590-101-TSA-W000-0004-91-00003, Rev 00A, *Elution Testing of Resorcinol-Formaldehyde Resins with AN-105 Simulant* (WTP-RPT-105).

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24590-PTF-RPT-RT-02-001, Rev 0, *WTP Pretreatment Alternative Resin Selection.*

24590-QL-HC9-WA49-00001-03-00001, Rev 00A, *Storage and Aging Effects on Spherical Resorcinol-Formaldehyde Resin Ion Exchange Performance.*

24590-WTP-MCR-PO-05-0017, Rev 0, *LAW Glass Chemistry Shell Update for Steady State Flowsheet.*

24590-WTP-MCR-PO-08-0012, Rev 0, *Incorporate Spherical Resorcinol-Formaldehyde Data in Dynamic Material Balances.*

24590-WTP-MCR-PT-02-103, Rev 0, *Ion Exchange Solution Mixing Between Cycles.*

24590-WTP-MRQ-PO-07-0009, Rev 0, *UFP-VSL-00001A/B Leaching With 7.5 MTD IHLW.*

24590-WTP-PL-PET-07-0003, Rev 0, *Issue Response Plan to Mature WTP Radioactive Cesium Removal to Technical Readiness Level 6.*

24590-WTP-RPT-PO-04-023, Rev 0, *Resin Degradation Data Reconciliation.*

24590-WTP-RPT-PR-06-001, Rev 0, *Technical Evaluation for Resolution of EFRT Issue P8 Cesium Ion Exchange System Breakthrough Monitoring.*

24590-WTP-RPT-RT-06-001, Rev 1, *Basis for Recommendation of Spherical Resorcinol Formaldehyde Resin as the Approved Equivalent to SuperLig 644.*

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SCT-M0SRLE60-00-110-00029, Rev 00B, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin* (WSRC-STI-2006-00071, Rev 0).

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SCT-M0SRLE60-00-221-00001, Rev 00B, *Spherical Resorcinol-Formaldehyde Resin Reactivity with Nitric Acid and Other Hanford RPP-WTP Process Solutions* (WSRC-TR-2005-00228, Rev 0).

Table 2.5-1 Spherical Resorcinol-Formaldehyde Resin Batch Production History Supporting Test Activities

Lot Number	Production Date	Lot Size[a]	Manufacturer[b]	Comments
BRF-14	June 2004	2 L	SINTEF	Resin lots prepared under different conditions to investigate CIX capacity and selectivity variation with production parameters. Parameters varied included relative resorcinol-to-formaldehyde mole ratio, curing time, curing temperature, and excess monomer added beyond the theoretical capacity of the resin sphere.
BRF-15	June 2004	2 L	SINTEF	
BRF-16A-B-C	June 2004	2 L	SINTEF	
BRF-17	June 2004	2 L	SINTEF	
BRF-18	June 2004	2 L	SINTEF	
PS-420	NA	< 2 L	Microbeads	
PS-424	October 2004	< 2 L	Microbeads	
BSC-3380-2P-0100	March 2005	0.5 gal	BSC	
BSC-3380-2P-0101	March 2005	0.5 gal	BSC	
BSC-3380-2P-0102	March 2005	0.5 gal	BSC	
BSC-3380-2P-0103	March 2005	0.5 gal	BSC	
PS-493	March 2005	0.15 L	Microbeads	
PS-501	March 2005	0.15 L	Microbeads	
5C-370/522	April 2005	2 gal	Microbeads	
5C-370/523	April 2005	2 gal	Microbeads	
PS-513	April 2005	0.15 L	Microbeads	
PS-514	April 2005	0.15 L	Microbeads	
PS-515	April 2005	0.15 L	Microbeads	
PS-517	April 2005	0.15 L	Microbeads	
PS-518	April 2005	0.15 L	Microbeads	
PS-502	April 2005	0.15 L	Microbeads	
5E-370/639	May 2005	50 gal	Microbeads	Scaled-up resin production lots manufactured under similar conditions supporting evaluation of resin quality and reproducibility.
5E-370/641	May 2005	75 gal	Microbeads	
5J-370/686	September 2005	72 gal	Microbeads	
3380-3-0200	November 2005	66 gal	BSC	
6C-370/745	April 2006	74 gal	Microbeads	
3380-3-0201	May 2006	66 gal	BSC	

Notes:

a) The lot size represents the as-produced hydrogen-form resin. Typically, the resin expands 50 to 60 % upon first conversion to the sodium-form.

b) Seed material provided by Microbeads (Skedsmokorset, Norway) for all resin lots. SINTEF is located in Trondheim, Norway. Boulder Scientific Corporation (BSC, Mead, CO) was subcontracted by Microbeads to prepare selected resin lots.

Source: 24590-101-TSA-W000-0004-99-00013, Rev 00B. *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Table 3.1).

Table 2.5-2 Skeletal Density of Spherical Resorcinol Formaldehyde

Resin Lot	Hydrogen Form Resin, g H-form solid/mL H-form solid	Sodium Form Resin, g Na-form solid/mL Na-form solid
5E-370/639	1.48	1.61
5E-370/641	1.48	1.63
5J-370/686	1.47	1.64
6C-370/745	1.48	1.63
3380-3-0200	1.47	1.64
3380-3-0201	1.48	1.66

Notes:

1. All skeletal densities measured in water using fresh pretreated resin.
2. Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Table 16.1).

Table 2.5-3 Variation of Spherical Resorcinol Formaldehyde Skeletal Density with Process Cycling

Resin Sample Source	Hydrogen Form Resin, g H-form solid/mL H-form solid	Sodium Form Resin, g Na-form solid/mL Na-form solid
Fresh Pretreated Resin	1.51	Not Measured
Resin Bed Core Sample after 10 Process Cycles	1.52	1.59
Resin Bed Core Sample after 16 Process Cycles	1.54	1.60
Top Layer of Dark Beads from Resin Bed after 16 Process Cycles	1.57	1.64

Notes:

1. Data obtained from 24-in. diameter pilot-scale test column using resin from lot 5E-370/641.
2. Source: SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin* (Table 17).

Table 2.5-4 As-Received Spherical Resorcinol Formaldehyde Resin Volume Expansion Observed during Pretreatment

Resin Lot	1st Cycle Expansion[2]	H-Form to Na-Form Expansion[3]	Total Expansion[4]
5E-370/639	1.27	1.21	1.55
5E-370/641	1.25	1.24	1.56
5J-370/686	1.25	1.23	1.55
6C-370/745	1.25	1.29	1.61
3380-3-0200	1.26	1.25	1.57
3380-3-0201	1.26	1.26	1.58

Notes:

1. All shrink-swell cycles performed in an open beaker. Agitation and soaking are associated with each pretreatment step.
2. The 1st cycle expansion represents the resin volume change after a rinsing in 3 BV water, 3 BV 1 M NaOH, three sequential water rinses (2 BV each), followed by contact with 6 BV 0.5 M HNO_3. Units are in mL resin after 1st cycle expansion/mL as-received resin. The liquid phase BV is defined based on the Na-form resin volume.
3. The H-form to Na-form expansion represents the resin volume change after resin from the 1st cycle expansion is rinsed twice in water (2 BV) followed by contacting with 5 BV of 1 M NaOH. Units are in mL Na-form resin/mL H-form resin after 1st cycle expansion.
4. Total expansion is the total resin volume change observed during pretreatment. Units are in mL Na-form resin/mL as-received resin.
5. Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Tables 11.2, 13.2, and 14.5).

Table 2.5-5 Bulk Density of Spherical Resorcinol Formaldehyde Resin Beds

Resin Lot	Hydrogen Form Bulk Density	Sodium Form Bulk Density	
	g dry H-form resin per mL wet H-form resin bed[1]	Equivalent g dry H-form resin per mL wet Na-form resin bed[2]	g dry Na-form resin per mL wet Na-form resin bed[1]
5E-370/639	0.36	0.29	0.36
5E-370/641	0.37	0.30	0.37
5J-370/686	0.37	0.30	0.37
6C-370/745	0.36	0.29	0.38
3380-3-0200	0.41	0.33	0.41
3380-3-0201	0.42	0.35	0.41

Notes:

1. Settled density of freshly pretreated resin as measured in a 25-mL graduated cylinder.
2. Determined for freshly pretreated resin in a 2-cm diameter test column based on resin mass loaded and measured bed height in 0.5 M NaOH. Bed compaction may influence density data measured in these column tests since regeneration was performed down-flow and bed expansion may have been constrained during regeneration.
3. Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Tables 11.4, 13.4, 14.7, and 16.1).

Table 2.5-6 Spherical Resorcinol Formaldehyde Bulk Density Observed in a 3-in. Column

Resin Lot	5J-370/686	Blend of 3380-3-0200 and 3380-3-0201
H-form Resin in water, g dry H-form resin per mL wet H-form resin	0.33	0.37
Resin in NaOH, g dry Na-form resin per mL wet Na-form resin	0.33	0.37
Resin in LAW simulant, equivalent g dry H-form resin per mL wet Na-form resin	0.27	0.29
Resin in 0.5 M NaOH, equivalent dry g H-form resin per mL wet Na-form resin	0.27	0.30

Notes:

1. Data obtained from resin volume in a 3-in. diameter test column after performing four process cycles by drying a measured volume fraction of the bed and applying the observed mass to the column volume.
2. Source: 24590-101-TSA-W000-0004-174-00002, *Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins* (Table 8-2).

Table 2.5-7 Particle Size Distributions of Spherical Resorcinol-Formaldehyde Resin Lots after Pretreatment

Resin Lot	Resin Form	Volume based Distribution, µm				Number based Distribution, µm				Area based Distribution, µm
		Mean Diameter, m_v	Standard Deviation	Low 5 %[a]	High 90 %[b]	Mean Diameter, m_n	Standard Deviation	Low 5 %[a]	High 90 %[b]	Mean Diameter, m_a
5E-370/639	H-form	407	73	302	511	369	56	283	445	392
5E-370/641		421	78	307	538	377	59	288	457	403
5J-370/686		412	72	307	514	376	58	288	454	398
6C-370/745		440	81	304	581	368	52	287	436	395
3380-3-0200		404	71	302	504	369	56	283	445	391
3380-3-0201		449	82	310	603	375	53	293	443	401
5E-370/639	Na-form	439	79	323	559	394	60	301	476	421
5E-370/641		452	83	333	575	406	70	308	793	434
5J-370/686		446	80	331	562	405	65	306	492	431
6C-370/745		468	103	324	640	398	63	301	487	433
3380-3-0200		437	77	326	547	398	63	302	484	423
3380-3-0201		484	118	329	691	404	65	304	496	443

Notes:

a 5 % of the particles are less than the given diameter

b 10 % of the particles are greater than the given diameter

c As-received H-form resin pretreated by water rinse, conversion to the Na-form water washed and converted to the H-form prior to particle size analysis. A portion of the pretreated H-form resin was converted to the Na-form to determine Na-form particle size analysis.

d Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Tables 11.3, 13.3, and 14.6).

Table 2.5-8 Radiation Degradation Data at 25 °C in LAW Simulant and Nitric Acid

Resin Contact Solution during Irradiation[1]	Exposure, Mrad	Batch Contact Tests in AP-101 Simulant				
		Initial Contact Solution [Cs], gmol/L	Initial Contact Solution Gamma Counts	Final Contact Solution Gamma Counts	Equilibrium Contact Solution [Cs], gmol/L[2]	Equilibrium Resin Cs Loading, mmol/g Dry H-form Resin[3]
AP-101	100	8.17E-05	218823	54993	2.05E-05	6.36E-03
AP-101	100	8.17E-05	218823	57323	2.14E-05	6.26E-03
AP-101	100	2.85E-03	219747	93040	1.21E-03	1.72E-01
AP-101	100	2.85E-03	219747	92629	1.20E-03	1.71E-01
AP-101	100	1.35E-02	224724	131484	7.90E-03	5.84E-01
AP-101	100	1.35E-02	224724	130942	7.87E-03	5.84E-01
AP-101	100	8.17E-05	219621	53504	1.99E-05	6.70E-03
AP-101	100	8.17E-05	219621	53848	2.00E-05	6.60E-03
AP-101	100	2.85E-03	222856	93287	1.19E-03	1.80E-01
AP-101	100	2.85E-03	222856	90781	1.16E-03	1.82E-01
AP-101	100	1.35E-02	225036	130707	7.84E-03	6.13E-01
AP-101	100	1.35E-02	225036	125766	7.54E-03	6.48E-01
AP-101	34	8.17E-05	218823	48926	1.83E-05	6.78E-03
AP-101	34	8.17E-05	218823	50188	1.87E-05	6.76E-03
AP-101	34	2.85E-03	224976	84791	1.07E-03	1.89E-01
AP-101	34	2.85E-03	224976	84520	1.07E-03	1.91E-01
AP-101	34	1.35E-02	223609	123850	7.48E-03	6.46E-01
AP-101	34	1.35E-02	223609	126162	7.62E-03	6.31E-01
AP-101	0	8.17E-05	219621	46896	1.74E-05	6.73E-03
AP-101	0	8.17E-05	219621	48306	1.80E-05	6.72E-03
AP-101	0	2.85E-03	222856	84358	1.08E-03	1.87E-01
AP-101	0	2.85E-03	222856	84489	1.08E-03	1.86E-01
AP-101	0	1.35E-02	225036	123267	7.39E-03	6.39E-01
AP-101	0	1.35E-02	225036	124331	7.46E-03	6.31E-01
HNO_3	100	8.17E-05	218823	54657	2.04E-05	7.05E-03
HNO_3	100	8.17E-05	218823	57953	2.16E-05	6.91E-03
HNO_3	100	2.85E-03	219747	96384	1.25E-03	1.84E-01
HNO_3	100	2.85E-03	219747	94497	1.23E-03	1.87E-01
HNO_3	100	1.35E-02	224724	134215	8.06E-03	6.27E-01
HNO_3	100	1.35E-02	224724	132485	7.96E-03	6.38E-01
HNO_3	100	8.17E-05	219621	48914	1.82E-05	6.32E-03
HNO_3	100	8.17E-05	219621	48124	1.79E-05	6.36E-03
HNO_3	100	2.85E-03	222856	85588	1.09E-03	1.75E-01
HNO_3	100	2.85E-03	222856	83394	1.07E-03	1.77E-01
HNO_3	100	1.35E-02	225036	124120	7.45E-03	6.00E-01
HNO_3	100	1.35E-02	225036	120706	7.24E-03	6.20E-01
HNO_3	34	8.17E-05	218823	44591	1.66E-05	6.67E-03
HNO_3	34	8.17E-05	218823	43623	1.63E-05	6.72E-03

Table 2.5-8 Radiation Degradation Data at 25 °C in LAW Simulant and Nitric Acid

Resin Contact Solution during Irradiation[1]	Exposure, Mrad	Batch Contact Tests in AP-101 Simulant				
		Initial Contact Solution [Cs], gmol/L	Initial Contact Solution Gamma Counts	Final Contact Solution Gamma Counts	Equilibrium Contact Solution [Cs], gmol/L[2]	Equilibrium Resin Cs Loading, mmol/g Dry H-form Resin[3]
HNO_3	34	2.85E-03	224976	79689	1.01E-03	1.89E-01
HNO_3	34	2.85E-03	224976	79384	1.01E-03	1.91E-01
HNO_3	34	1.35E-02	223609	119988	7.24E-03	6.48E-01
HNO_3	34	1.35E-02	223609	119606	7.22E-03	6.50E-01
HNO_3	0	8.17E-05	222999	38680	1.42E-05	6.50E-03
HNO_3	0	8.17E-05	222999	37534	1.38E-05	6.58E-03
HNO_3	0	2.85E-03	221954	72330	9.29E-04	1.85E-01
HNO_3	0	2.85E-03	221954	67300	8.64E-04	1.92E-01
HNO_3	0	1.35E-02	226440	109988	6.56E-03	6.71E-01
HNO_3	0	1.35E-02	226440	112814	6.73E-03	6.51E-01

Notes:

1. Solution contacting resin for 10 days during test at 25 °C. AP-101 simulant is characterized as [Na] = 4.55 M, [K] = 0.748 M, [OH] = 1.88 M. HNO_3 is characterized by $[HNO_3] = 0.5$ M.
2. Cs concentration in equilibrium with resin loading is determined by ratio of final gamma counts to initial gamma counts multiplied by the initial solution Cs concentration.
3. All equilibrium resin loadings determined in AP-101 simulant.
4. Source: SCT-M0SRLE60-00-10-00005, *Radiolytic, Thermal, and Physical Degradation Testing of Spherical Resorcinol-Formaldehyde (RF) Resin (U)* (Table 4-13).

Table 2.5-9 Resin Performance Data from Radiation Degradation Tests

Dose, Mrad	Equilibrium Cs Loading at Liquid Phase $[Cs] = 1\times10^{-4}$ M, mmol/g Dry H-form Resin	Resin Capacity Relative to Initial Capacity, R/R_0
Irradiated in AP-101 Simulant[1]		
0	2.93E-02	1
34	2.92E-02	9.95E-01
100	2.46E-02	8.38E-01
Irradiated in 0.5 M HNO_3[2]		
0	3.54E-02	1
34	3.16E-02	8.93E-01
100	2.63E-02	7.45E-01

Notes:

1. Based on interpolating curves shown on Figure 2.5-11.
2. Based on interpolating curves shown on Figure 2.5-12.

Table 2.5-10 Spherical Resorcinol-Formaldehyde Resin Oxidation Data

Resin lot	BRF-14 (AP-101)	BRF-14 (AZ-102)	BRF-15	BRF-17	5E-360/641	
Pre-exposure 50 % breakthrough, BV[1]	121	170	120	123	136	
Post-exposure 50 % breakthrough, BV	110	142	107	105	123	
Oxygen Exposure, mmol O2/g dry H-form resin	0.92	0.78	0.95	0.65	0.5	0.63
Relative Capacity of Post-exposure Resin, R/R_0[2]	0.91	0.84	0.89	0.85	0.90	
Source	[3]				[4]	

Notes:

1. BV = bed volume.
2. Calculated as ratio of (post-exposure 50 % breakthrough)/(pre-exposure 50 % breakthrough).
3. Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Table 6.3).
4. Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Table 11.8 and Figure 12.4). Range for oxygen exposure reported in Section 6.4.

Table 2.5-11 Oxygen Concentration for Ion Exchange Process Solutions Saturated in Air at 20 °C

Feed Solution	Measured Oxygen Concentration, mmol O_2/L[1]	Estimated Pressure of Air in Equilibrium with Column Feed, psia[2]	Estimated Column Feed Oxygen Concentration, mmol O_2/L[3]
Fluid Displacement Cycle (0.1 M NaOH)	0.203	15.68	0.22
Pre-elution Rinse and Post-elution Rinse Cycles (water)	0.212	15.68	0.23
Elution Cycle (0.5 M HNO_3)	0.206	13.48	0.19
Regeneration Cycle (0.25 to 0.5 M NaOH)	0.21	13.48	0.19

Notes:

1. Source: SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin* (Table 25) for solutions in equilibrium with air at a pressure of 14.7 psia.
2. Assumes a base barometric pressure at the Hanford Site of 14.38 psia. Feed vessels are assumed to operate at a headspace air pressure of -1 psig. Solutions entering a column via CXP-VSL-00005 are assumed to have the potential to equilibriate with air at a pressure equivalent to 5 ft of water, gage (2.2 psig) larger than the headspace pressure (total air pressure equilibriating with solution = 14.48 psia – 1 psi + 2.2 psi = 15.68 psia).
3. Modified to adjust for solution equilibrium with indicated air pressure assuming Henry's law is applicable (example: $0.203 \times (15.68/14.7) = 0.22$).

Table 2.5-12 Summary of Spent Resin Metals and Radionuclide Concentrations after Processing a Sequence of Actual Waste Samples in Column Tests

Component	Resin A	Resin B
Metals	**µg/g dry H-form resin**	**µg/g dry H-form resin**
Ag	[3.1][(2)]	[3.4][(2)]
As	<6.4	[6.9]
Ba	[1.5]	[1.0]
Cd	[0.58]	[0.69]
Cr	338	337
Cs (total)	0.0204	0.187
Na	[68]	[160]
Ni	26.1	[9.7]
Pb	[9.5]	[8.6]
Se	[8.8]	[9.5]
Th	<75	< 74
U	193	101
Radionuclides	**µCi/g dry H-form resin**	**µCi/g dry H-form resin**
^{60}Co	0.0787	0.0196
$^{126}Sn/Sb$	0.000358	<0.0008
^{99}Tc	0.321	0.330
^{106}Ru	<0.001	<0.001
^{134}Cs	<0.0001	<0.00008
^{137}Cs	0.352	3.68
^{154}Eu	<0.0002	<0.0001
^{155}Eu	<0.0004	<0.003
Sum of beta	0.753	4.02
Total beta	0.660	3.70
Transuranics	**nCi/g dry H-form resin**	**nCi/g dry H-form resin**
^{238}Pu	0.361	0.169
$^{239+240}Pu$	1.72	0.621
^{241}Am	0.272	0.241
^{242}Cm	<0.01	<0.01
$^{243+244}Cm$	<0.02	<0.02
Sum of alpha	2.35	1.04
Total alpha	1.86	0.632

Notes:

1. Reported values greater than detection limits for spent resin reported in 24590-101-TSA-W000-0004-114-00020, Rev 00B, *Spherical Resorcinol-Formaldehyde Analysis Following Actual Hanford Tank Waste Processing* (Table S.1 and Table 3.3). Analyses are based on acid digestion of resin samples and are not applicable for comparison to toxicity characteristics leach procedure criteria. Does not list opportunistic analytes reported for information only.
2. Bracketed results are greater than the method detection limit but less than the estimated quantification limit and errors are likely to exceed 15 %.
3. Values reported for ^{99}Tc are 18.9 µg/g and 19.4 µg/g for Resin A and Resin B, respectively. These were converted to a curie basis by the conversion factor for ^{99}Tc of 0.017 Ci/g to simplify results presentation.

Table 2.5-13 Summary of Data used to Estimate Spherical Resorcinol-Formaldehyde Disassociation Constants

Equilibrated Resin and Solution			Average Consumed Na, mmoles[1]	mmol Na Consumed per mL Na-form Resin[2]	mmol Na Consumed per g Dry H-form Resin[3]	Fraction of Total Sites that Adsorbed Na Ion[4]	Predicted Fraction of Sites that Adsorb Na Ion as R^{-2}, F_{Na2R}[5]	Predicted Fraction of Sites that Adsorb Na Ion as RH^{-}, F_{NaHR}[5]	Predicted Fraction of Total Sites that Adsorb Na Ion, F_{sa}[5]
Resin Volume, mL[1]	Na, M[1]	OH^{-}, M[1]							
14.4	0.0572	0.0490	17.5	1.22	4.08	0.600	0.235	0.759	0.614
15.0	0.0893	0.0852	20.1	1.34	4.50	0.661	0.349	0.648	0.673
15.1	0.123	0.109	22.4	1.48	4.98	0.732	0.407	0.591	0.702
15.4	0.195	0.179	23.8	1.55	5.19	0.763	0.530	0.469	0.764
15.7	0.236	0.231	25.1	1.60	5.36	0.789	0.593	0.407	0.796
15.2	0.138	0.125	21.6	1.42	4.77	0.701	0.440	0.558	0.719
Test Data				Calculated from Test Data			Calculated from Prediction		

Notes:

1. Data from tests using material from resin lot 5J-370/686 reported in Table 14.2 of 24590-101-TSA-W000-0004-99-00013, Rev 00B, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant.*
2. Calculated from (Average Consumed Na)/(Resin Volume)
3. Calculated assuming a bulk resin density of 0.298 g dry H-form resin/mL Na-form resin from Table 16.2 of 24590-101-TSA-W000-0004-99-00013, Rev 00B, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant.*
4. Calculated assuming a total resin capacity of 6.8 meq/g dry H-form resin indicated to be reported by Hubler and others (1995) in Section 3.8.5 of SCT-M0SRLE60-00-110-00029, Rev 00A, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin.*
5. Calculated using Equation 2.5-29, Equation 2.5-30, Equation 2.5-31, and Equation 2.5-32.

Table 2.5-14 Batch Equilibrium Data for Resin Lot 5E-370/641 at 15 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Predicted / Measured	Test Solution Description[1]
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$				
4.95	0.69	1.875	5.12E-06	4.01E-03	3.55E-03	88.5 %	Full Recipe
4.95	0.69	1.875	5.33E-06	3.98E-03	3.67E-03	92.2 %	Full Recipe
4.95	0.69	1.875	5.45E-06	3.98E-03	3.74E-03	94.0 %	Full Recipe
4.95	0.69	1.875	5.52E-06	3.97E-03	3.79E-03	95.4 %	Full Recipe
4.95	0.69	1.875	5.63E-06	3.97E-03	3.86E-03	97.1 %	Full Recipe
4.95	0.69	1.875	4.79E-05	2.61E-02	2.35E-02	90.1 %	Full Recipe
4.95	0.69	1.875	4.93E-05	2.61E-02	2.41E-02	92.3 %	Full Recipe
4.95	0.69	1.875	3.73E-04	1.21E-01	1.12E-01	91.9 %	Full Recipe
4.95	0.69	1.875	3.81E-04	1.20E-01	1.13E-01	94.4 %	Full Recipe
4.95	0.69	1.875	3.89E-03	5.66E-01	5.33E-01	94.2 %	Full Recipe
4.95	0.69	1.875	3.96E-03	5.57E-01	5.40E-01	96.9 %	Full Recipe

Notes:

1. Test solutions are described as follows:
   Nominal: AP-101 simulant without the toxic metals and aluminum
   Full Recipe: AP-101 simulant including the toxic metals and aluminum
   No Rubidium: Nominal simulant with rubidium has been omitted
   Modified: Nominal simulant where Na^+, K^+, or OH^- concentration was altered for isotherm development
   Simple: Solution of NaOH, NaCl, and trace Cs to support investigating hydroxide ion variation
2. Source: Data as reported in Table A.1 of 24590-WTP-RPT-RT-06-001, *Basis for Recommendation of Spherical Resorcinol Formaldehyde Resin as the Approved Equivalent to SuperLig 644*. Original source of these test data is SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin* (Tables 6 through 10).
3. Calculated using Equation 2.5-33 for Prediction Method 1.
4. All data obtained using material from resin lot 5E-370/641.

Table 2.5-15 Batch Equilibrium Data for Resin Lot 5E-370/641 at 25 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Predicted / Measured	Test Solution Description[1]
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$				
5.95	0.69	1.871	8.43E-06	3.64E-03	3.76E-03	103.3 %	Modified
5.95	0.69	1.87	8.78E-06	3.63E-03	3.90E-03	107.3 %	Modified
5.95	0.69	1.871	4.66E-03	4.86E-01	4.89E-01	100.6 %	Modified
5.95	0.69	1.871	4.84E-03	4.70E-01	5.01E-01	106.5 %	Modified
4.96	0.69	0.138	7.40E-06	3.85E-03	3.09E-03	80.2 %	Modified
4.96	0.69	0.136	8.40E-06	3.62E-03	3.45E-03	95.3 %	Modified
4.96	0.69	0.735	4.81E-03	4.50E-01	4.93E-01	109.6 %	Modified
4.96	0.69	0.136	4.92E-03	4.45E-01	4.03E-01	90.5 %	Modified
4.96	0.69	0.136	5.06E-03	4.32E-01	4.10E-01	95.0 %	Modified
4.95	0.69	1.872	7.29E-06	3.60E-03	3.69E-03	102.5 %	Full Recipe
4.95	0.69	1.872	7.29E-06	3.59E-03	3.69E-03	102.8 %	Full Recipe
4.95	0.69	1.871	7.40E-06	3.55E-03	3.74E-03	105.5 %	Nominal
4.95	0.69	1.871	7.53E-06	3.79E-03	3.80E-03	100.3 %	No Rubidium
4.95	0.69	1.872	7.54E-06	3.82E-03	3.80E-03	99.6 %	No Rubidium
4.95	0.69	1.871	7.61E-06	3.76E-03	3.84E-03	102.3 %	No Rubidium
4.95	0.69	1.872	7.68E-06	3.54E-03	3.87E-03	109.3 %	Nominal
4.95	0.69	1.872	7.73E-06	3.55E-03	3.89E-03	109.7 %	Nominal
4.95	0.69	1.872	7.75E-06	3.54E-03	3.90E-03	110.1 %	Nominal
4.95	0.69	0.734	7.95E-06	3.84E-03	3.88E-03	101.0 %	Modified
4.95	0.69	0.734	8.32E-06	3.81E-03	4.04E-03	105.9 %	Modified
4.95	0.69	1.871	5.00E-05	1.99E-02	1.97E-02	98.8 %	No Rubidium
4.95	0.69	1.871	5.13E-05	1.98E-02	2.01E-02	101.3 %	No Rubidium
4.95	0.69	1.872	5.19E-05	1.97E-02	2.02E-02	102.8 %	Nominal
4.95	0.69	1.871	5.23E-05	1.94E-02	2.04E-02	104.9 %	Nominal
4.95	0.69	1.871	5.25E-05	1.95E-02	2.04E-02	104.8 %	Nominal
4.95	0.69	1.871	5.91E-05	2.36E-02	2.25E-02	95.4 %	Full Recipe
4.95	0.69	1.872	5.97E-05	2.37E-02	2.27E-02	95.8 %	Full Recipe
4.95	0.69	1.871	3.89E-04	1.16E-01	9.84E-02	84.8 %	Nominal
4.95	0.69	1.872	4.18E-04	1.14E-01	1.04E-01	91.1 %	Nominal
4.95	0.69	1.872	4.18E-04	1.07E-01	1.04E-01	96.9 %	No Rubidium

Table 2.5-15 Batch Equilibrium Data for Resin Lot 5E-370/641 at 25 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Predicted / Measured	Test Solution Description[1]
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$				
4.95	0.69	1.871	4.29E-04	1.08E-01	1.06E-01	97.5 %	Full Recipe
4.95	0.69	1.871	4.34E-04	1.12E-01	1.07E-01	95.1 %	Nominal
4.95	0.69	1.872	4.44E-04	1.08E-01	1.09E-01	100.1 %	Full Recipe
4.95	0.69	1.871	4.45E-04	1.07E-01	1.09E-01	101.3 %	Full Recipe
4.95	0.69	1.872	4.48E-04	1.04E-01	1.09E-01	105.4 %	No Rubidium
4.95	0.69	1.872	4.04E-03	5.22E-01	5.01E-01	96.0 %	Nominal
4.95	0.69	1.871	4.12E-03	5.12E-01	5.07E-01	98.9 %	Full Recipe
4.95	0.69	1.871	4.19E-03	5.05E-01	5.13E-01	101.5 %	Full Recipe
4.95	0.69	1.872	4.23E-03	5.12E-01	5.16E-01	100.7 %	No Rubidium
4.95	0.69	1.872	4.24E-03	5.10E-01	5.16E-01	101.2 %	No Rubidium
4.95	0.69	1.872	4.25E-03	5.02E-01	5.18E-01	103.0 %	Nominal
4.95	0.69	1.871	4.30E-03	4.95E-01	5.21E-01	105.3 %	Nominal
4.95	0.69	0.734	4.67E-03	4.54E-01	4.84E-01	106.6 %	Modified
3.95	0.69	1.871	6.68E-06	3.84E-03	3.48E-03	90.7 %	Modified
3.95	0.69	1.871	7.00E-06	3.80E-03	3.63E-03	95.6 %	Modified
3.95	0.69	1.871	3.94E-03	5.38E-01	5.02E-01	93.4 %	Modified
3.95	0.69	1.871	3.98E-03	5.34E-01	5.05E-01	94.6 %	Modified
5.93	0	1.87	7.62E-07	4.45E-03	4.08E-03	91.6 %	Modified
5.93	0	1.871	8.19E-07	4.47E-03	4.31E-03	96.5 %	Modified
5.93	0	1.871	2.99E-03	6.10E-01	5.03E-01	82.4 %	Modified
5.93	0	1.871	3.14E-03	5.97E-01	5.13E-01	85.9 %	Modified
4.94	0	0.038	6.00E-09	8.04E-05	7.72E-05	96.0 %	Simple
4.94	0	0.039	6.05E-09	8.08E-05	7.78E-05	96.3 %	Simple
4.94	0	0.038	8.45E-07	4.39E-03	4.59E-03	104.5 %	Simple
4.94	0	0.039	8.90E-07	4.40E-03	4.77E-03	108.3 %	Simple
4.94	0	0.039	4.44E-03	6.20E-01	4.95E-01	79.8 %	Simple
4.94	0	0.039	4.69E-03	5.95E-01	5.05E-01	84.9 %	Simple
4.93	0	1.933	4.29E-09	7.92E-05	6.41E-05	80.8 %	Simple
4.93	0	0.925	5.10E-09	7.87E-05	8.27E-05	105.1 %	Simple
4.93	0	0.926	5.20E-09	7.92E-05	8.42E-05	106.4 %	Simple

Table 2.5-15 Batch Equilibrium Data for Resin Lot 5E-370/641 at 25 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Predicted / Measured	Test Solution Description[1]
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$				
4.93	0	1.871	5.16E-07	4.50E-03	4.12E-03	91.4 %	Modified
4.93	0	1.87	5.40E-07	4.49E-03	4.26E-03	94.9 %	Modified
4.93	0	0.925	7.10E-07	4.46E-03	5.34E-03	119.7 %	Simple
4.93	0	0.925	7.11E-07	4.46E-03	5.34E-03	119.8 %	Simple
4.93	0	0.925	7.21E-07	4.45E-03	5.40E-03	121.5 %	Simple
4.93	0	1.871	2.42E-03	6.84E-01	6.25E-01	91.4 %	Modified
4.93	0	1.871	2.49E-03	6.75E-01	6.32E-01	93.6 %	Modified
4.93	0	0.925	3.87E-03	6.89E-01	6.89E-01	100.0 %	Simple
4.93	0	0.925	4.20E-03	6.54E-01	7.11E-01	108.7 %	Simple
4.92	0	1.922	4.57E-09	7.89E-05	6.83E-05	86.6 %	Simple
4.92	0	1.922	5.10E-09	7.88E-05	7.61E-05	96.5 %	Simple
4.92	0	1.922	5.63E-07	4.77E-03	4.40E-03	92.4 %	Simple
4.92	0	1.922	5.65E-07	4.77E-03	4.41E-03	92.5 %	Simple
4.92	0	1.922	6.04E-07	4.76E-03	4.65E-03	97.6 %	Simple
4.92	0	1.923	3.34E-03	7.26E-01	7.18E-01	98.8 %	Simple
4.92	0	1.923	3.82E-03	6.78E-01	7.58E-01	111.9 %	Simple
3.93	0	1.869	3.54E-07	4.47E-03	4.17E-03	93.2 %	Modified
3.93	0	1.869	3.65E-07	4.47E-03	4.27E-03	95.6 %	Modified
3.93	0	1.871	1.87E-03	7.35E-01	7.60E-01	103.3 %	Modified
3.93	0	1.871	2.06E-03	7.19E-01	7.92E-01	110.2 %	Modified

Notes:

1. Test solutions are described as follows:

   Nominal: AP-101 simulant without the toxic metals and aluminum

   Full Recipe: AP-101 simulant including the toxic metals and aluminum

   No Rubidium: Nominal simulant with rubidium has been omitted

   Modified: Nominal simulant where Na^+, K^+, or OH^- concentration was altered for isotherm development

   Simple: Solution of NaOH, NaCl, and trace Cs to support investigating hydroxide ion variation

2. Source: Data as reported in Table A.1 of 24590-WTP-RPT-RT-06-001, *Basis for Recommendation of Spherical Resorcinol Formaldehyde Resin as the Approved Equivalent to SuperLig 644*. Original source of these test data is SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin* (Tables 6 through 10).
3. Calculated using Equation 2.5-33 for Prediction Method 1.
4. All data obtained using material from resin lot 5E-370/641.

Table 2.5-16 Resin Equilibrium Data from Column Tests for Large Scale Resin Lots at 25 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Resin Lot
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$		
4.89	0.679	1.81	4.40E-05	1.93E-02	5E-370/639
4.89	0.679	1.81	4.40E-05	1.88E-02	5E-370/641
4.89	0.679	1.81	4.40E-05	1.76E-02	5E-370/641
4.89	0.679	1.81	4.40E-05	1.74E-02	5E-370/641
4.89	0.679	1.81	4.40E-05	1.81E-02	5J-370/686
4.89	0.679	1.81	4.40E-05	1.75E-02	3380-3-0200
4.89	0.679	1.81	4.40E-05	1.82E-02	6C-370/745
4.89	0.679	1.81	4.40E-05	1.59E-02	3380-3-201
5.18	0.145	0.454	3.92E-04	2.13E-01	3380-3-201

Source: 24590-101-TSA-W000-0004-99-00013, Rev 00B, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Table 16.2).

Table 2.5-17 Batch Equilibrium Data for Resin Lot 5E-370/641 at 45 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Predicted / Measured	Test Solution Description[1]
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$				
5.96	0.69	1.875	1.36E-05	3.23E-03	3.60E-03	111.7 %	Modified
5.95	0.69	1.872	1.19E-05	3.56E-03	3.19E-03	89.7 %	Modified
5.95	0.69	1.872	5.17E-03	4.47E-01	4.52E-01	101.3 %	Modified
5.95	0.69	1.871	5.22E-03	4.37E-01	4.56E-01	104.2 %	Modified
4.96	0.69	0.137	1.06E-05	3.50E-03	2.90E-03	82.9 %	Modified
4.96	0.69	0.736	1.13E-05	3.61E-03	3.50E-03	96.8 %	Modified
4.96	0.69	0.736	1.16E-05	3.59E-03	3.59E-03	100.0 %	Modified
4.96	0.69	0.137	1.17E-05	3.39E-03	3.17E-03	93.3 %	Modified
4.96	0.69	0.736	4.74E-03	4.59E-01	4.49E-01	97.9 %	Modified
4.96	0.69	0.736	5.11E-03	4.25E-01	4.72E-01	111.1 %	Modified
4.96	0.69	0.137	5.22E-03	4.27E-01	3.99E-01	93.4 %	Modified
4.96	0.69	0.137	5.39E-03	4.11E-01	4.08E-01	99.3 %	Modified
4.95	0.69	1.871	1.10E-05	3.19E-03	3.34E-03	104.5 %	Full Recipe
4.95	0.69	1.87	1.11E-05	3.18E-03	3.36E-03	105.5 %	Full Recipe
4.95	0.69	1.871	1.16E-05	3.13E-03	3.49E-03	111.6 %	Nominal
4.95	0.69	1.87	1.16E-05	3.35E-03	3.51E-03	104.7 %	No Rubidium
4.95	0.69	1.87	1.18E-05	3.32E-03	3.55E-03	106.9 %	No Rubidium
4.95	0.69	1.871	1.20E-05	3.08E-03	3.62E-03	117.6 %	Nominal
4.95	0.69	1.87	7.29E-05	1.76E-02	1.84E-02	104.4 %	No Rubidium
4.95	0.69	1.871	7.29E-05	1.76E-02	1.84E-02	104.9 %	No Rubidium
4.95	0.69	1.87	7.40E-05	1.71E-02	1.87E-02	109.0 %	Nominal
4.95	0.69	1.87	7.66E-05	1.70E-02	1.92E-02	113.2 %	Nominal
4.95	0.69	1.87	8.27E-05	2.11E-02	2.05E-02	97.1 %	Full Recipe
4.95	0.69	1.87	8.56E-05	2.09E-02	2.12E-02	101.1 %	Full Recipe
4.95	0.69	1.87	5.52E-04	9.22E-02	9.78E-02	106.2 %	No Rubidium
4.95	0.69	1.871	5.59E-04	9.55E-02	9.88E-02	103.4 %	Full Recipe
4.95	0.69	1.87	5.60E-04	9.15E-02	9.88E-02	108.0 %	No Rubidium
4.95	0.69	1.87	5.62E-04	9.48E-02	9.92E-02	104.6 %	Full Recipe
4.95	0.69	1.87	5.63E-04	9.83E-02	9.93E-02	101.0 %	Nominal
4.95	0.69	1.871	5.64E-04	9.89E-02	9.94E-02	100.8 %	Nominal

Table 2.5-17 Batch Equilibrium Data for Resin Lot 5E-370/641 at 45 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Predicted / Measured	Test Solution Description[1]
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$				
4.95	0.69	1.87	4.68E-03	4.53E-01	4.74E-01	104.6 %	Full Recipe
4.95	0.69	1.87	4.74E-03	4.53E-01	4.78E-01	105.5 %	No Rubidium
4.95	0.69	1.87	4.77E-03	4.44E-01	4.80E-01	108.2 %	Full Recipe
4.95	0.69	1.871	4.84E-03	4.49E-01	4.85E-01	108.1 %	No Rubidium
4.95	0.69	1.87	4.85E-03	4.38E-01	4.86E-01	110.8 %	Nominal
4.95	0.69	1.87	4.86E-03	4.36E-01	4.87E-01	111.5 %	Nominal
3.95	0.69	1.872	9.97E-06	3.59E-03	3.08E-03	86.0 %	Modified
3.95	0.69	1.872	1.02E-05	3.56E-03	3.17E-03	88.9 %	Modified
3.95	0.69	1.872	4.43E-03	5.03E-01	4.65E-01	92.5 %	Modified
3.95	0.69	1.872	4.50E-03	4.94E-01	4.70E-01	95.1 %	Modified
5.93	0	1.872	1.68E-06	4.47E-03	4.47E-03	100.0 %	Modified
5.93	0	1.872	1.80E-06	4.47E-03	4.70E-03	105.1 %	Modified
5.93	0	1.872	3.64E-03	5.61E-01	5.03E-01	89.8 %	Modified
5.93	0	1.872	3.72E-03	5.52E-01	5.08E-01	92.0 %	Modified
4.94	0	0.039	1.57E-06	4.40E-03	4.81E-03	109.5 %	Simple
4.94	0	0.039	1.84E-06	4.34E-03	5.42E-03	124.7 %	Simple
4.94	0	0.039	5.21E-03	5.49E-01	5.49E-01	100.0 %	Simple
4.94	0	0.039	5.21E-03	5.51E-01	5.49E-01	99.6 %	Simple
4.93	0	1.923	1.12E-06	4.77E-03	4.42E-03	92.6 %	Simple
4.93	0	1.923	1.17E-06	4.77E-03	4.54E-03	95.2 %	Simple
4.93	0	1.872	1.20E-06	4.53E-03	4.66E-03	102.8 %	Modified
4.93	0	1.872	1.25E-06	4.51E-03	4.81E-03	106.6 %	Modified
4.93	0	0.927	1.32E-06	4.47E-03	5.35E-03	119.7 %	Simple
4.93	0	0.926	1.45E-06	4.44E-03	5.75E-03	129.5 %	Simple
4.93	0	1.872	3.04E-03	6.39E-01	6.28E-01	98.4 %	Modified
4.93	0	1.872	3.10E-03	6.33E-01	6.34E-01	100.1 %	Modified
4.93	0	1.924	3.74E-03	6.93E-01	6.94E-01	100.2 %	Simple
4.93	0	1.924	3.80E-03	6.89E-01	6.99E-01	101.5 %	Simple
4.93	0	0.926	4.27E-03	6.56E-01	7.04E-01	107.3 %	Simple
4.93	0	0.926	4.48E-03	6.34E-01	7.19E-01	113.4 %	Simple

Table 2.5-17 Batch Equilibrium Data for Resin Lot 5E-370/641 at 45 °C

Liquid Phase Equilibrium Composition, gmol/L				Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Predicted / Measured	Test Solution Description[1]
$[Na^+]$	$[K^+]$	$[OH^-]$	$[Cs^+]$				
3.93	0	1.872	7.43E-07	4.67E-03	4.31E-03	92.2 %	Modified
3.93	0	1.872	7.50E-07	4.64E-03	4.34E-03	93.6 %	Modified
3.93	0	1.872	2.36E-03	7.05E-01	7.57E-01	107.5 %	Modified
3.93	0	1.872	2.53E-03	6.89E-01	7.83E-01	113.6 %	Modified

Notes:

1. Test solutions are described as follows:

   Nominal: AP-101 simulant without the toxic metals and aluminum

   Full Recipe: AP-101 simulant including the toxic metals and aluminum

   No Rubidium: Nominal simulant with rubidium has been omitted

   Modified: Nominal simulant where Na^+, K^+, or OH^- concentration was altered for isotherm development

   Simple: Solution of NaOH, NaCl, and trace Cs to support investigating hydroxide ion variation

2. Source: Data as reported in Table A.1 of 24590-WTP-RPT-RT-06-001, *Basis for Recommendation of Spherical Resorcinol Formaldehyde Resin as the Approved Equivalent to SuperLig 644.* Original source of these test data is SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin* (Tables 6 through 10).
3. Calculated using Equation 2.5-33 for Prediction Method 1.
4. All data obtained using material from resin lot 5E-370/641.

Table 2.5-18 Basis for Constants in Cs Batch Equilibrium Prediction Method 2 from Resin Lot 5E-370/641 Data

Test Data[1]							
[Na+], M	[K+], M	[OH-], M	[Cs+], M	Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	F_{sa}[2]	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Δ^2 [4]
5.95	0.69	1.871	8.43E-06	3.64E-03	0.9609	4.10E-03	1.57E-02
5.95	0.69	1.87	8.78E-06	3.63E-03	0.9609	4.24E-03	2.84E-02
5.95	0.69	1.871	4.66E-03	4.86E-01	0.9609	4.52E-01	4.98E-03
5.95	0.69	1.871	4.84E-03	4.70E-01	0.9609	4.59E-01	5.69E-04
4.96	0.69	0.138	7.40E-06	3.85E-03	0.7316	2.90E-03	6.13E-02
4.96	0.69	0.136	8.40E-06	3.62E-03	0.7298	3.22E-03	1.20E-02
4.96	0.69	0.735	4.81E-03	4.50E-01	0.9112	4.42E-01	3.47E-04
4.96	0.69	0.136	4.92E-03	4.45E-01	0.7298	3.57E-01	3.92E-02
4.96	0.69	0.136	5.06E-03	4.32E-01	0.7298	3.61E-01	2.71E-02
4.95	0.69	1.872	7.29E-06	3.60E-03	0.9610	3.76E-03	1.92E-03
4.95	0.69	1.872	7.29E-06	3.59E-03	0.9610	3.76E-03	2.18E-03
4.95	0.69	1.871	7.40E-06	3.55E-03	0.9609	3.81E-03	5.21E-03
4.95	0.69	1.871	7.53E-06	3.79E-03	0.9609	3.86E-03	3.80E-04
4.95	0.69	1.872	7.54E-06	3.82E-03	0.9610	3.87E-03	1.60E-04
4.95	0.69	1.871	7.61E-06	3.76E-03	0.9609	3.90E-03	1.37E-03
4.95	0.69	1.872	7.68E-06	3.54E-03	0.9610	3.93E-03	1.21E-02
4.95	0.69	1.872	7.73E-06	3.55E-03	0.9610	3.95E-03	1.28E-02
4.95	0.69	1.872	7.75E-06	3.54E-03	0.9610	3.96E-03	1.41E-02
4.95	0.69	0.734	7.95E-06	3.84E-03	0.9111	3.84E-03	8.02E-08
4.95	0.69	0.734	8.32E-06	3.81E-03	0.9111	3.99E-03	2.29E-03
4.95	0.69	1.871	5.00E-05	1.99E-02	0.9609	1.95E-02	4.06E-04
4.95	0.69	1.871	5.13E-05	1.98E-02	0.9609	1.99E-02	4.06E-05
4.95	0.69	1.872	5.19E-05	1.97E-02	0.9610	2.01E-02	4.61E-04
4.95	0.69	1.871	5.23E-05	1.94E-02	0.9609	2.03E-02	1.93E-03
4.95	0.69	1.871	5.25E-05	1.95E-02	0.9609	2.03E-02	1.76E-03
4.95	0.69	1.871	5.91E-05	2.36E-02	0.9609	2.24E-02	2.38E-03
4.95	0.69	1.872	5.97E-05	2.37E-02	0.9610	2.26E-02	1.99E-03
4.95	0.69	1.871	3.89E-04	1.16E-01	0.9609	1.03E-01	1.27E-02
4.95	0.69	1.872	4.18E-04	1.14E-01	0.9610	1.09E-01	2.21E-03
4.95	0.69	1.872	4.18E-04	1.07E-01	0.9610	1.09E-01	2.35E-04
4.95	0.69	1.871	4.29E-04	1.08E-01	0.9609	1.11E-01	6.59E-04
4.95	0.69	1.871	4.34E-04	1.12E-01	0.9609	1.12E-01	5.53E-06
4.95	0.69	1.872	4.44E-04	1.08E-01	0.9610	1.14E-01	2.74E-03
4.95	0.69	1.871	4.45E-04	1.07E-01	0.9609	1.14E-01	4.09E-03

Table 2.5-18 Basis for Constants in Cs Batch Equilibrium Prediction Method 2 from Resin Lot 5E-370/641 Data

Test Data[1]							
[Na+], M	[K+], M	[OH-], M	[Cs+], M	Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin	F_{sa}[2]	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Δ^2 [4]
4.95	0.69	1.872	4.48E-04	1.04E-01	0.9610	1.14E-01	1.00E-02
4.95	0.69	1.872	4.04E-03	5.22E-01	0.9610	4.33E-01	2.89E-02
4.95	0.69	1.871	4.12E-03	5.12E-01	0.9609	4.37E-01	2.15E-02
4.95	0.69	1.871	4.19E-03	5.05E-01	0.9609	4.40E-01	1.65E-02
4.95	0.69	1.872	4.23E-03	5.12E-01	0.9610	4.42E-01	1.88E-02
4.95	0.69	1.872	4.24E-03	5.10E-01	0.9610	4.42E-01	1.76E-02
4.95	0.69	1.872	4.25E-03	5.02E-01	0.9610	4.43E-01	1.40E-02
4.95	0.69	1.871	4.30E-03	4.95E-01	0.9609	4.45E-01	1.03E-02
4.95	0.69	0.734	4.67E-03	4.54E-01	0.9111	4.36E-01	1.50E-03
3.95	0.69	1.871	6.68E-06	3.84E-03	0.9609	3.58E-03	4.50E-03
3.95	0.69	1.871	7.00E-06	3.80E-03	0.9609	3.73E-03	3.41E-04
3.95	0.69	1.871	3.94E-03	5.38E-01	0.9609	4.34E-01	3.71E-02
3.95	0.69	1.871	3.98E-03	5.34E-01	0.9609	4.36E-01	3.35E-02
5.93	0	1.87	7.62E-07	4.45E-03	0.9609	4.14E-03	4.82E-03
5.93	0	1.871	8.19E-07	4.47E-03	0.9609	4.41E-03	2.03E-04
5.93	0	1.871	2.99E-03	6.10E-01	0.9609	7.20E-01	3.23E-02
5.93	0	1.871	3.14E-03	5.97E-01	0.9609	7.24E-01	4.56E-02
4.94	0	0.038	6.00E-09	8.04E-05	0.5917	5.58E-05	9.40E-02
4.94	0	0.039	6.05E-09	8.08E-05	0.5939	5.64E-05	9.15E-02
4.94	0	0.038	8.45E-07	4.39E-03	0.5917	4.01E-03	7.50E-03
4.94	0	0.039	8.90E-07	4.40E-03	0.5939	4.21E-03	1.91E-03
4.94	0	0.039	4.44E-03	6.20E-01	0.5939	4.82E-01	4.99E-02
4.94	0	0.039	4.69E-03	5.95E-01	0.5939	4.84E-01	3.50E-02
4.93	0	1.933	4.29E-09	7.92E-05	0.9621	6.80E-05	1.98E-02
4.93	0	0.925	5.10E-09	7.87E-05	0.9268	7.61E-05	1.05E-03
4.93	0	0.926	5.20E-09	7.92E-05	0.9269	7.74E-05	4.93E-04
4.93	0	1.871	5.16E-07	4.50E-03	0.9609	4.28E-03	2.44E-03
4.93	0	1.87	5.40E-07	4.49E-03	0.9609	4.45E-03	8.56E-05
4.93	0	0.925	7.10E-07	4.46E-03	0.9268	5.43E-03	4.72E-02
4.93	0	0.925	7.11E-07	4.46E-03	0.9268	5.44E-03	4.78E-02
4.93	0	0.925	7.21E-07	4.45E-03	0.9268	5.50E-03	5.58E-02
4.93	0	1.871	2.42E-03	6.84E-01	0.9609	7.33E-01	5.13E-03
4.93	0	1.871	2.49E-03	6.75E-01	0.9609	7.35E-01	8.03E-03
4.93	0	0.925	3.87E-03	6.89E-01	0.9268	7.43E-01	6.05E-03

Table 2.5-18 Basis for Constants in Cs Batch Equilibrium Prediction Method 2 from Resin Lot 5E-370/641 Data

Test Data[1]					F_{sa}[2]	Predicted Resin Cs Loading, mmol Cs/g Dry H-form Resin[3]	Δ^2 [4]
[Na+], M	[K+], M	[OH^-], M	[Cs+], M	Measured Resin Cs Loading, mmol Cs/g Dry H-form Resin			
4.93	0	0.925	4.20E-03	6.54E-01	0.9268	7.48E-01	2.07E-02
4.92	0	1.922	4.57E-09	7.89E-05	0.9619	7.21E-05	7.36E-03
4.92	0	1.922	5.10E-09	7.88E-05	0.9619	7.93E-05	4.39E-05
4.92	0	1.922	5.63E-07	4.77E-03	0.9619	4.63E-03	8.27E-04
4.92	0	1.922	5.65E-07	4.77E-03	0.9619	4.65E-03	6.65E-04
4.92	0	1.922	6.04E-07	4.76E-03	0.9619	4.92E-03	1.15E-03
4.92	0	1.923	3.34E-03	7.26E-01	0.9619	7.60E-01	2.23E-03
4.92	0	1.923	3.82E-03	6.78E-01	0.9619	7.70E-01	1.84E-02
3.93	0	1.869	3.54E-07	4.47E-03	0.9609	4.45E-03	2.37E-05
3.93	0	1.869	3.65E-07	4.47E-03	0.9609	4.57E-03	4.70E-04
3.93	0	1.871	1.87E-03	7.35E-01	0.9609	7.40E-01	4.22E-05
3.93	0	1.871	2.06E-03	7.19E-01	0.9609	7.47E-01	1.55E-03
4.89	0.679	1.81	4.40E-05	1.93E-02	0.9597	1.77E-02	7.02E-03
4.89	0.679	1.81	4.40E-05	1.88E-02	0.9597	1.77E-02	3.38E-03
4.89	0.679	1.81	4.40E-05	1.76E-02	0.9597	1.77E-02	3.90E-05
4.89	0.679	1.81	4.40E-05	1.74E-02	0.9597	1.77E-02	3.73E-04
4.89	0.679	1.81	4.40E-05	1.81E-02	0.9597	1.77E-02	5.28E-04
4.89	0.679	1.81	4.40E-05	1.75E-02	0.9597	1.77E-02	1.12E-04
4.89	0.679	1.81	4.40E-05	1.82E-02	0.9597	1.77E-02	7.30E-04
4.89	0.679	1.81	4.40E-05	1.59E-02	0.9597	1.77E-02	1.34E-02
5.18	0.145	0.454	3.92E-04	2.13E-01	0.8704	2.13E-01	1.73E-06[5]
						Sum(Δ^2) =	1.12E+00

Notes:

1. Test data from Table 2.5-15 and Table 2.5-16
2. F_{sa} = fraction of total IX sites available to capture cations from Equation 2.5-31
3. Calculated using Equation 2.5-35 with $Q_{Cs\,tot} = 1$, ma1 = 0.866, mb1 = 0.840, $K_{12} = 1.12\times10^{-2}$, m2 = 0.809, $K_{13} = 4.84\times10^{-5}$, and m2 = 1.769.
4. Δ = (Measured Loading – Predicted Loading)/Measured Loading)
5. Weighting for this point was increased by a factor of 50 since it represents the only intermediate value between $[K^+] = 0$ and 0.69 M.

Table 2.5-19 Variation of Resin Pretreatment Condition Evaluated during Laboratory Testing

Protocol P1-RF			Modification 1			Modification 2		
Reagent	Volume, mL (BV)[a]	Agitation/ Soak Time, min	Reagent	Volume, mL (BV)[a]	Agitation/ Soak Time, min	Reagent	Volume, mL (BV)[a]	Agitation/ Soak Time, min
Resin	61.0 (0.67)[b]	na	Resin	13.6 (0.75)[b]	na	Resin	13.6 (0.75)[b]	na
Water rinse	305 (3.1)	30	Water rinse	25.8 (1.2)	60	Water rinse	25.5 (1.2)	60
1 M NaOH	305 (3.1)	30/947	Water	29.7 (1.4)	120 (mix)/	Water	32.7 (1.5)	120 (mix)/
Water rinse	187 (1.9)	30	+		869 (soak)/	+		869 (soak)/
Water rinse	184 (1.9)	30	2 M NaOH	19.4 (0.89)	10 (mix)	2 M NaOH	17.0 (0.77)	10 (mix)
Water rinse	188 (1.9)	30	Load in column			0.5 M HNO3	41.5 (1.9)	42
0.5 M HNO_3	600 (6.1)	30/110				0,5 M HNO3	22.7 (1.0)	69
Water rinse	183 (1.9)	30				Water	26.1 (1.2)	125 (mix)/
Water rinse	186 (1.9)	30				+		984 (soak)/
Water rinse	185 (1.9)	30				2 M NaOH	20.0 (0.91)	10 (mix)
Subsample for column processing	17.0	na				Load in column		
1 M NaOH[c]	85 (5.0)	86						
Water rinse[d]	161 (7.7)	160						
0.5 M HNO_3[d]	144 (6.9)	143						
Water rinse[d]	62 (2.9)	125						
0.5 M NaOH[d]	118 (5.6)	120						

Notes:

(a) The BV shown is relative to the Na-form resin volume instead of the as-received form volume.

(b) The as-received resin volume was measured in the H-form and is shown in mL. The relative measure in terms of BV was corrected for the expansion factor of 1.6 mL pretreated Na-form resin/mL as-received H-form resin.

(c) The expanded resin was loaded into the IX column in preparation for in-column pretreatment.

(d) One shrink-swell cycle was conducted in-column before actual waste loading.

na = not applicable.

Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Table 14.3).

Table 2.5-20 Summary of Column Loading Cycle Tests

Column Test ID	Resin Lot[2]	Column Diameter, cm	Bed Volume, L		Waste Identifier	Temperature, °C	Waste Feed Rate		Waste Feed Composition					Source[14]
			In 0.5M NaOH	In Waste			Actual, L/min	In waste basis, BV/hr	[Na], M	[K], M	[OH], M	[^{137}C], uCi/mL	[Cs], M	
RF1	5E-370/641	1.5	1.11E-02	1.10E-02	AP-101DF sim (C=1)	19 - 25	5.46E-04	2.94	4.89	0.679	1.89	NA[7]	4.37E-05	a
RF2	5E-370/641	1.5	1.13E-02	1.11E-02	AP-101DF (C=2)	26 - 27	5.36E-04	2.89	5.13	0.737	1.98	117	4.45E-05	a
RF3	5E-370/641	1.5	1.13E-02	1.15E-02	AN-102 (C=2, prior lag as lead)	26 - 27	5.47E-04	2.95	4.94	0.0266	1.07	143	5.92E-05	b
RF4	5E-370/639	2	1.76E-02	1.79E-02	AP-101 DF sim (C=1)	19	4.31E-04 to 8.47E-04	1.47 to 2.89	4.89	0.679	1.89	NA	4.40E-05	c
RF5	5E-370/639	2	1.76E-02	1.82E-02	AP-101 DF sim (C=2)	20 - 23	4.42E-04 to 8.88E-04	1.51 to 3.03	4.89	0.679	1.89	NA	4.40E-05	c
RF6	5E-370/641	2	1.79E-02	1.79E-02	AP-101 DF sim (C=1)	19	4.47E-04 to 9.10E-04	1.50 to 3.05	4.89	0.679	1.89	NA	4.40E-05	c
RF7	5E-370/641	2	1.82E-02	1.82E-02	AP-101 DF sim (C=2)	20 - 23	4.46E-04 to 9.00E-04	1.49 to 3.02	4.89	0.679	1.89	NA	4.40E-05	c
RF8	5E-370/641[3]	2	2.04E-02	2.04E-02	AP-101 DF sim (C=17)	21 - 22	4.97E-04 to 1.06E-03	1.46 to 3.13	4.89	0.679	1.89	NA	4.40E-05	c
RF9[4]	5E-370/641[3]	2	2.04E-02	2.04E-02	AP-101 DF sim (C=17)	21 - 22	4.97E-04 to 5.05E-04	1.46 to 1.48	4.89	0.679	1.89	NA	4.40E-05	c
RF10	5J-370/686	2	2.01E-02	2.01E-02	AP-101 DF sim (C=1)	21 - 22	4.97E-04 to 1.00E-03	1.48 to 2.99	4.89	0.679	1.89	NA	4.40E-05	c
RF11	3380-3-0200	2	2.01E-02	2.01E-02	AP-101 DF sim (C=1)	21 - 22	4.91E-04 to 1.00E-03	1.47 to 2.98	4.89	0.679	1.89	NA	4.40E-05	c
RF12	6C-370/745	2	2.10E-02	2.10E-02	AP-101 DF sim (C=1)	22 - 24	5.19E-04 to 1.01E-03	1.48 to 2.88	4.89	0.679	1.89	NA	4.40E-05	c
RF13	3380-3-0201	2	2.07E-02	2.10E-02	AP-101 DF sim (C=1)	22 - 24	5.03E-04 to 1.01E-03	1.46 to 2.94	4.89	0.679	1.89	NA	4.40E-05	c
RF14[5]	6C-370/745	2	2.04E-02	2.17E-02	AP-101 DF sim (C=1)	22 - 24	5.24E-04 to 1.02E-03	1.54 to 3.00	4.89	0.679	1.89	NA	4.40E-05	c
RF15[6]	6C-370/745	2	2.04E-02	2.17E-02	AP-101 DF sim (C=1)	22 - 24	5.24E-04 to 1.04E-03	1.54 to 3.05	4.89	0.679	1.89	NA	4.40E-05	c
RF16	3380-3-0201	2	1.98E-02	2.07E-02	AZ-102 sim (C=1)	19 - 24	4.95E-04	1.50	5.18	0.145	0.454	NA	3.92E-04	c
RF17	5E-370/641	1.574	1.05E-02	1.13E-02	AP-101DF sim (C=1)	45	2.50E-04	1.36	4.54	0.748	1.94	NA	4.51E-05	d
RF18	5E-370/641	1.574	1.05E-02	1.08E-02	AN-107 sim (C=1)	25	2.50E-04	1.37	5.65	0.0285	0.70	NA	6.94E-05	d
RF19	5E-370/641	27.9	nd[7]	2.24E+01	AP-101DF sim (C=2)	ambient	5.0E-01	1.4	5.00	0.727	1.28	NA	5.0E-05 ave. (3.7E-05 to 7.3E-05)	e
FR20	5E-370/641	59	1.97E+02	1.98E+02	AP-101DF sim (C=3)	ambient	4.9E+00	1.5	5.00	0.727	1.28	NA	5.0E-05	e
RF21	5E-370/641	59	1.97E+02	2.02E+02	AP-101DF sim (C=13)	ambient	4.9E+00	1.5	5.00	0.727	1.28	NA	5.0E-05	e
RF22	6C-370/745[8]	2	1.98E-02	1.92E-02	AP-101 DF sim (C=1)	19 - 24	4.94E-04 to 9,67E-04	1.5 to 2.93	4.89	0.679	1.89	NA	4.40E-05	f
RF23	6C-370/745[9]	2	1.98E-02	1.88E-02	AP-101 DF sim (C=1)	19 - 24	4.91E-04 to 9.87E-04	1.49 to 2.99	4.89	0.679	1.89	NA	4.40E-05	f
RF24	6C-370/745[10]	2	1.92E-02	1.88E-02	AP-101 DF sim (C=1)	19 - 24	4.87E-04 to 9.40E-04	1.53 to 2.94	4.89	0.679	1.89	NA	4.40E-05	f
RF25	5J-370/686[11]	2	1.98E-02	1.92E-02	AP-101 DF sim (C=1)	19 - 24	4.89E-04 to 9.98E-04	1.48 to 3.02	4.89	0.679	1.89	NA	4.40E-05	f
RF26	5J-370/686[12]	2	1.92E-02	1.92E-02	AP-101 DF sim (C=1)	19 - 24	4.75E-04 to 9.64E-04	1.49 to 3.02	4.89	0.679	1.89	NA	4.40E-05	f
RF27	5J-370/686[13]	2	1.88E-02	1.85E-02	AP-101 DF sim (C=1)	19 - 24	4.88E-04 to 9.40E-04	1.55 to 2.99	4.89	0.679	1.89	NA	4.40E-05	f

Notes:

(1) Indicates waste tank composition used as basis for IX feed. If followed by "sim", then waste simulant was used in test. Otherwise, actual waste used. Some tests were performed using a resin bed multiple times. The cycle number for a bed in each test (bed cycled through loading, elution, and regeneration) is indicated in the identifier (where C=1 is the first equivalent Cs loading cycle). Pretreatment cycling as part of loading in a column is not included in the cycle number. In some cases, resin was cycled in a larger scale column and a sub-sample transferred to a smaller scale column for Cs removal performance testing. When a lead-lag column configuration is used for testing, data from the lead column were included in this summary table.

(2) All resin pretreated by protocol P1-RF similar to that indicated in Table 2.5-19 prior to testing, except where noted.

(3) Material cycled 16 times in 24-in. pilot scale hydraulic testing and transferred to laboratory-scale column for Cs removal performance testing.

(4) Stop flow loading cycle test.

(5) Column test using resin pretreatment procedure described by Modification 1 in Table 2.5-19.

(6) Column test using resin pretreatment procedure described by Modification 2 in Table 2.5-19.

(7) nd = no data. NA = not applicable.

(8) Resin stored wet at ambient temperature for a 1 year period after sampling (sampled ~1 month after production)

(9) Resin stored wet at 35 °C for a 1 year period after sampling (sampled ~1 month after production)

(10) Resin stored wet at 45 °C for a 1 year period after sampling (sampled ~1 month after production)

(11) Resin stored wet at ambient temperature for a 1 year period after sampling (sampled ~8 months after production)

(12) Resin stored wet at 45 °C for a 1 year period after sampling (sampled ~8 months after production)

(13) Resin stored dry at 45 °C for a 1 year period after sampling (sampled ~8 months after production)

(14) Source:

a 24590-101-TSA-W000-0004-174-00001, *Spherical Resorcinol-Formaldehyde Resin Testing for ^{137}Cs Removal from Simulated and Actual Hanford Waste Tank 241-AP-101 Diluted Feed (Envelope A) Using Small Column Ion Exchange*

b 24590-101-TSA-W000-0004-72-00017, *Small Column Ion Exchange Testing of Spherical Resorcinol-Formaldehyde Resin for ^{137}Cs Removal from Pre-Treated Hanford Tank 241-AN-102 Waste (Envelope C)*

c 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant*

d SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin*

e SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin*

f 24590-QL-HC9-WA49-00001-03-00001, Rev 00A, *Storage and Aging Effects on Spherical Resorcinol-Formaldehyde Resin Ion Exchange Performance*

Table 2.5-21 Summary of Column Elution Tests

Column Test ID	Resin Bed Volume in Eluant, L	Resin Mass, g dry H-form resin	Eluate Flow Rate			Eluant Temperature, °C	Eluate $[HNO_3]$, M	Eluate Volume, L	Eluate Composite Sample				Cs Loading, mmol/g dry H-form resin	Total Ion Loading, mmol/g dry H-form resin	Apparent Eluate [K]/[Na] Mole Ratio
			Flow rate, L/min	BV/hr based on bed in 0.5 M NaOH	BV/hr based on bed in eluate				$[^{137}Cs]$, uCi/mL	[Cs], M	[Na], M	[K], M			
RF1	8.70E-03	2.87	2.78E-04	1.50	1.9	20 - 22	0.5	0.170	nm	nm	nm	nm	NA	NA	NA
RF2	9.00E-03	2.87	2.63E-04	1.42	1.8	20 - 22	0.5	0.174	703	1.63E-04	6.26E-02	2.33E-02	9.88E-03	5.2	0.37
RF3	9.20E-03	2.87	2.61E-04	1.43	1.7	25 - 27	0.5	0.339	1110	2.60E-04	4.03E-02	<1.92E-03	3.07E-02(2)	5.0	<0.048
RF4	1.45E-02	5.16	4.14E-04	1.41	1.7	20	0.25	0.335	NA	nm	nm	nm	1.93E-02	NA	NA
RF5	1.45E-02	5.16	4.20E-04	1.43	1.7	20	0.4	0.282	NA	nm	nm	nm	1.95E-02	NA	NA
RF6	1.41E-02	5.32	4.21E-04	1.41	1.8	20	0.4	0.286	NA	3.50E-04	7.70E-02	3.12E-02	1.88E-02	5.8	0.41
RF7	1.45E-02	5.32	4.17E-04	1.40	1.7	20	0.25	0.341	NA	nm	nm	nm	1.89E-02	NA	NA
RF8(3)	1.63E-02	5.99	4.77E-04	1.40	1.7	22	0.5	0.296	NA	nm	nm	nm	1.76E-02	NA	NA
RF9	1.63E-02	6.02	4.77E-04	1.40	1.8	21 - 22	0.5	0.306	NA	nm	nm	nm	1.74E-02	NA	NA
RF10	1.63E-02	5.99	4.74E-04	1.41	1.7	22	0.5	0.302	NA	nm	nm	nm	1.81E-02	NA	NA
RF11	1.67E-02	6.72	4.75E-04	1.42	1.7	22	0.5	0.303	NA	nm	nm	nm	1.75E-02	NA	NA
RF12	1.70E-02	6.16	4.96E-04	1.41	1.7	22	0.5	0.258	NA	nm	nm	nm	1.82E-02	NA	NA
RF13	1.67E-02	7.19	4.82E-04	1.40	1.7	22	0.5	0.251	NA	nm	nm	nm	1.59E-02	NA	NA
RF14	1.73E-02	6.14	4.80E-04	1.41	1.7	22	0.5	0.307	NA	nm	nm	nm	1.77E-02	NA	NA
RF15	1.73E-02	6.14	4.98E-04	1.46	1.7	22	0.5	0.316	NA	nm	nm	nm	1.83E-02	NA	NA
RF16	1.70E-02	7.19	4.67E-04	1.41	1.6	22 - 23	0.5	0.576	NA	nm	nm	nm	2.13E-01	NA	NA
RF17	8.54E-03	2.89	2.40E-04	1.37	1.7	45	0.5	0.214	NA	1.81E-04	5.45E-02	1.64E-02	1.40E-02	5.3	0.30
RF18	8.53E-03	2.89	2.40E-04	1.37	1.7	25	0.5	0.211	NA	7.91E-04	8.99E-02	2.90E-03	6.00E-02(2)	6.8	0.032
RF19	1.8E+01	6.7E+03	7.9E+00	21	26	ambient	0.5	308	NA	nm	nm	nm	NA	NA	NA
RF20	1.5E+02	5.8E+04	1.7E+01	5.0	6.5	ambient	0.5	2850	NA	nm	nm	nm	NA	NA	NA
RF21	1.6E+02	5.8E+04	1.7E+01	5.0	6.4	ambient	0.5	2850	NA	nm	nm	nm	NA	NA	NA
RF22	1.60E-02	5.84	4.63E-04	1.40	1.7	22 - 24	0.45	0.399	NA	nm	nm	nm	1.84E-02	NA	NA
RF23	1.63E-02	5.92	4.66E-04	1.41	1.7	22 - 24	0.45	0.392	NA	nm	nm	nm	1.87E-02	NA	NA
RF24	1.63E-02	6.06	4.53E-04	1.42	1.7	22 - 24	0.45	0.385	NA	nm	nm	nm	1.93E-02	NA	NA
RF25	1.60E-02	6.05	4.56E-04	1.38	1.7	22 - 24	0.45	0.392	NA	nm	nm	nm	1.90E-02	NA	NA
RF26	1.60E-02	6.16	4.47E-04	1.40	1.7	22 - 24	0.45	0.386	NA	nm	nm	nm	1.89E-02	NA	NA
RF27	1.54E-02	6.09	4.47E-04	1.42	1.7	22 - 24	0.45	0.385	NA	nm	nm	nm	1.88E--02	NA	NA

Notes:

1 See Table 2.5-20 for data sources and resin lot used in test based on Column Test ID.

2 Column Cs loading did not approach 100% breakthrough; therefore, is not an appropriate estimate of the Cs loading.

3 Up-flow elution test performed

4 nm = not measured, NA = not applicable.

Table 2.5-22 Cs Removal System Process Stream Descriptions for Material Balance Calculations

Cycle	Column Feed	Volume, gal	Flow Rate, gpm	Completion Time, h	Column Effluent Disposition
1 Loading	LAW from CXP-VSL-00004	Determined by waste composition	Variable up to 30[a]	[b]	To LAW collection vessels (CXP-VSL-00026A/B/C) via lead, lag, and polishing columns
2 Fluid Displacement	Nominal 0.1 M NaOH[c] from blending solutions from SHR-TK-00001 and DIW-TK-00001 via CXP-VSL-00005	1800	30	1	To CXP-VSL-00004
3 Pre-elution Rinse	Demin water from DIW-TK-00001 via CXP-VSL-00005	1200[d]	30	0.7	To PWD-VSL-00015/16
4 Elution	0.45 M HNO_3 from CNP-VSL-00004	9000[e]	10	15	To CNP-BRKPT-00002
5 Post-Elution Rinse	Demin water from DIW-TK-00001 via CXP-VSL-00005	1500[d]	10	2.5	To CNP-BRKPT-00002
6 Regeneration	0.5 M NaOH from in-line blending solutions from SHR-TK-00001 and DIW-TK-00001	2000[f]	7 to 47[g]	1.2[g]	To PWD-VSL-00015/16
7 Regeneration Fluid Displacement[j]	Treated LAW from CXP-VSL-00004	1250[h]	9.4 to 15[i]	2.6[i]	To CXP-VSL-00004

Notes:

a Design basis flow rate specified in SOW (DE-AC27-01RV14136). See Section 2.5.1.

b Determined from loading cycle volume and flow rate.

c Nominal NaOH concentration consistent with laboratory test procedures, but higher concentrations are acceptable for precluding aluminum precipitate formation.

d Neglects resin outlet flush with 21 gal of demineralized water.

e Neglects resin outlet flush with 21 gal of 0.45 M HNO_3.

f Neglects resin outlet flush with 21 gal of 0.5 M NaOH.

g Assumes 1800 gal fed up-flow at 47 gpm, followed by bed settling for 7 min (no flow), followed by 200 gal up-flow at 7 gpm.

h Neglects 54 gal sample line flush with treated LAW.

i Assumes 1100 gal fed up-flow at 9.4 gpm, followed by 150 gal up-flow at 15 gpm, followed by 30 min of bed settling (no flow).

j This cycle has been neglected for the purpose of estimating material balances.

Table 2.5-23 Cs Ion Exchange Vessel Batch Volumes

Vessel	Function	Batch Volume, gal	Basis
CXP-VSL-00004	LAW Feed Tank (Cs IX Column Feed)	6000	Sized to contain treated LAW for displacement in four columns plus 20 % contingency.
CXP-VSL-00005	Cs Reagent Vessel	150	Sized to provide a buffer between RFD transfers from CXP-VSL-00004 and the CXP feed pumps.
CXP-IXC-00001	Cs Ion Exchange Column	600	Batch volume is not meaningful for the IX columns because they process a continuous flow of liquid. The listed batch volume represents the resin bed volume calculated in Section 2.5.2 to support production rates. These batch volumes are adequate for use as flowsheet input parameters as long as the combination with other column inputs yields the volumes and flow rates listed on Table 2.5-22.
CXP-IXC-00002	Cs Ion Exchange Column	600	
CXP-IXC-00003	Cs Ion Exchange Column	600	
CXP-IXC-00004	Cs Ion Exchange Column	600	

Table 2.5-24 Results from IX Performance Parametric Calculations

Resin Bed Volume = 600 gal

Results from IX Performance Parametric Calculation

Average Loading Cycle Estimates over 40 Loading Cycles/column

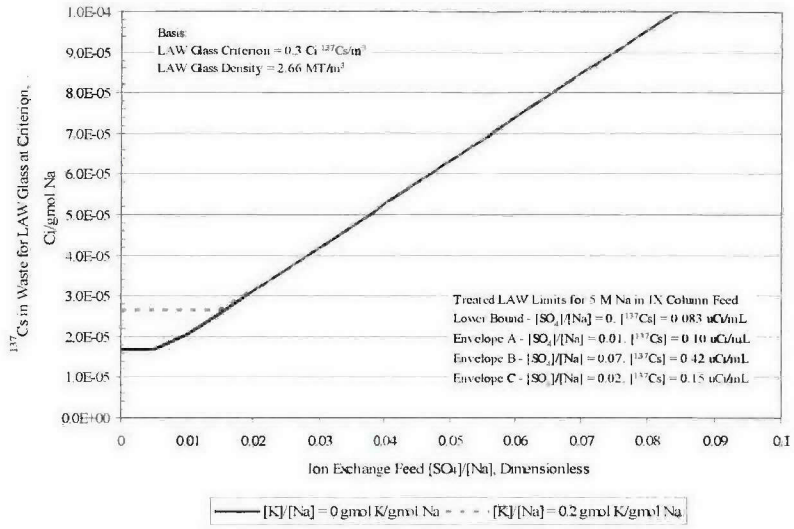
(Performance after 20 loading cycle use)

Values in this table were calculated from multiple runs of the MathCAD file titled IX Performance Parametric Calculation.

[Na]	[OH]	[K]	[Cs]	Load BV	Cs DF	Load Vol, gal
5	3	0	1.00E-06	757.2	4257.3	454320
5	3	0	1.00E-05	496	4260.8	297600
5	3	0	1.00E-04	248.1	4270.3	148860
5	3	0	1.00E-03	92.7	4295.7	55620
5	3	0.1	1.00E-06	623.6	4257	374160
5	3	0.1	1.00E-05	419.3	4260.8	251580
5	3	0.1	1.00E-04	218.5	4271	131100
5	3	0.1	1.00E-03	85.9	4296.7	51540
5	3	0.2	1.00E-06	502.75	4257.2	301650
5	3	0.2	1.00E-05	349.4	4291.4	209640
5	3	0.2	1.00E-04	190.7	4272.2	114420
5	3	0.2	1.00E-03	79.3	4297.9	47580
5	3	0.3	1.00E-06	396.8	4258	238080
5	3	0.3	1.00E-05	287.2	4262.5	172320
5	3	0.3	1.00E-04	165.1	4274	99060
5	3	0.3	1.00E-03	73.1	4299.2	43860
5	3	0.4	1.00E-06	306.5	4259.8	183900
5	3	0.4	1.00E-05	233	4264.5	139800
5	3	0.4	1.00E-04	141.9	4276.4	85140
5	3	0.4	1.00E-03	67.1	4300.5	40260
5	3	0.6	1.00E-06	172.8	4267.6	103680
5	3	0.6	1.00E-05	148.2	4271.7	88920
5	3	0.6	1.00E-04	102.9	4283.4	61740
5	3	0.6	1.00E-03	56.1	4302.7	33660

Min Cs DF =	42574
Cs Removal Efficiency =	0.999765093
Max Cs DF =	4302.7
Cs Removal Efficiency =	0.999767588

Figure 2.5-1 ^{137}Cs Removal Requirements for Treated LAW Supernate



Based on the LAW glass loading algorithm described in 24590-WTP-MCR-PO-05-0017, *LAW Glass Chemistry Shell Update for Steady State Flowsheet.* Rearrangement of the glass loading analyses result in a treated LAW criterion producing glass at 0.3 Ci $^{137}Cs/m^3$ estimated from the glass loading as follows:

$$\frac{\left[^{137}Cs\right]_{criterion}}{[Na]} = \frac{\left(0.3\ \frac{Ci\ ^{137}Cs}{m^3}\right)\left(62\ \frac{g\ Na_2O}{gmol\ Na_2O}\right)}{\left(g^{initial}_{Na_2O}\ \frac{g\ Na_2O}{g\ Glass}\right)\left(\rho_{Glass}\ \frac{MT\ Glass}{m^3}\right)\left(10^6\ \frac{g\ Glass}{MT\ Glass}\right)\left(2\ \frac{gmol\ Na}{gmol\ Na_2O}\right)}$$

$$= \frac{9.3\times10^{-6}}{\left(g^{initial}_{Na_2O}\right)\left(\rho_{Glass}\right)}\ \frac{Ci\ ^{137}Cs}{gmol\ Na}$$

$$g^{initial}_{Na2O} = Minimum\left\{X_{Na2O}, 0.04\left(\frac{62}{94.2}\right)\left(\frac{[Na]}{[K]}\right)\right\}$$

$$X_{Na2O} = Minimum\left\{0.21, C^{initial}_{K2O+Na2O}, C^{initial}_{Transition}, C^{initial}_{High\ Sulfate}\right\}$$

$$C^{initial}_{K2O+Na2O} = \frac{0.215}{1+0.66\left(\frac{94.2}{62}\right)\left(\frac{[K]}{[Na]}\right)}$$

$$C^{initial}_{Transition} = \frac{0.35875}{1+42.5\left(\frac{(2)(80.06)}{(62)}\right)\left(\frac{[SO_4]}{[Na]}\right)}$$

$$C^{initial}_{High\ Slufate} = \frac{0.0077}{\left(\frac{(2)(80.06)}{(62)}\right)\left(\frac{[SO_4]}{[Na]}\right)}$$

where ρ_{Glass} is in MT/m^3 and $[SO_4]$, [Na], [K] are the treated LAW component concentrations in gmol/L.

Figure 2.5-2 Total Cs Concentration Limits for Treated LAW Supernate

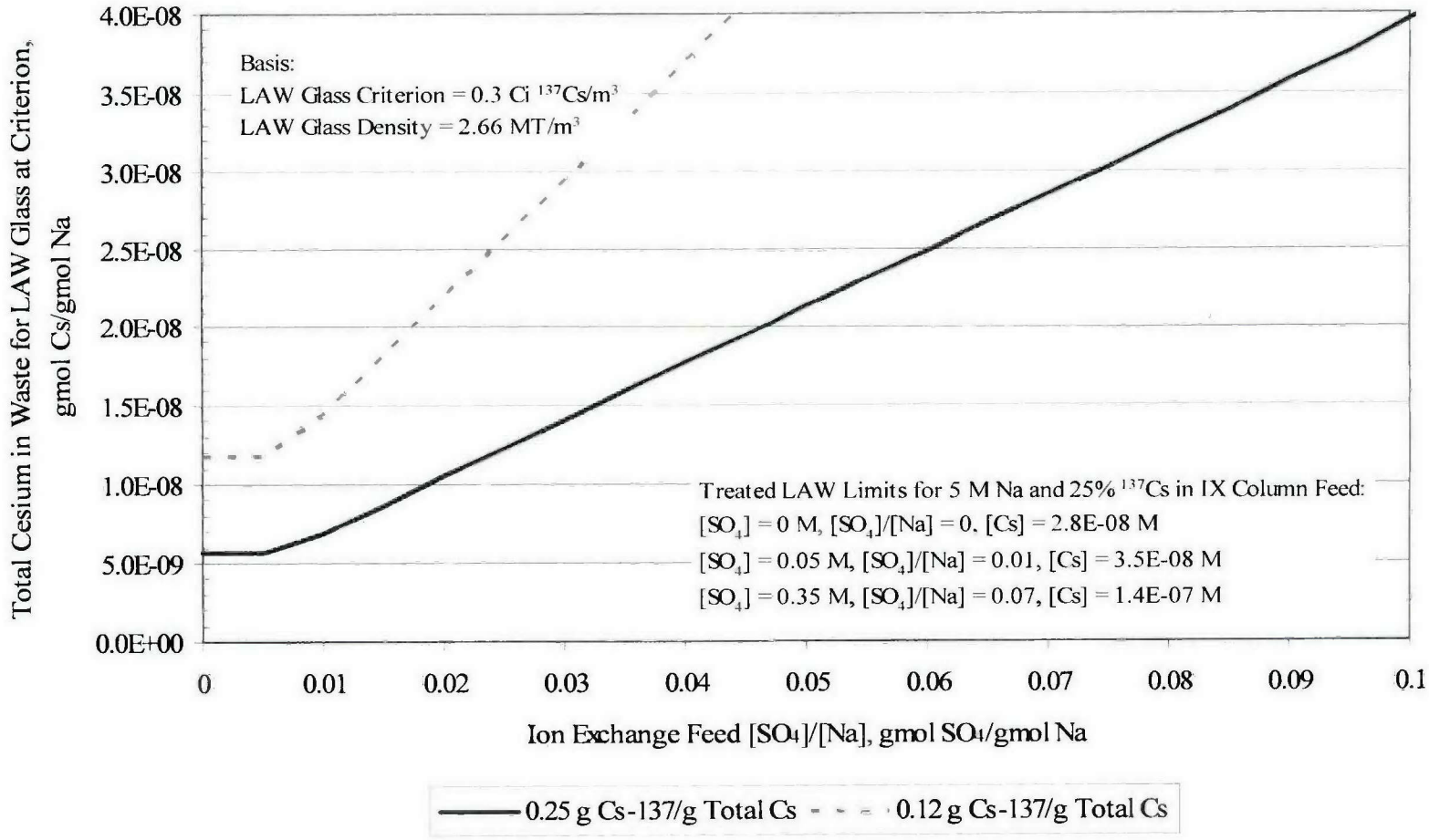
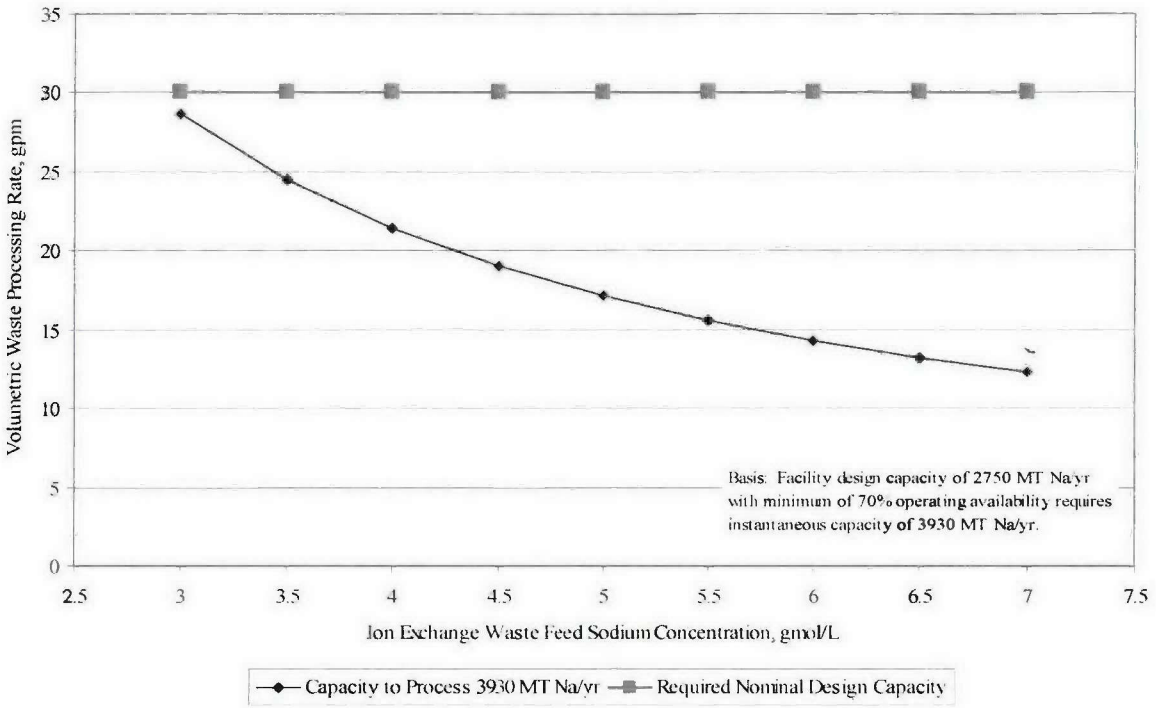


Figure 2.5-3 Volumetric Waste Processing Flow Rate Required for Cs Ion Exchange



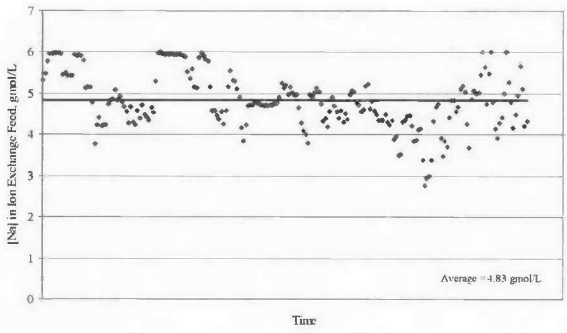
Waste processing volumetric flow rate to process 3930 MT Na/yr estimated as follows:

$$\text{Flow, gpm} = \frac{(3930\,\frac{\text{MT Na}}{\text{yr}})\,(10^6\,\frac{\text{g Total Na}}{\text{MT Total Na}})}{(23\,\frac{\text{g Total Na}}{\text{gmol Na}})\,([\text{Na}],\,\frac{\text{gmol Na}}{\text{L}})\,(3.785\,\frac{\text{L}}{\text{gal}})\,(365\,\frac{\text{day}}{\text{yr}})\,(24\,\frac{\text{hr}}{\text{day}})\,(60\,\frac{\text{min}}{\text{hr}})}$$

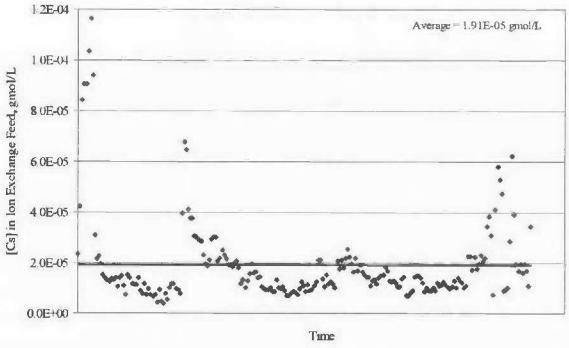
where:

[Na] = total sodium concentration in IX waste feed. For a waste feed at [Na] = 5 M, this results in a volumetric flow rate of 17.2 gpm.

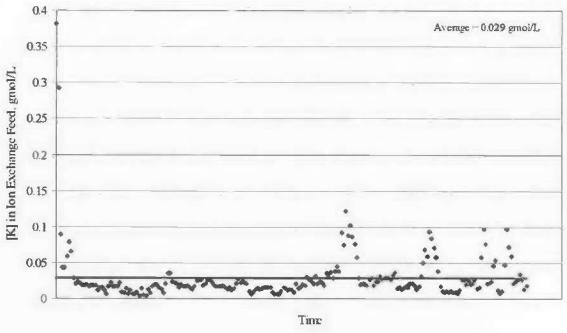
Figure 2.5-4 Predicted Variation of Ion Exchange Feed Characteristics



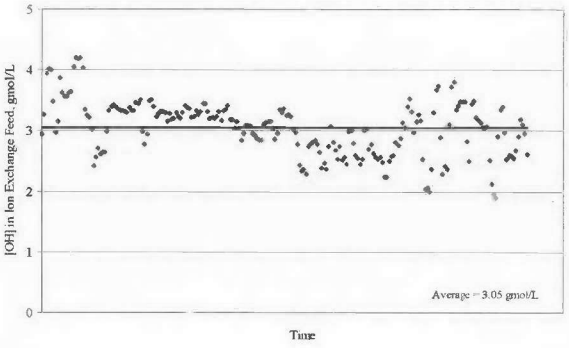
(a) Sodium Ion Concentration



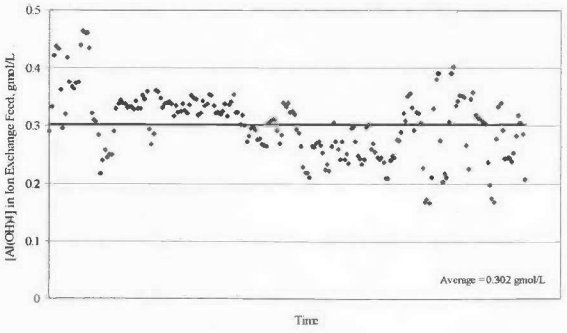
(b) Total Cs Ion Concentration



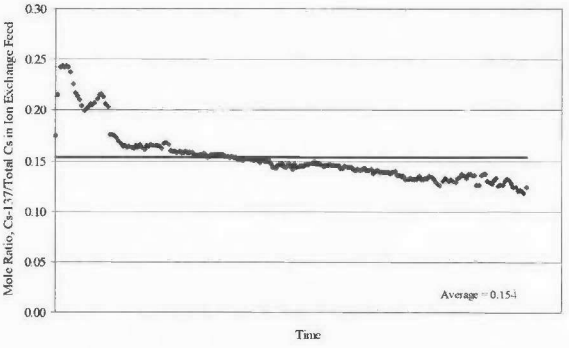
(c) Potassium Ion Concentration



(d) Hydroxide Ion Concentration



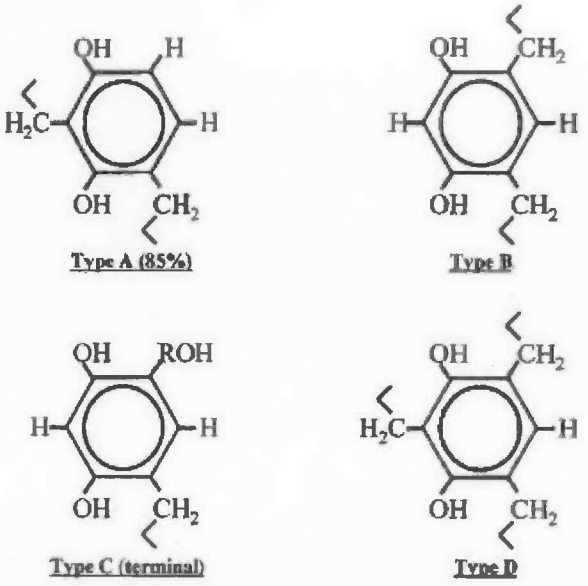
(e) Aluminate Ion Concentration



(f) ^{137}Cs to Total Cs Mole Ratio

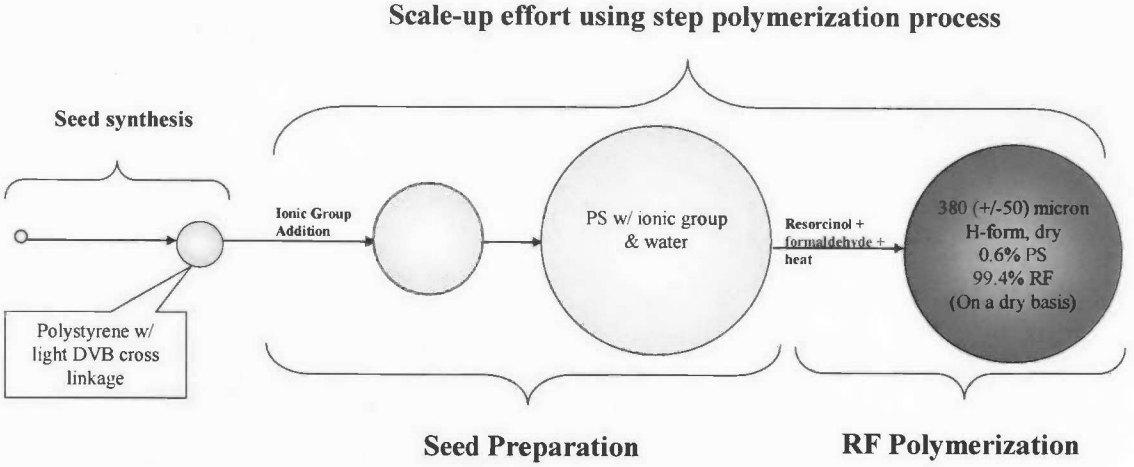
Source: Prediction results for ultra-filtration permeate in MRQ-07-0009, Scenario 4.1.48a.

Figure 2.5-5 Possible Structural Units within Resorcinol-Formaldehyde Polymer



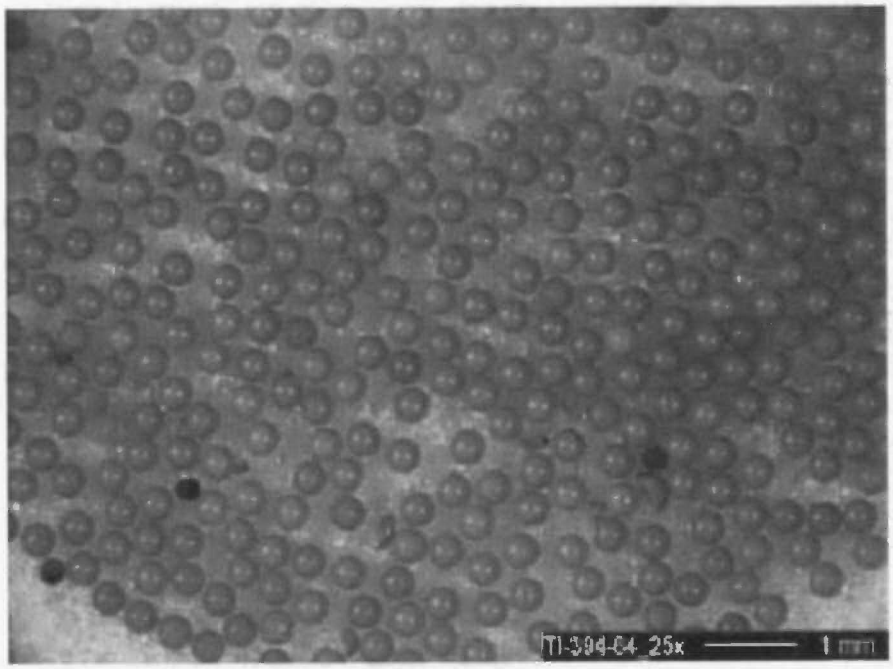
Source: SCT-M0SRLE60-00-221-00001, *Spherical Resorcinol-Formaldehyde Resin Reactivity with Nitric Acid and Other Hanford RPP-WTP Process Solutions* (Figure 2-1).

Figure 2.5-6 Spherical Resorcinol-Formaldehyde Synthesis Schematic



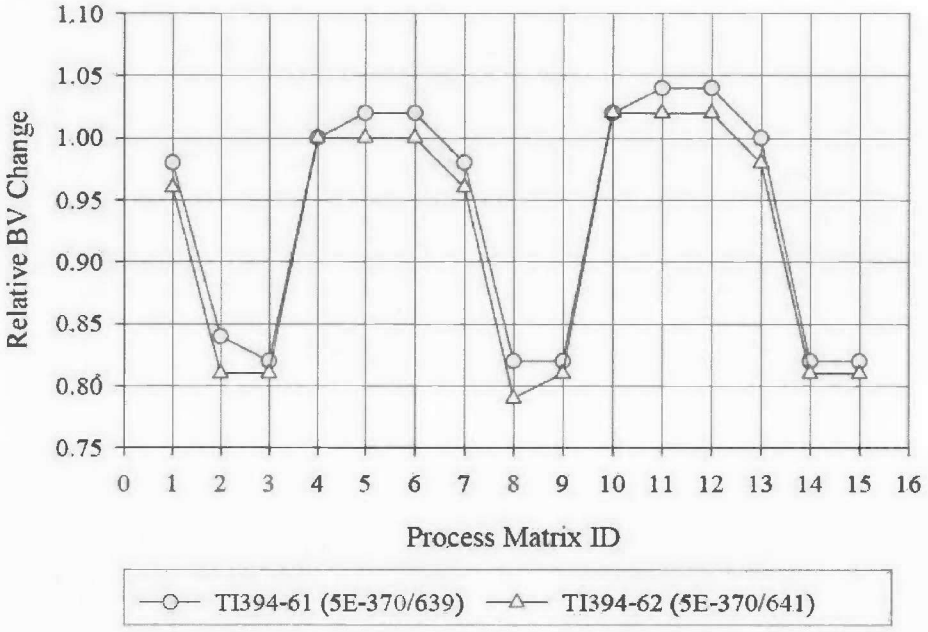
Source: 24590-WTP-RPT-RT-06-001, *Basis for Recommendation of Spherical Resorcinol Formaldehyde Resin as the Approved Equivalent for SuperLig 644* (Figure 7).

Figure 2.5-7 Micrograph of Spherical Resorcinol-Formaldehyde Resin Beads



Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Figure S.1, for Resin Lot 5J-370/686).

Figure 2.5-8 Typical Spherical Resorcinol-Formaldehyde Resin Bed Volume Changes during Waste Processing

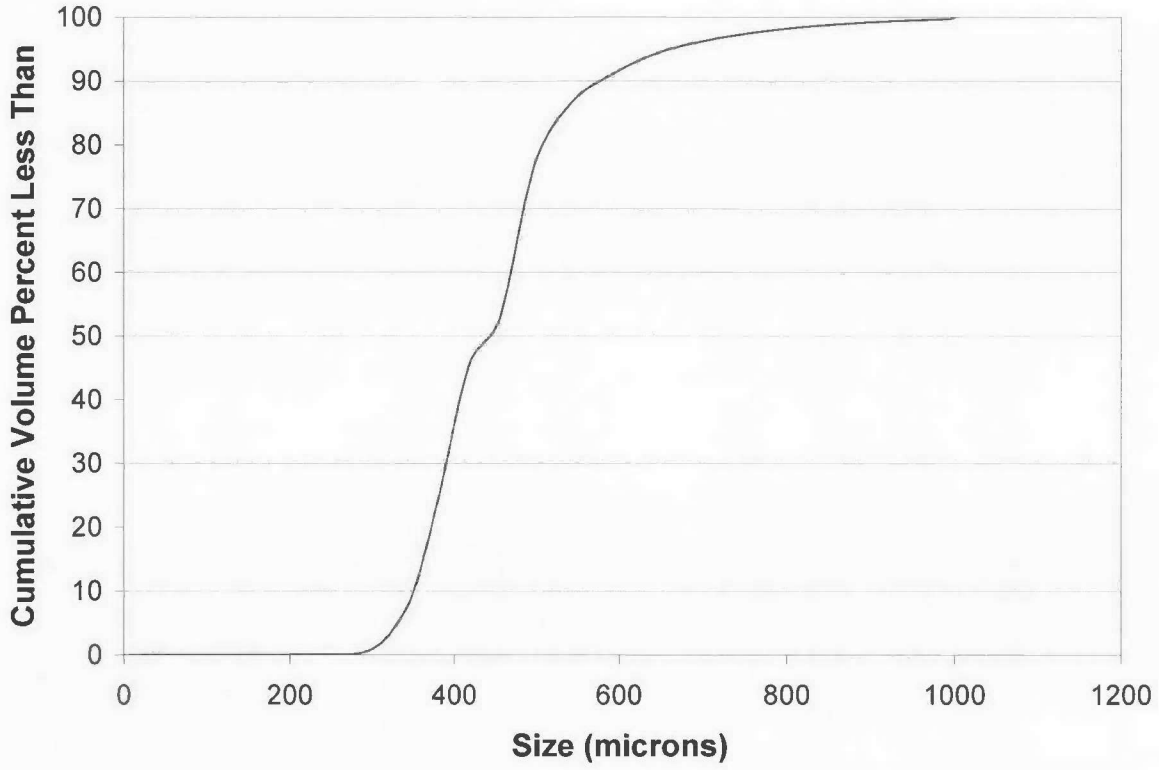


Matrix IDs

1: Loaded in column (Na-form)
2: 0.5M HNO_3
3: DI water rinse
4, 10: 0.5 M NaOH
5, 11: AP101 simulant
6, 12: 0.1 M NaOH feed displacement
7, 13: DI water
8, 14: 0.25 M or 0.4 M HNO_3
9, 15: DI water

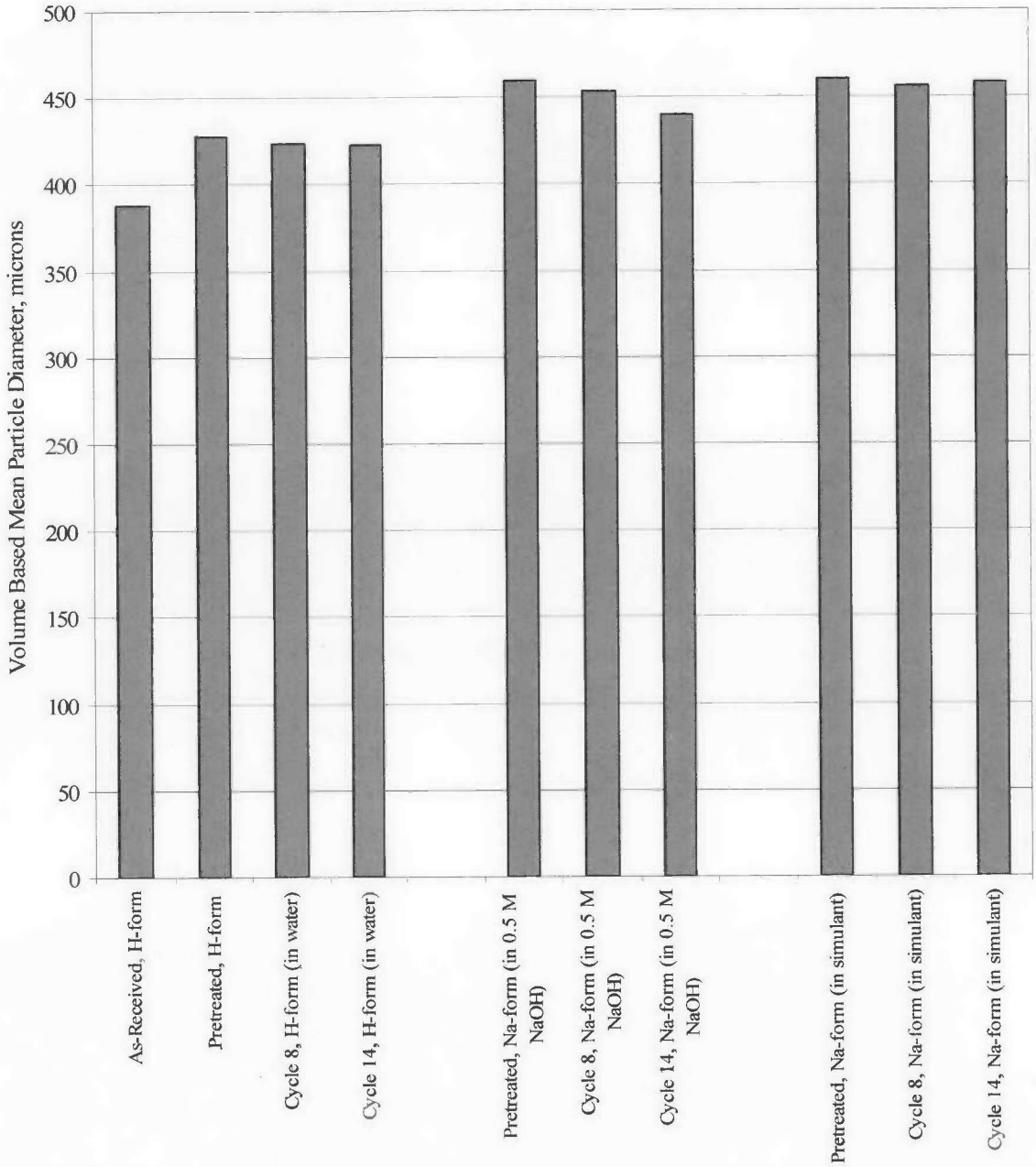
Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Figure 11.11).

Figure 2.5-9 Example Volume Based Particle Size Distribution for Spherical Resorcinol-Formaldehyde



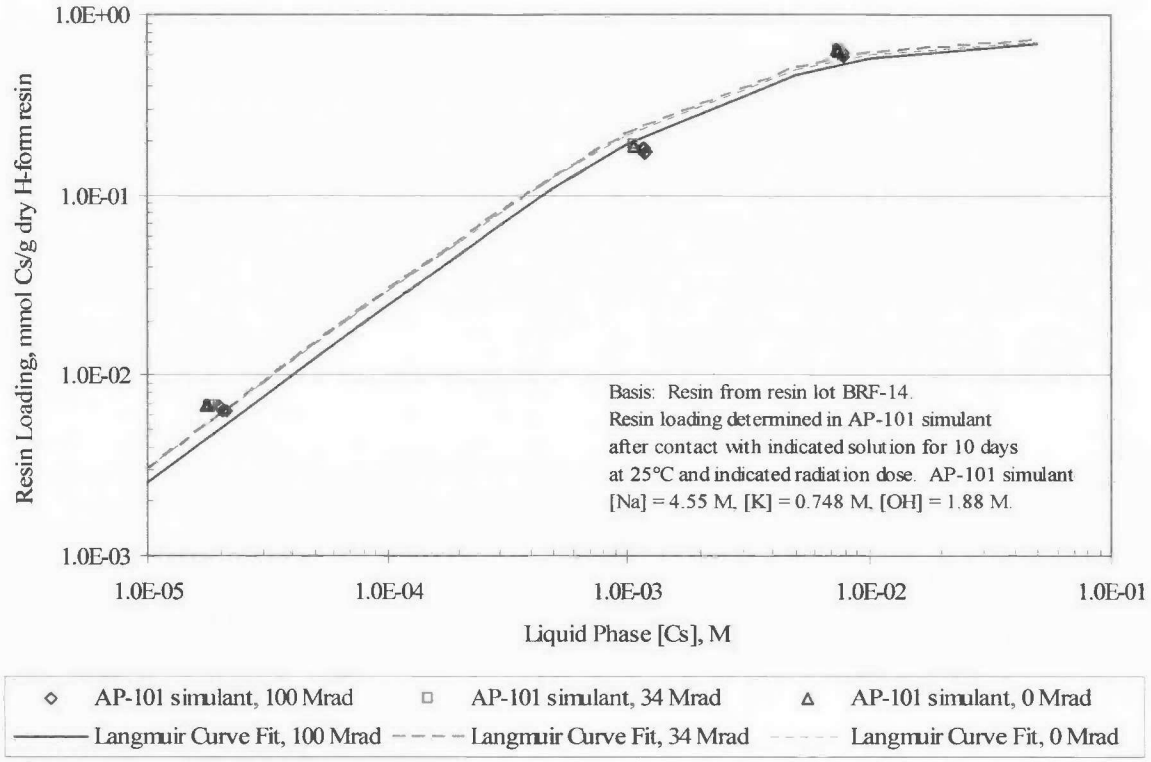
Data source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant* (Page D.5 for sodium form of resin lot 5E-370/641).

Figure 2.5-10 Variation of Spherical Resorcinol-Formaldehyde Resin Particle Size with Multiple Process Cycling



Note: Source data from SCT-M0SRLE60-00-110-00028, Rev 00B, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin* (Table 14) for material from resin lot 5E-370/641.

Figure 2.5-11 Variation of Cs Loading Isotherm with Irradiation in AP-101 Simulant



Langmuir binary isotherm model assumed to interpolate data is of the form:

$$\text{Cs Loading} = \frac{A\,[\text{Cs}]}{B + [\text{Cs}]}$$

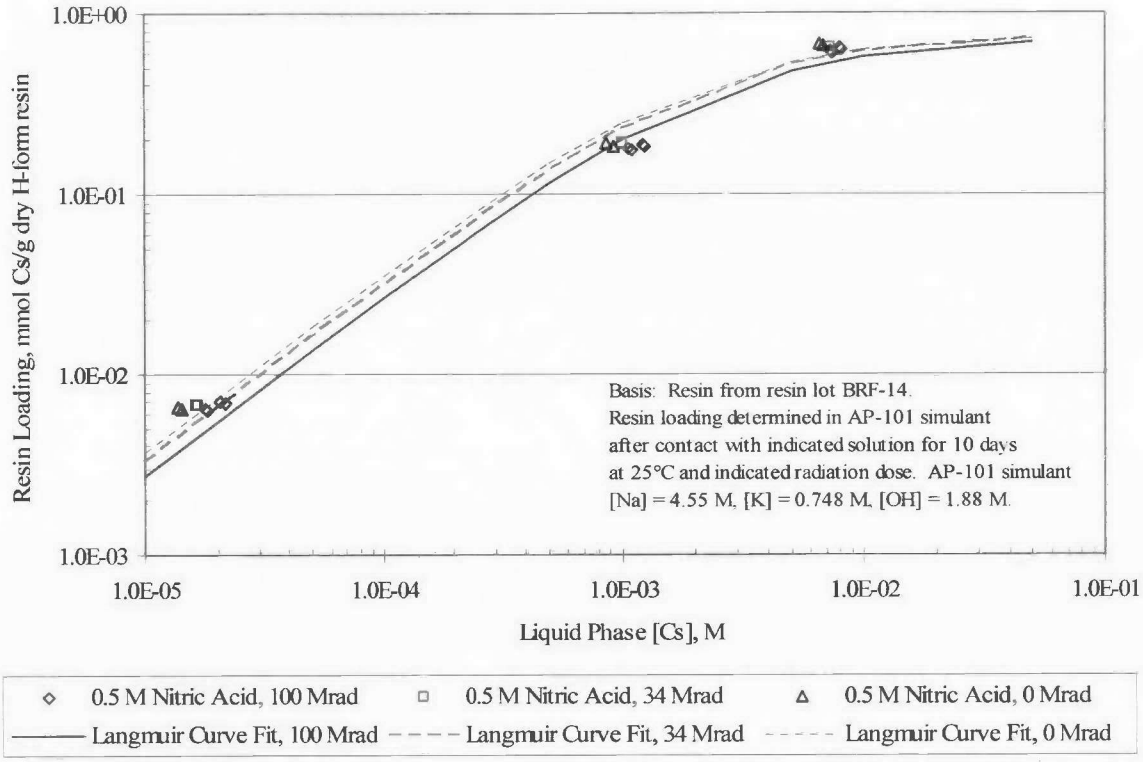
Source data plotted are from Table 2.5-8. Parameters for each irradiation test were determined by finding A and B to minimize:

$$\sum \left(\frac{(\text{Cs Loading})_{\text{observed}} - (\text{Cs Loading})_{\text{estimated}}}{(\text{Cs Loading})_{\text{observed}}} \right)^2$$

Results are summarized below:

Total Dose, Mrad	A, mmol/g dry H-form resin	B, gmol/L
0	0.736	2.41E-03
34	0.761	2.51E-03
100	0.729	2.87E-03

Figure 2.5-12 Variation of Cs Loading Isotherm with Irradiation in Nitric Acid



Langmuir binary isotherm model assumed to interpolate data is of the form:

$$\text{Cs Loading} = \frac{A\,[\text{Cs}]}{B + [\text{Cs}]}$$

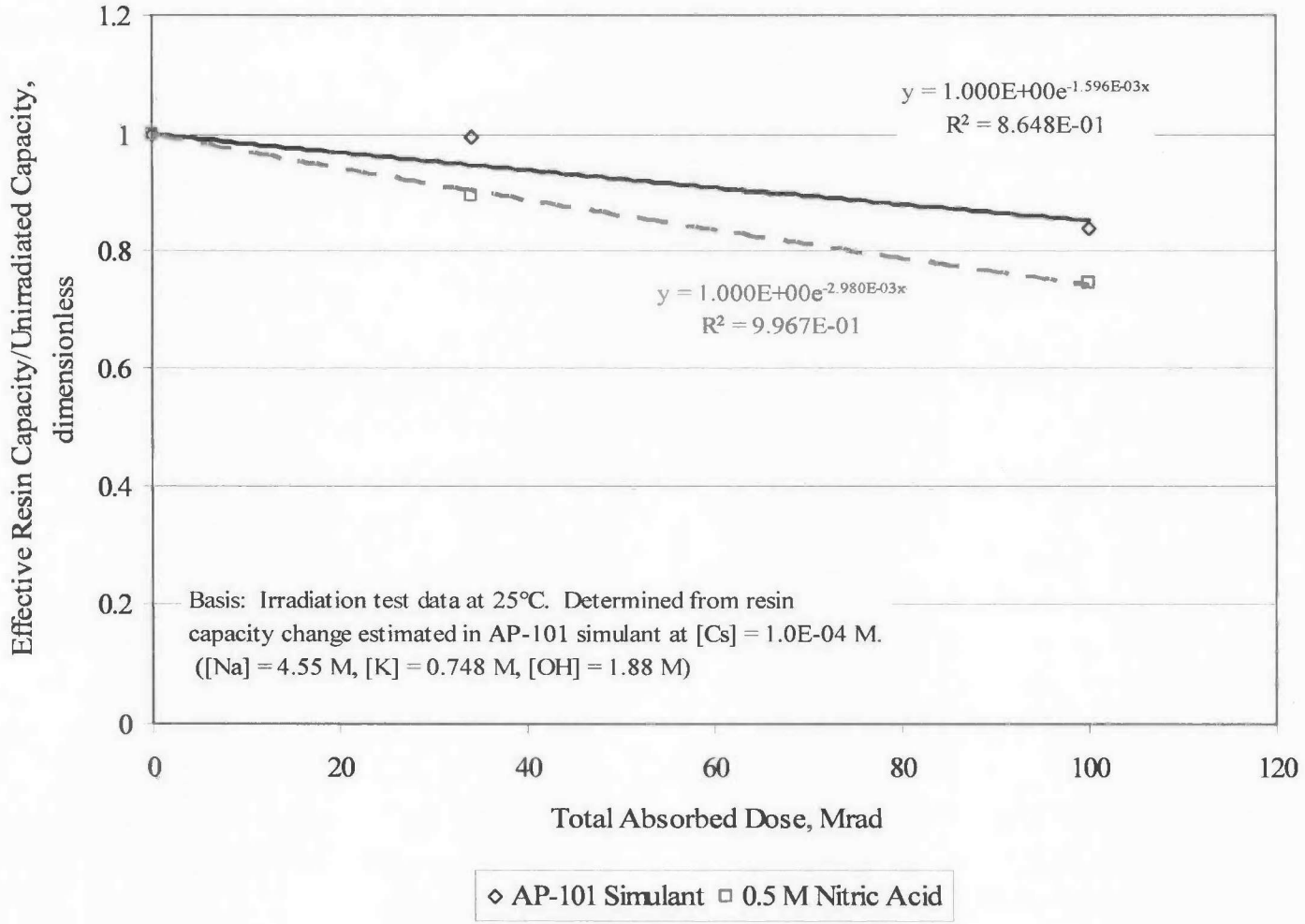
Source data plotted are from Table 2.5-8. Parameters for each irradiation test were determined by finding A and B to minimize:

$$\sum \left(\frac{(\text{Cs Loading})_{\text{observed}} - (\text{Cs Loading})_{\text{estimated}}}{(\text{Cs Loading})_{\text{observed}}} \right)^2$$

Results are summarized below:

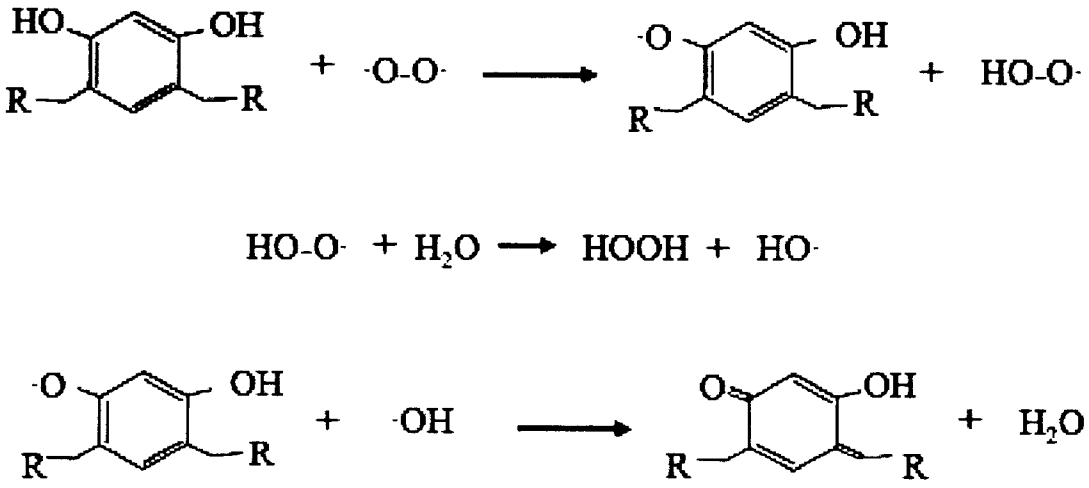
Total Dose, Mrad	A, mmol/g dry H-form resin	B, gmol/L
0	0.753	2.03E-03
34	0.755	2.29E-03
100	0.733	2.68E-03

Figure 2.5-13 Projected Variation of Spherical Resorcinol-Formaldehyde Resin Capacity with Absorbed Dose



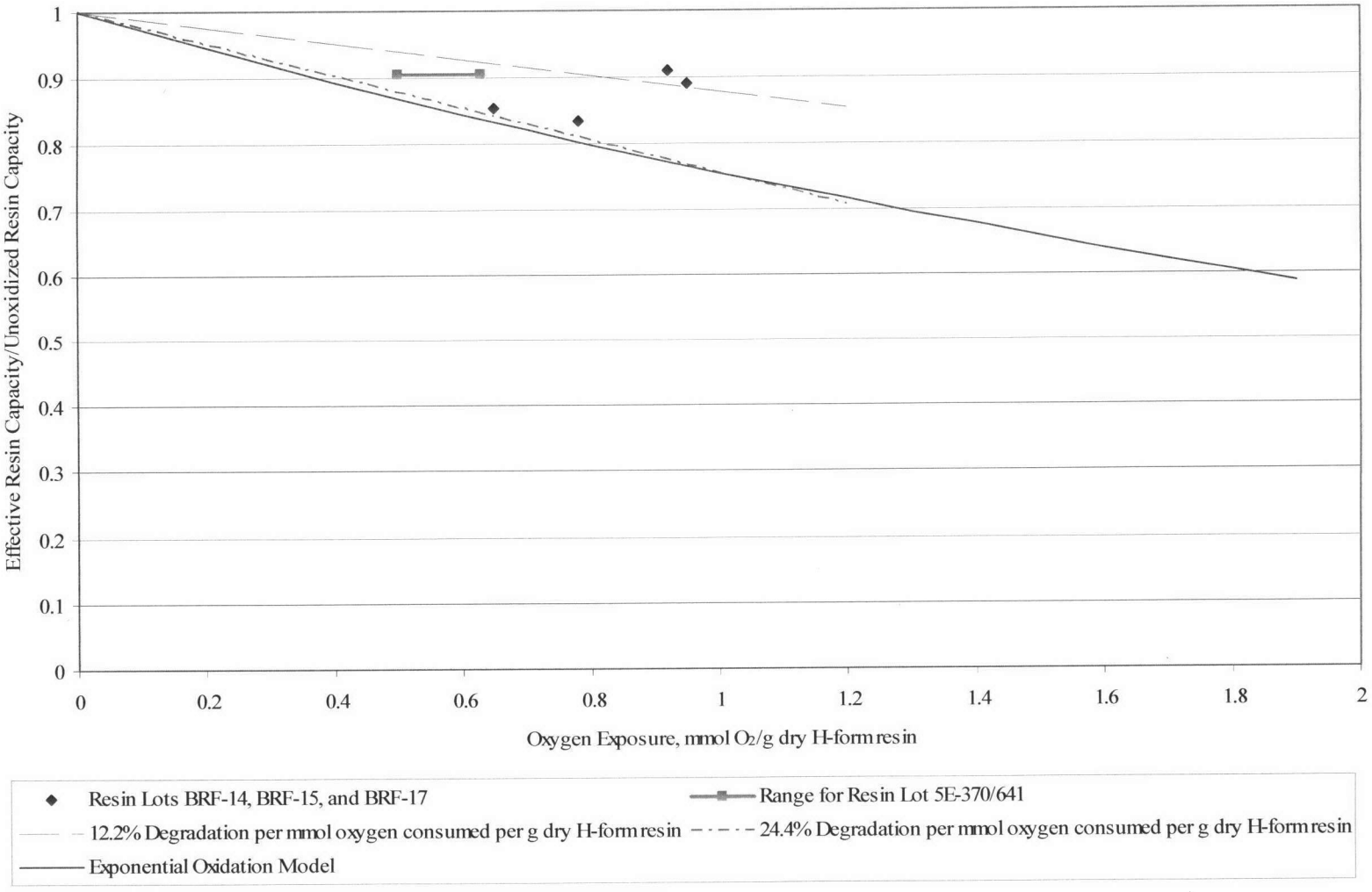
Note: Source data plotted from Table 2.5-9.

Figure 2.5-14 Proposed Mechanism for Resorcinol-Formaldehyde Oxidation



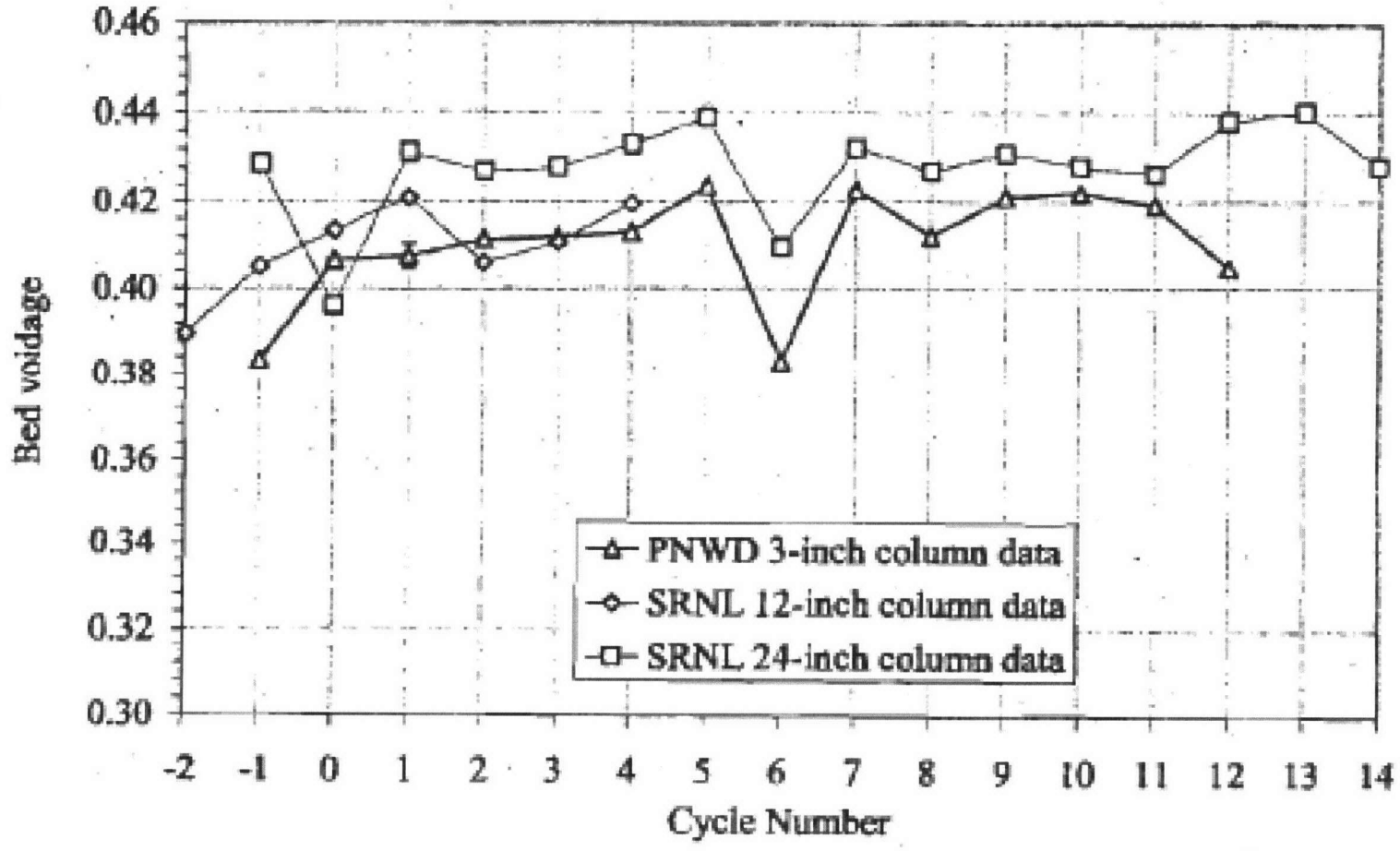
Source: 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project Waste Treatment Plant* (Figure 6.6).

Figure 2.5-15 Projected Variation of Spherical Resorcinol-Formaldehyde Resin Capacity with Oxygen Exposure



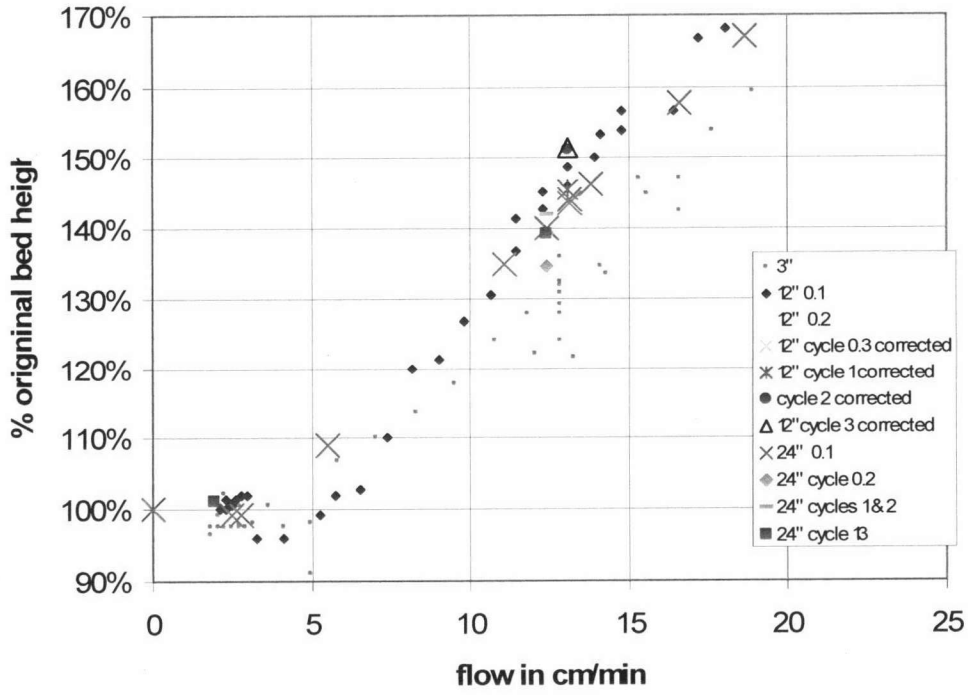
Note: Source data plotted from Table 2.5-10.

Figure 2.5-16 Variation of Spherical Resorcinol-Formaldehyde Resin Bed Porosity over Multiple Loading and Elution Cycles



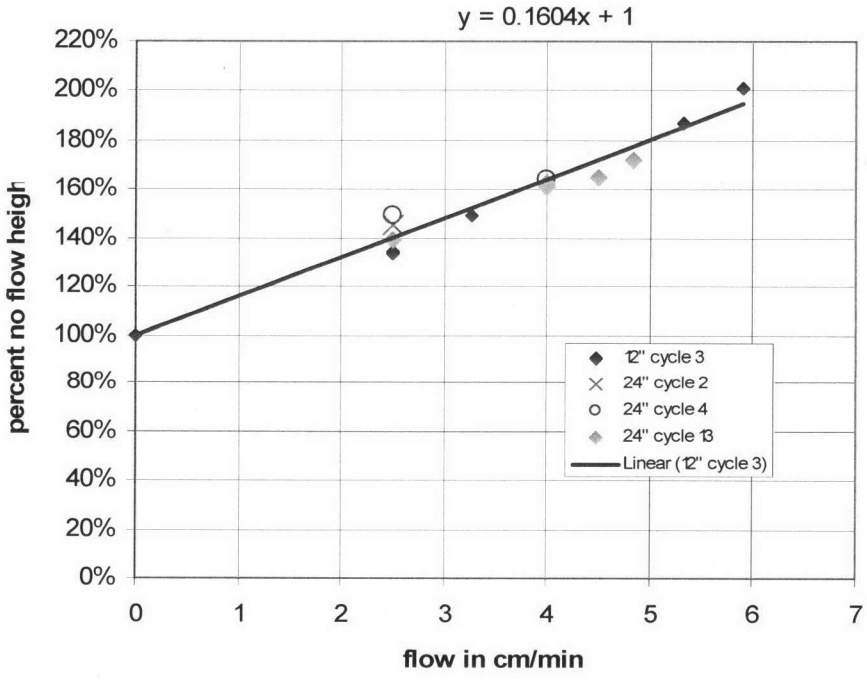
Source: 24590-101-TSA-W000-0004-174-00002, Rev 00B, *Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins* (Figure 7-1). Data obtained using material from resin lot 5E-370/641.

Figure 2.5-17 Bed Height during Up-Flow Regeneration Using 0.5 M NaOH



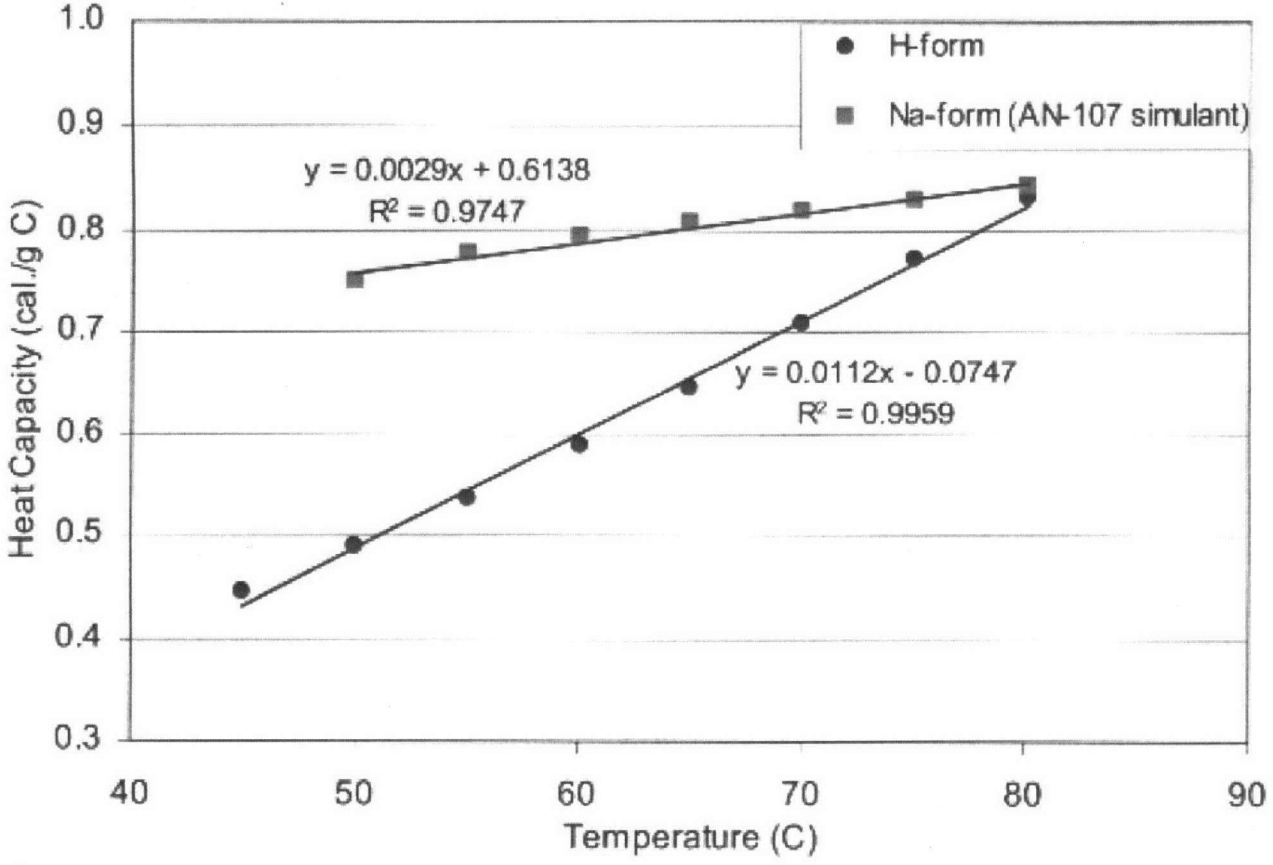
Source: SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin* using material from resin lot 5E-370/641 (Figure 50). Test data from hydraulic tests using 3-in., 12-in., and 24-in. diameter resin beds.

Figure 2.5-18 Resin Bed Height during Up-Flow Waste Simulant Introduction



Source: SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin* using material from resin lot 5E-370/641 (Figure 51). Test data from hydraulic tests using 12-in. and 24-in. diameter resin beds.

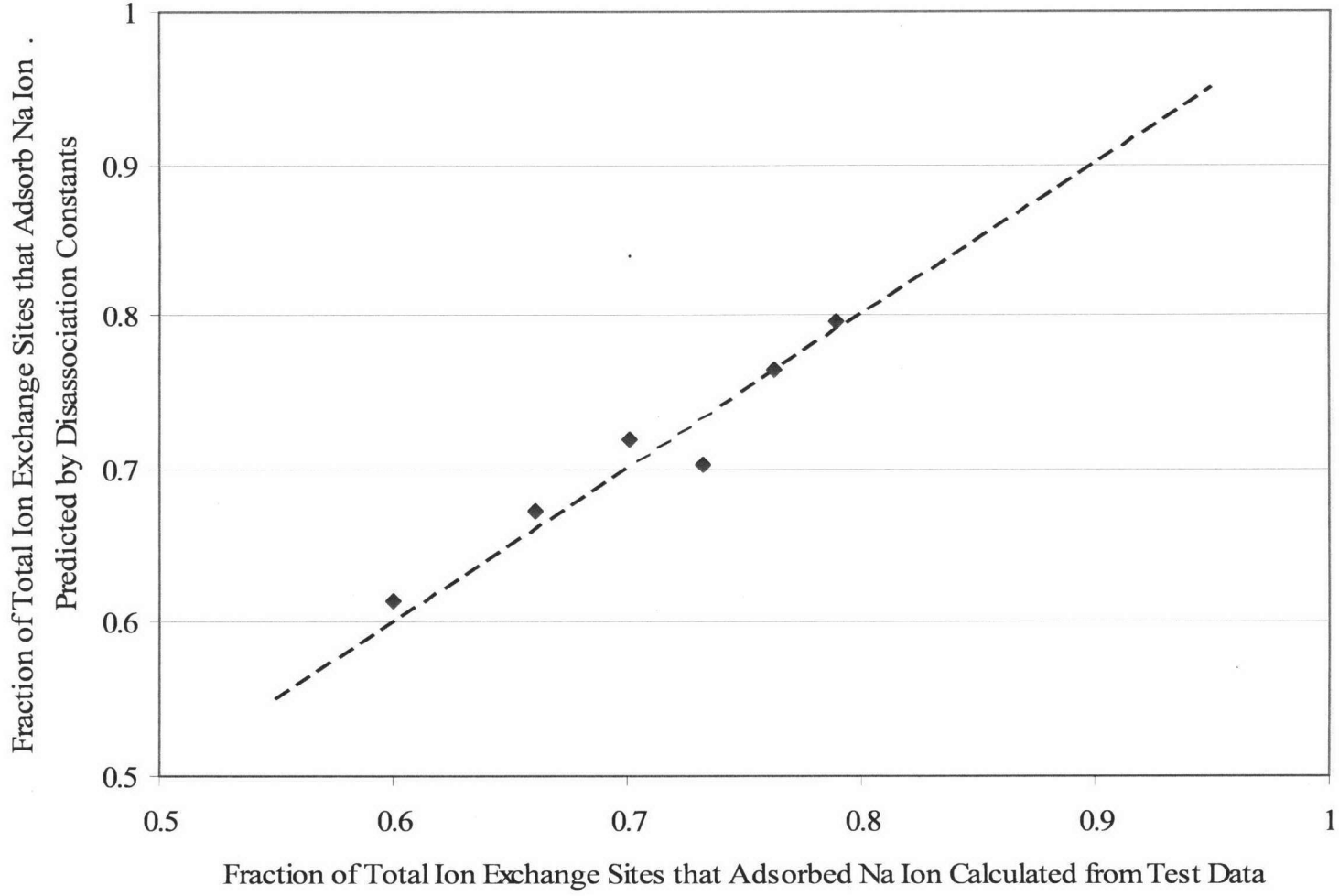
Figure 2.5-19 Heat Capacity for Sodium and Hydrogen Forms of Spherical Resorcinol-Formaldehyde Resin



Notes:

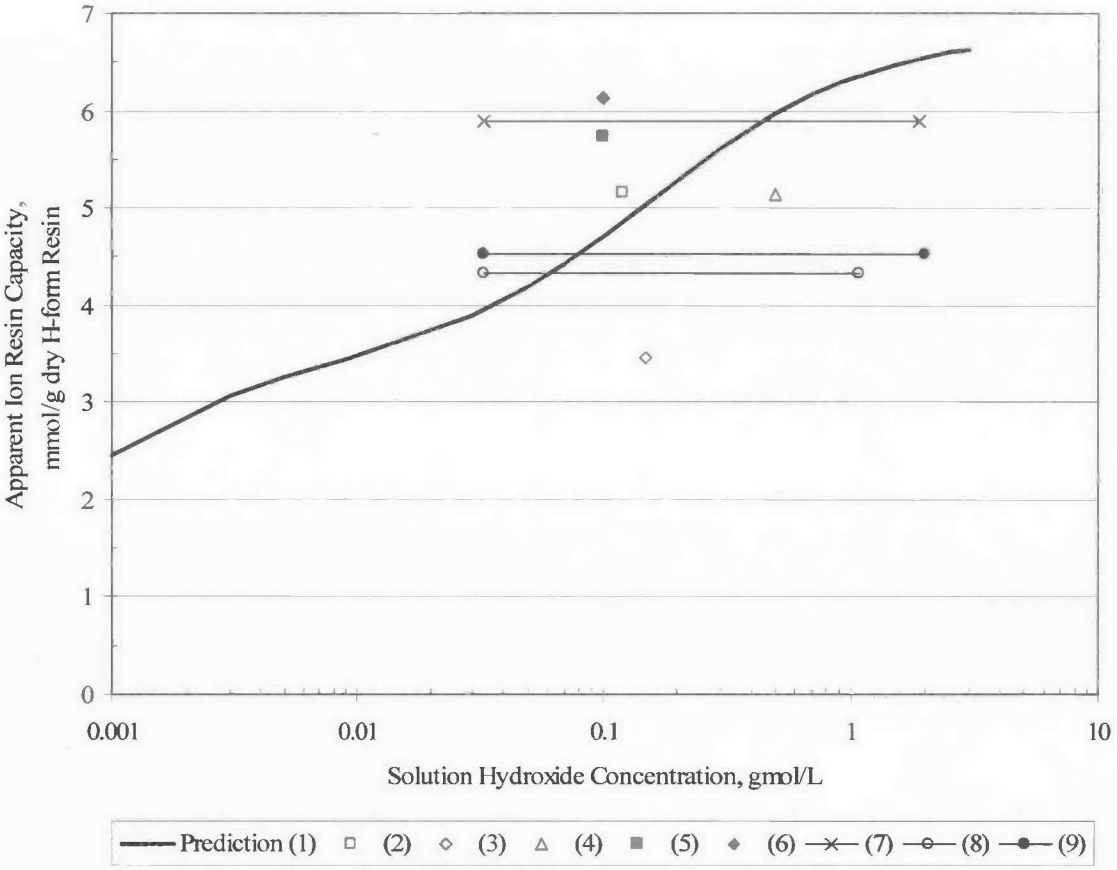
1. Based on data obtained using material from resin lot BRF-14.
2. The mass basis for reported heat capacity is 30 wt % dry H-form resin and 70 wt % contacting solution.
3. Contacting solution for H-form resin is water (pH ~ 5).
4. Contacting solution for Na-form resin is AN-107 simulant which is characterized by $[Na^+]$ = 5.068 M, $[K^+]$ = 0.093 M, [Al] = 0.502 M, $[NO_3^-]$ = 1.128 M, $[NO_2^-]$ = 1.015 M, $[OH^-]$ = 1.47 M.
5. Source: SCT-M0SRLE60-00-221-00001, Rev 00A, *Spherical Resorcinol-Formaldehyde Resin Reactivity with Nitric Acid and Other Hanford RPP-WTP Process Solutions* (Table 3-2 and Figure 4-42).

Figure 2.5-20 Comparison of Observed Influence of Hydroxide Ion Concentration on Sodium Ion Adsorption with Predictions Using Disassociation Constants



Note: Plotted data from Table 2.5-13.

Figure 2.5-21 Comparison of Apparent Ion Resin Capacity with Observations



Key:

(1) Prediction based on Equation 2.5-29, Equation 2.5-30, Equation 2.5-31, and Equation 2.5-32.

(2) Na consumption during 3-in. column regeneration (resin 5E-370/641 from 24590-101-TSA-W000-0004-174-00002, *Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins*).

(3) Na consumption during 12-in. column regeneration (resin 5E-370/641 from SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin*).

(4) Na consumption during 24-in. column regeneration (resin 5E-370/641 from SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin*).

(5) Na consumption during 3-in. column regeneration (resin 5J-370/686 from 24590-101-TSA-W000-0004-174-00002, *Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins*).

(6) Na consumption during 3-in. column regeneration (resin blend of 3380-3-200 and 3380-3-201 from 24590-101-TSA-W000-0004-174-00002, *Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins*).

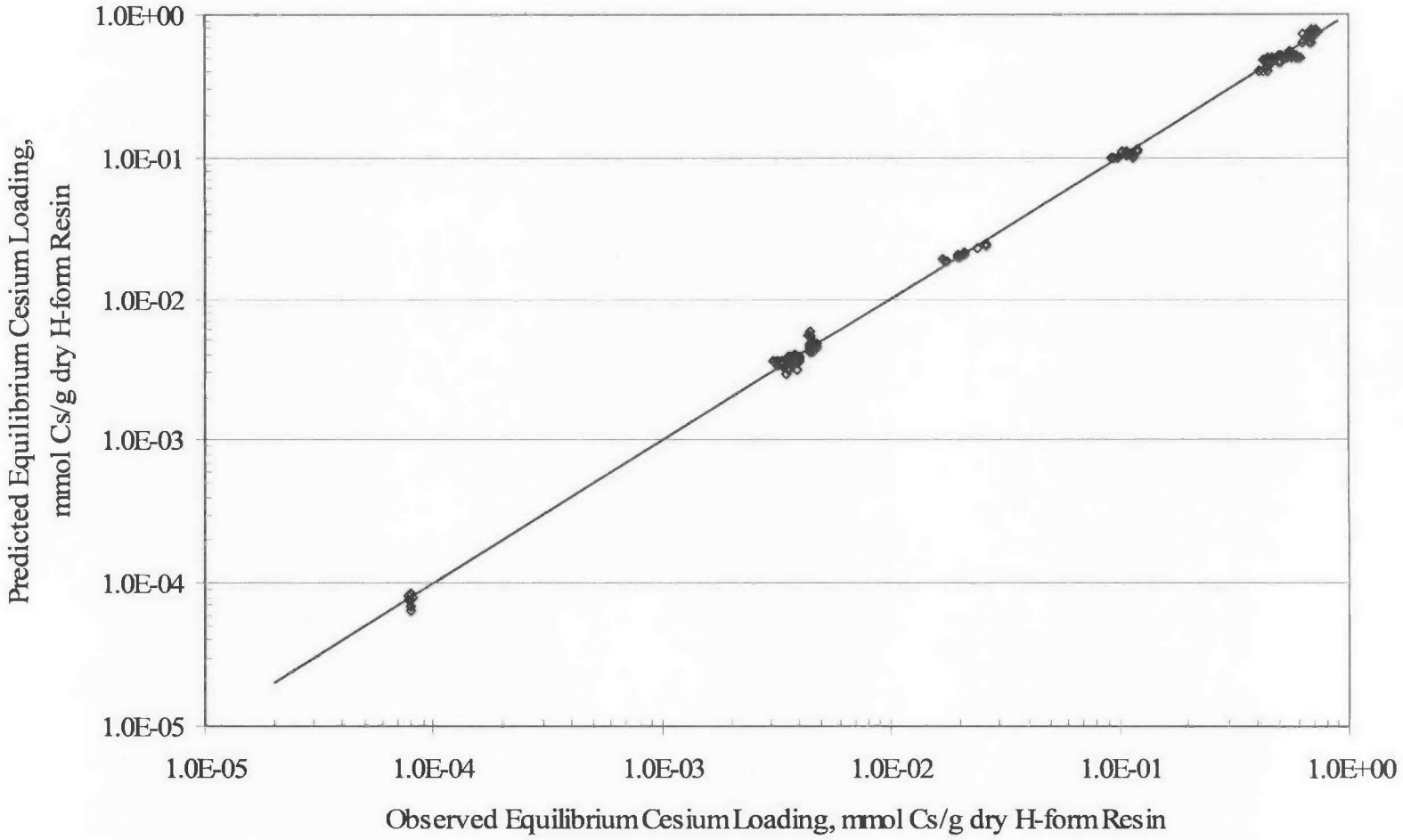
(7) Eluate composition from 2-cm column test (for resin 5E-370/641 from 24590-101-TSA-W000-0004-99-00013, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant*).

(8) Eluate composition from 2-cm column test (resin 5E-370/641 from 24590-101-TSA-W000-0004-72-00017, *Small Column Ion Exchange Testing of Spherical Resorcinol-Formaldehyde Resin for ^{137}Cs Removal from Pre-Treated Hanford Tank 241-AN-102 Waste (Envelope C)*).

(9) Eluate composition from 2-cm column test (resin 5E-370/641 from 24590-101-TSA-W000-0004-174-00001, Spherical *Resorcinol-Formaldehyde Resin Testing for ^{137}Cs Removal from Simulated and Actual Hanford Waste Tank 241-AP-101 Diluted Feed (Envelope A) Using Small Column Ion Exchange*).

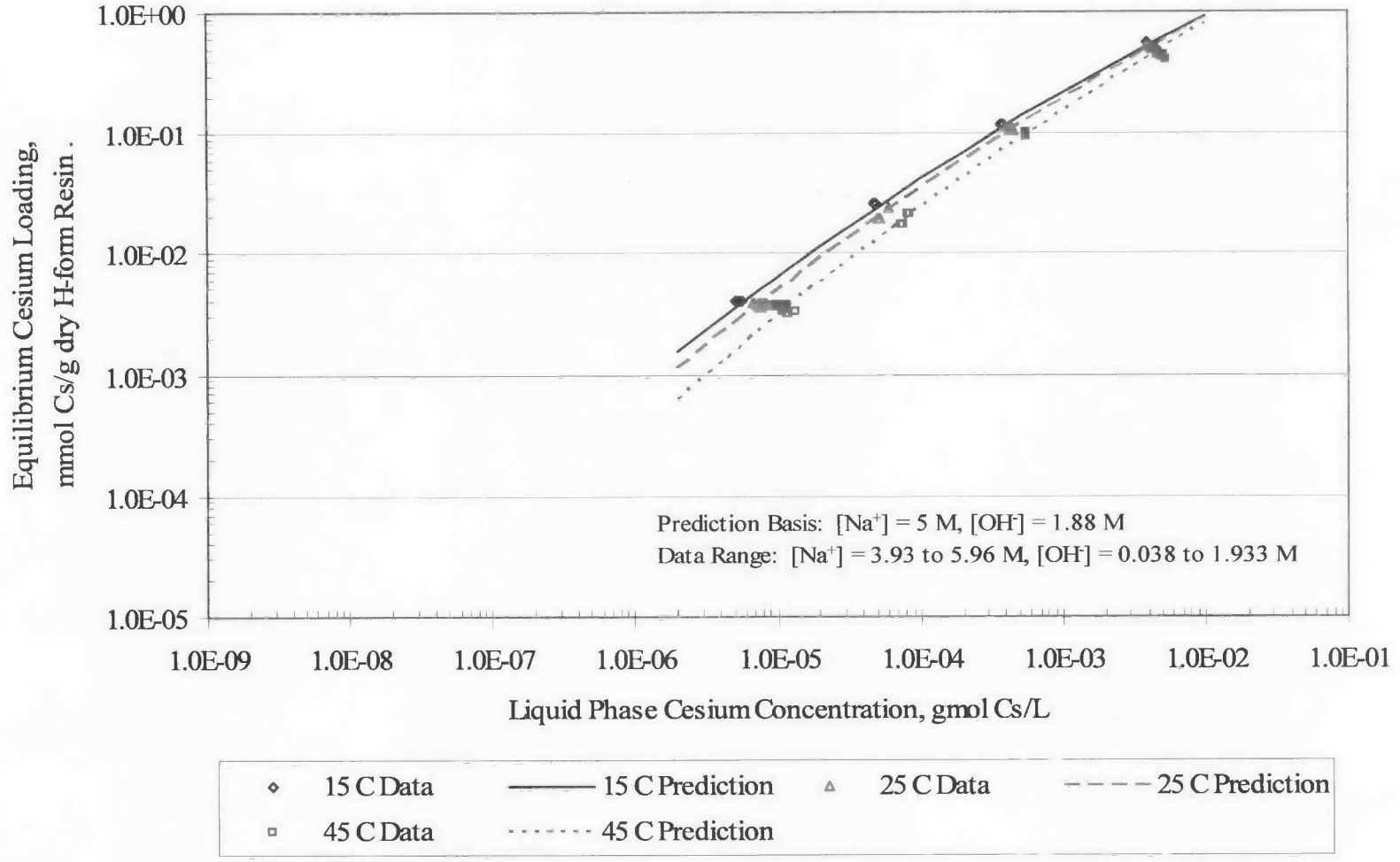
Note: A range is shown for capacities estimated from test column eluate compositions because it is not clear how feed displacement with 0.1 M NaOH and pre-elution rinse with water impact the hydroxide ion concentration applicable to the apparent resin capacity. The range shown varies from an assumed value of 0.03 M to the hydroxide concentration of waste during the loading cycle.

Figure 2.5-22 Comparison of Observed Cs Loading at 15 °C, 25 °C, and 45 °C with Predictions Using Method 1



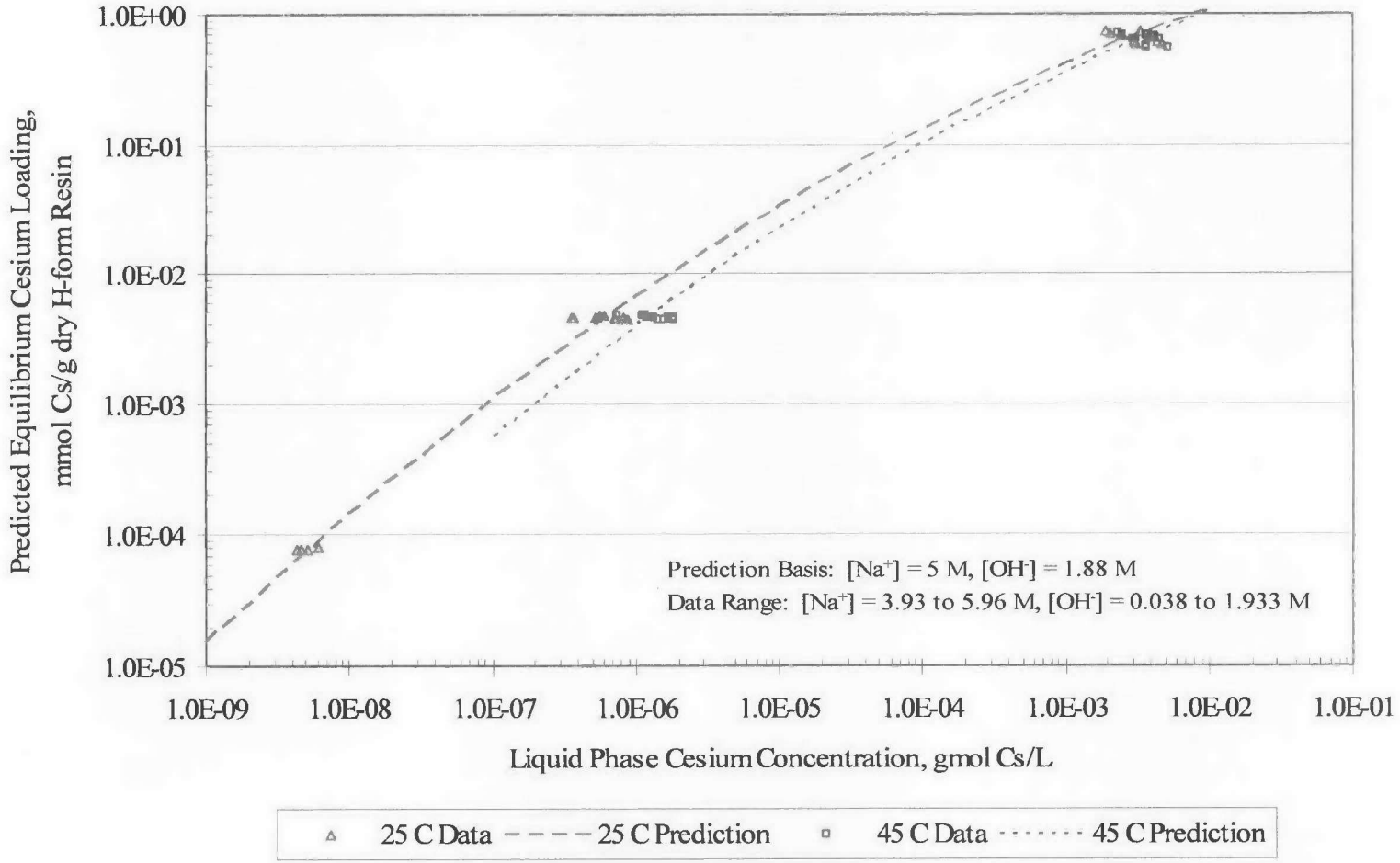
Note: Observed equilibrium Cs loadings are obtained from Table 2.5-14, Table 2.5-15, and Table 2.5-17. Predictions at the same conditions indicated for each data point are obtained using Equation 2.5-33.

Figure 2.5-23 Qualitative Comparison of Spherical Resorcinol-Formaldehyde Cs Batch Equilibrium Loading Predictions Using Method 1 with Test Observations at 15 °C, 25 °C, and 45 °C
(Figure 1 of 2)



(a) [K+] = 0.69 M

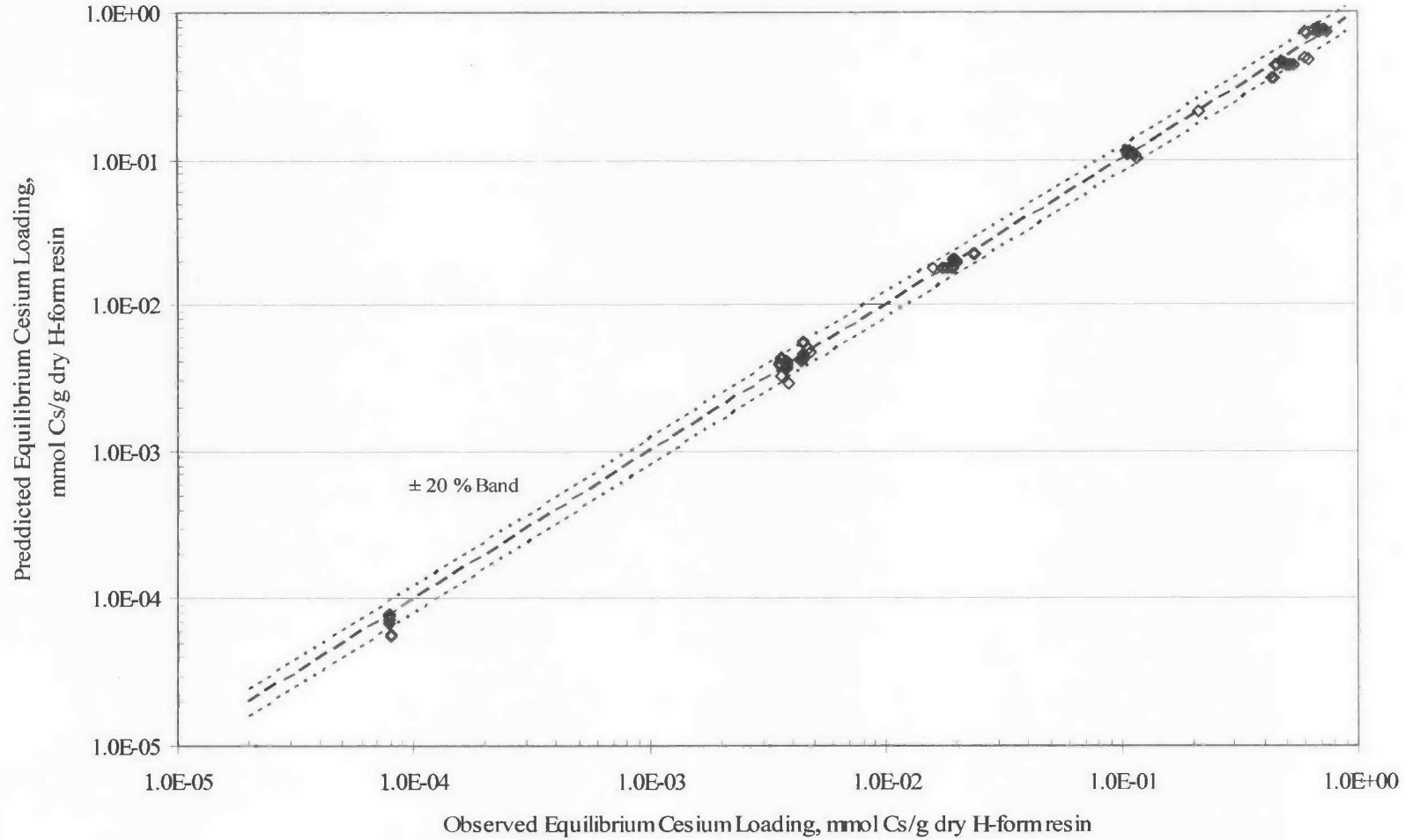
Figure 2.5-23 Qualitative Comparison of Spherical Resorcinol-Formaldehyde Cs Batch Equilibrium Loading Predictions Using Method 1 with Test Observations at 15 °C, 25 °C, and 45 °C
(Figure 2 of 2)



(b) [K+] = 0 M

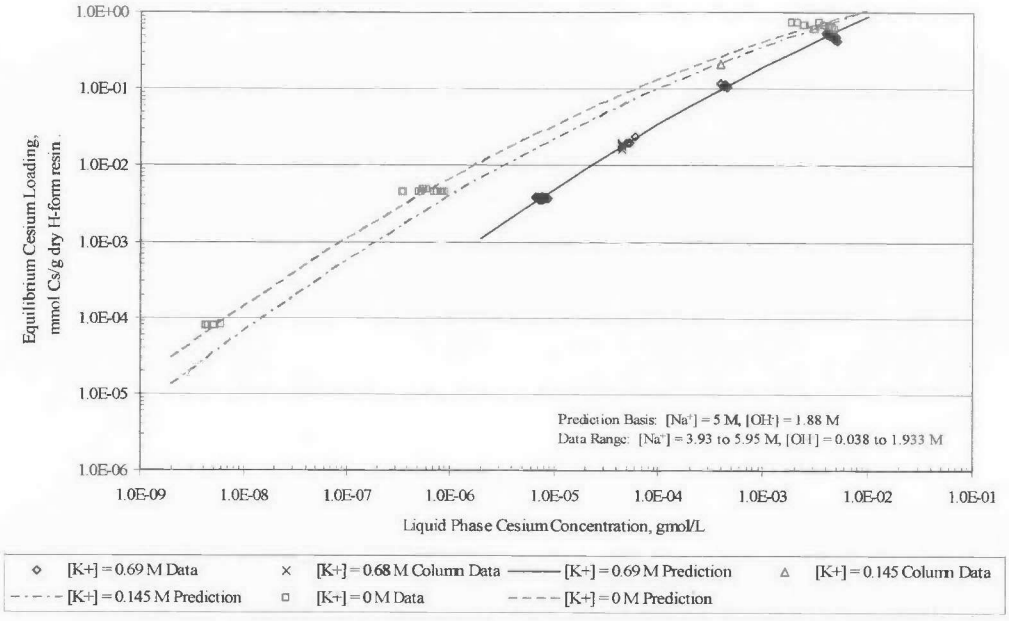
Note: Observed equilibrium Cs loadings are obtained from Table 2.5-14, Table 2.5-15, and Table 2.5-17. Predictions for comparison with data are obtained using Equation 2.5-33.

Figure 2.5-24 Comparison of Observed Cs Loading at 25 °C with Predictions Using Method 2

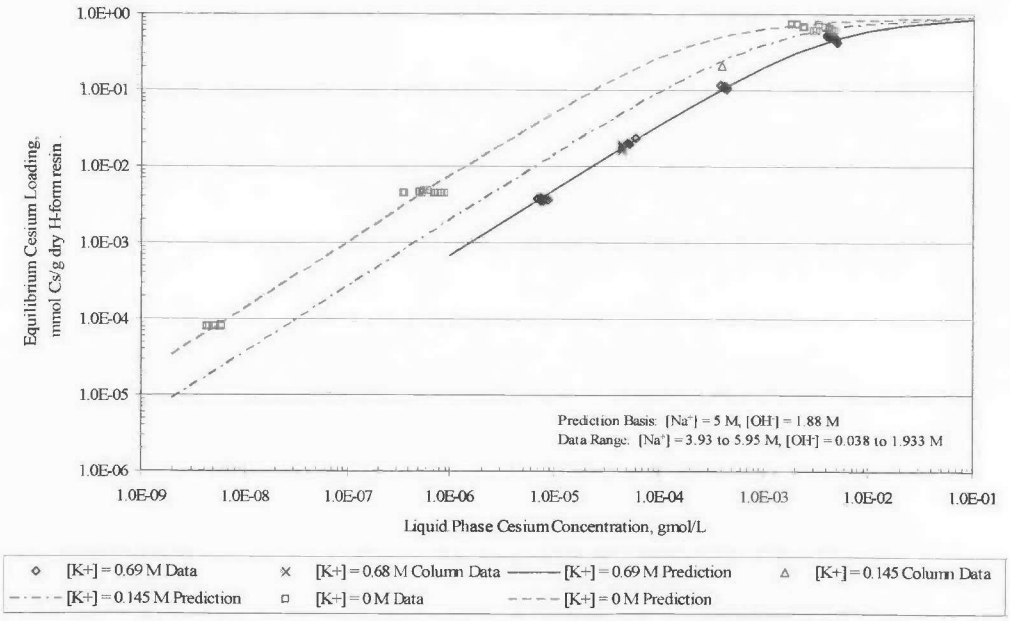


Note: Observed equilibrium Cs loadings are obtained from Table 2.5-15 and Table 2.5-16. Predictions at the same conditions indicated for each data point are obtained using Equation 2.5-35 and Equation 2.5-37.

Figure 2.5-25 Qualitative Comparison of Spherical Resorcinol-Formaldehyde Cs Batch Equilibrium Loading Predictions with Test Observations at 25 °C



(a) Prediction Method 1 using Equation 2.5-33



(b) Prediction Method 2 using Equation 2.5-35 and Equation 2.5-37

Note: Observed equilibrium Cs loadings are obtained from Table 2.5-15 and Table 2.5-16.

Figure 2.5-26 Comparison of Predicted Batch Equilibrium Cs Loading for Spherical Resorcinol-Formaldehyde Using Prediction Methods 1 and 2

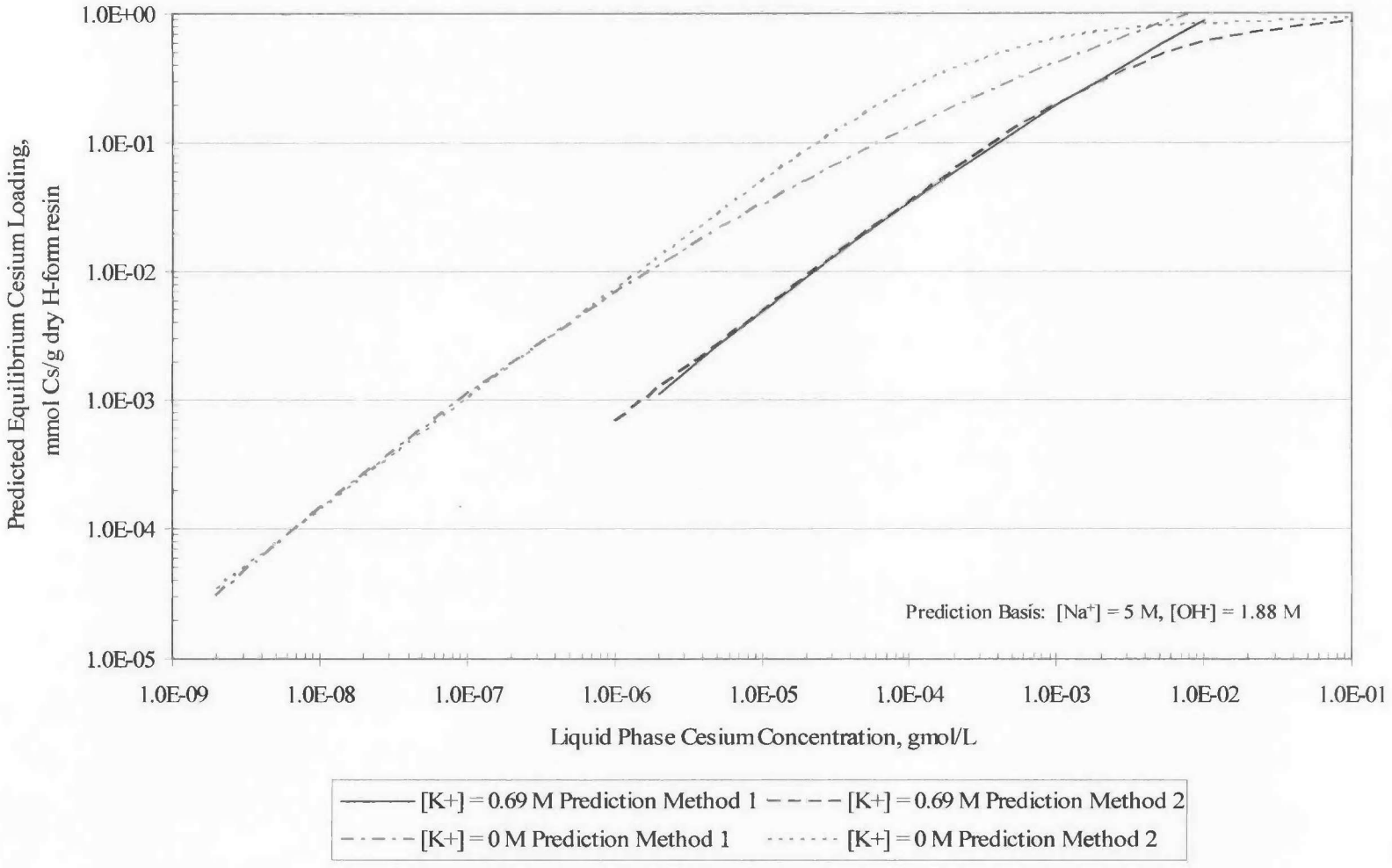
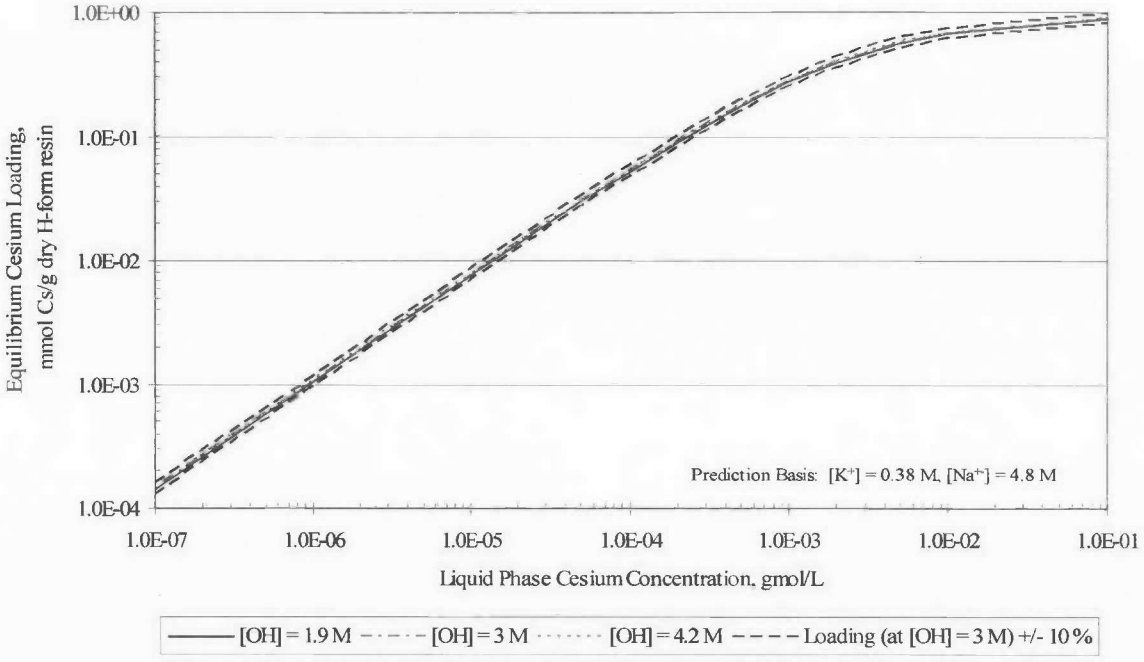
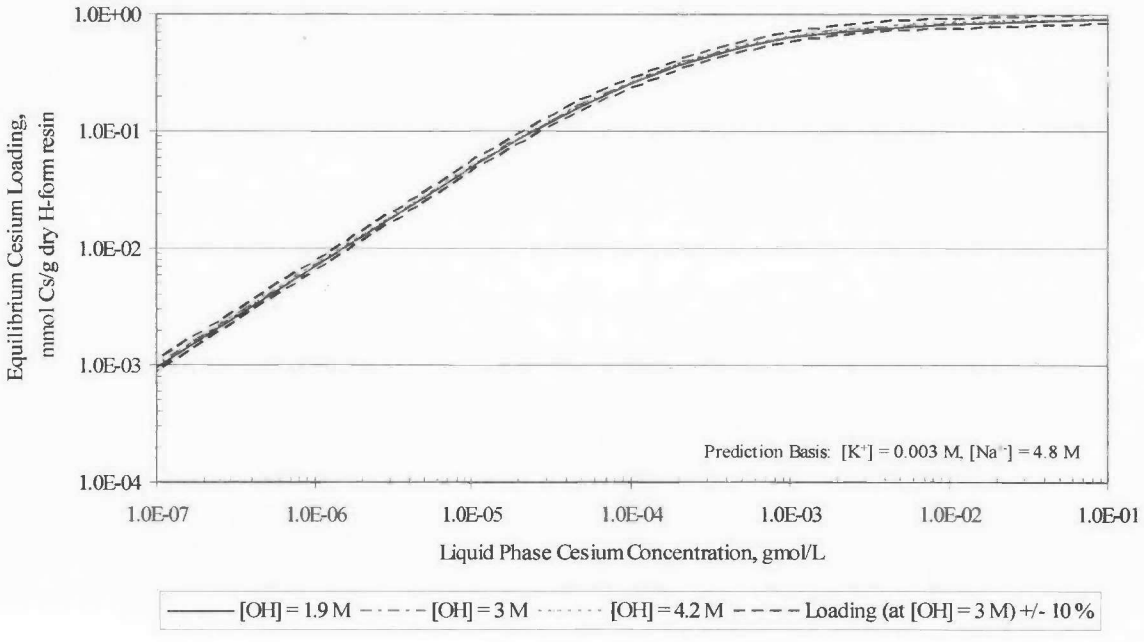


Figure 2.5-27 Sensitivity of Resin Cs Loading to Hydroxide Ion Concentration under Loading Cycle Conditions

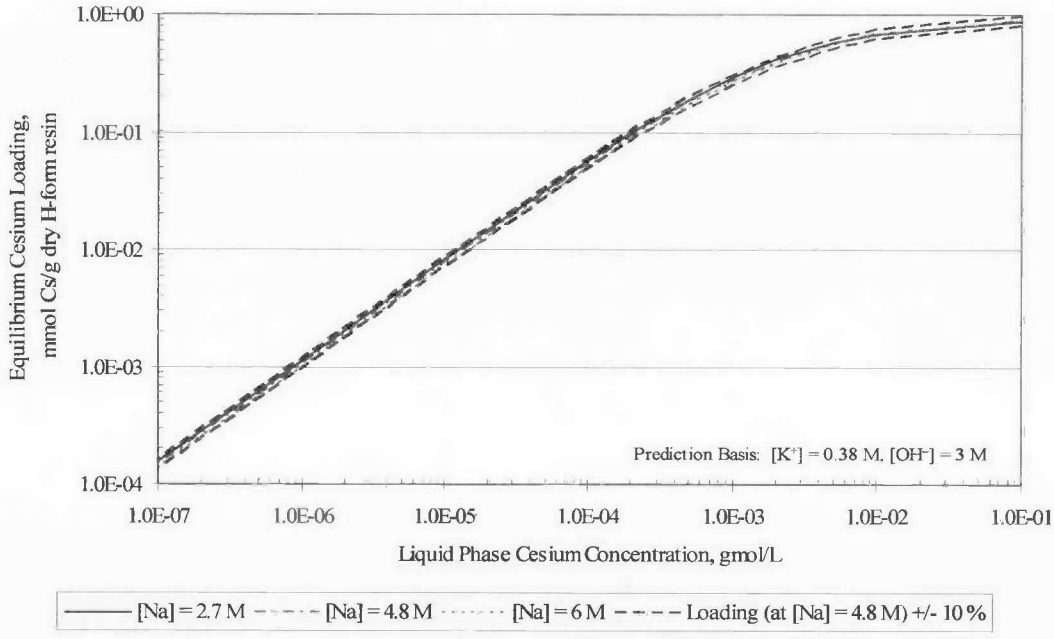


(a) High Potassium Ion Concentration

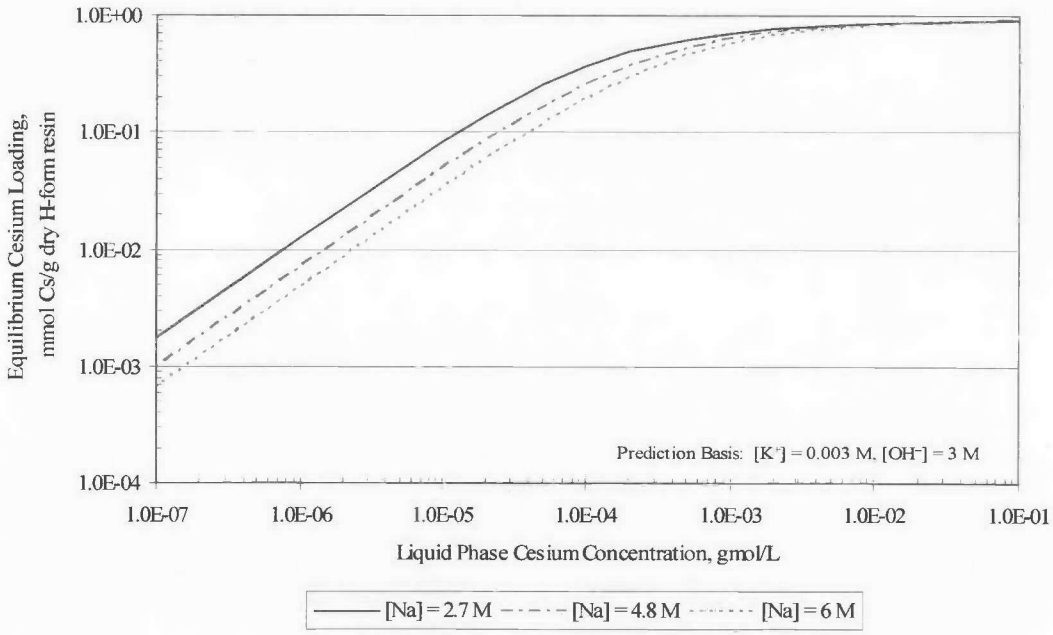


(b) Low Potassium Ion Concentration

Figure 2.5-28 Sensitivity of Resin Cs Loading to Sodium Ion Concentration under Loading Cycle Conditions

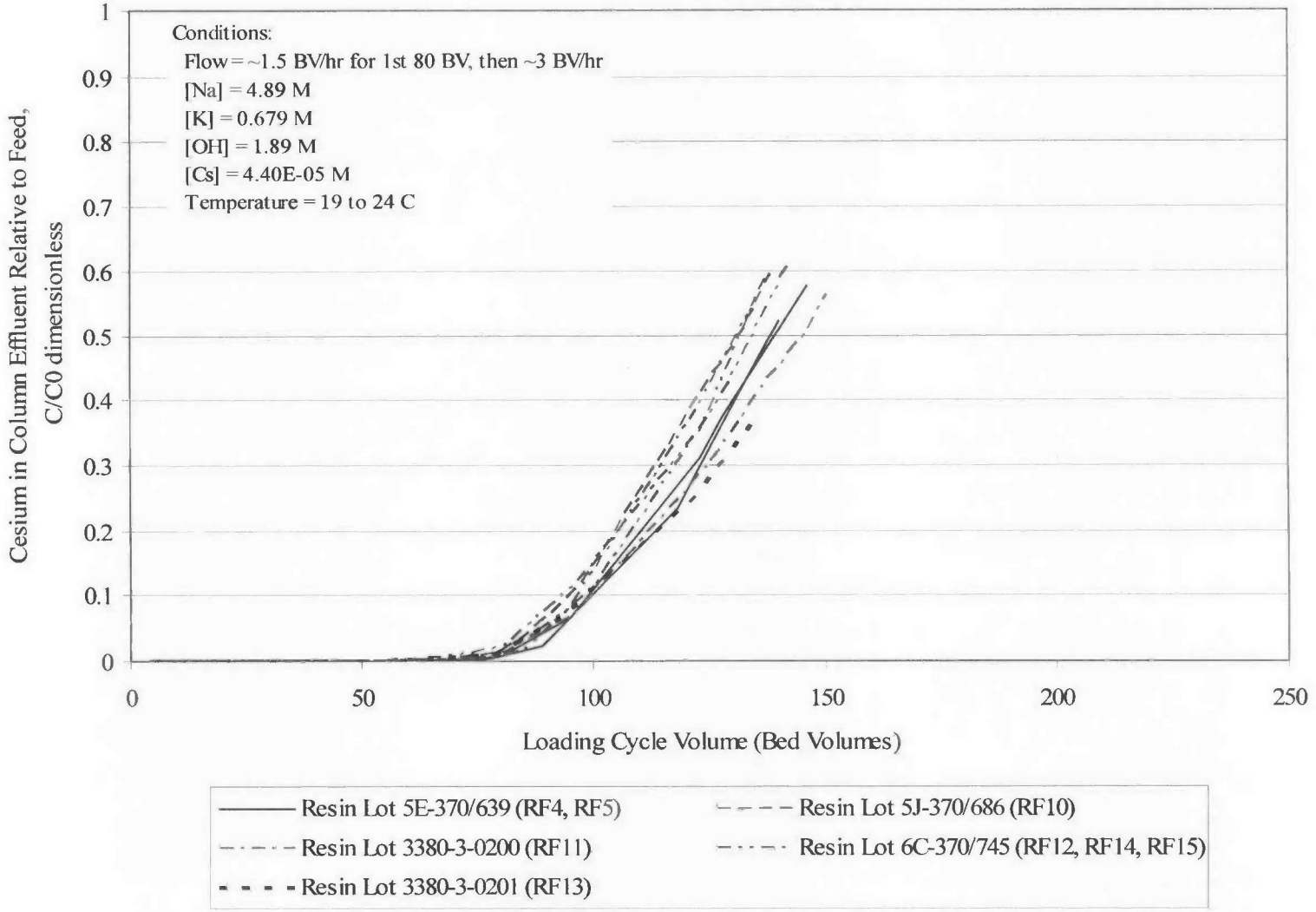


(a) High Potassium Ion Concentration



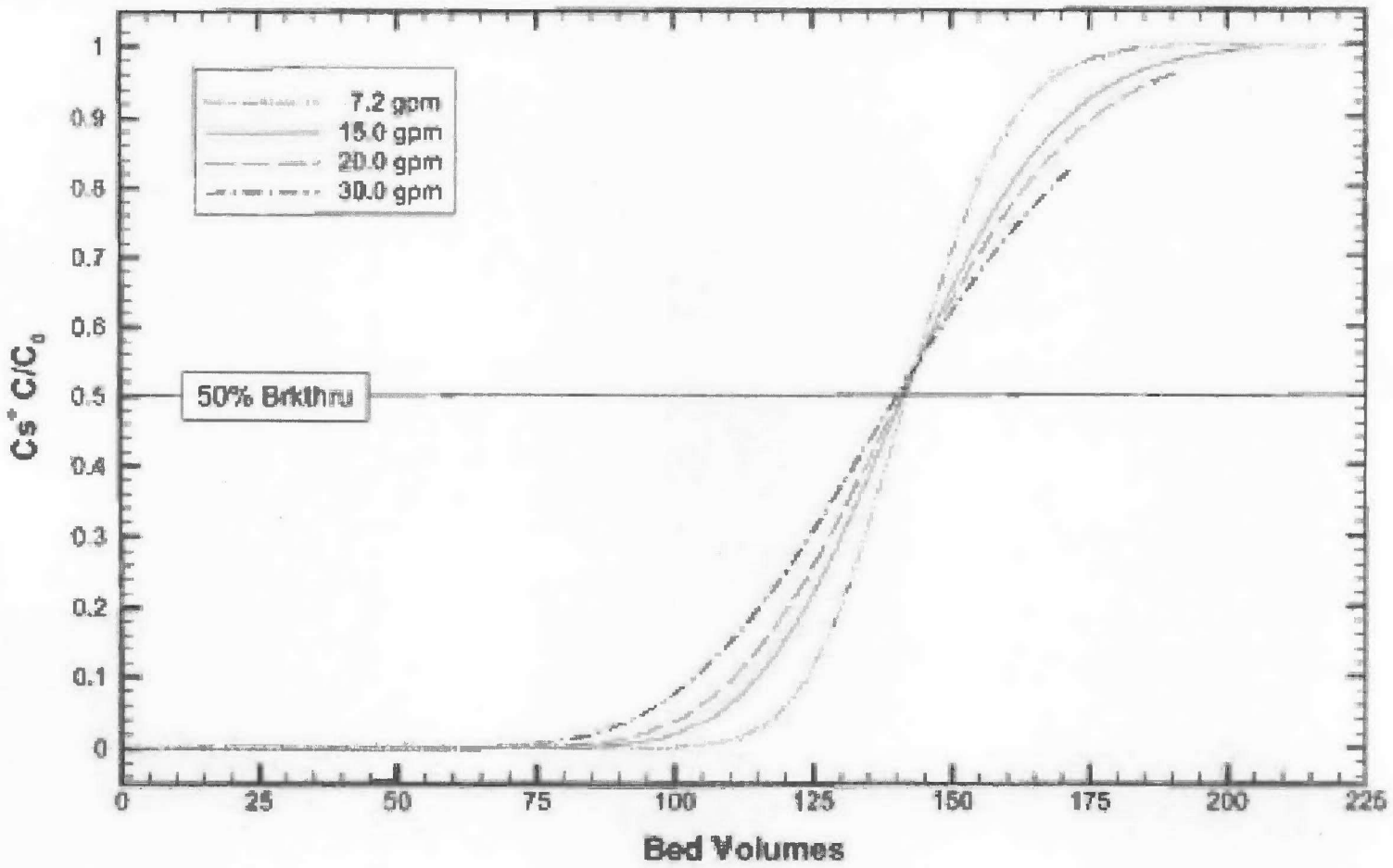
(b) Low Potassium Ion Concentration

Figure 2.5-29 Influence of Resin Batch on Cs Breakthrough Test Observations



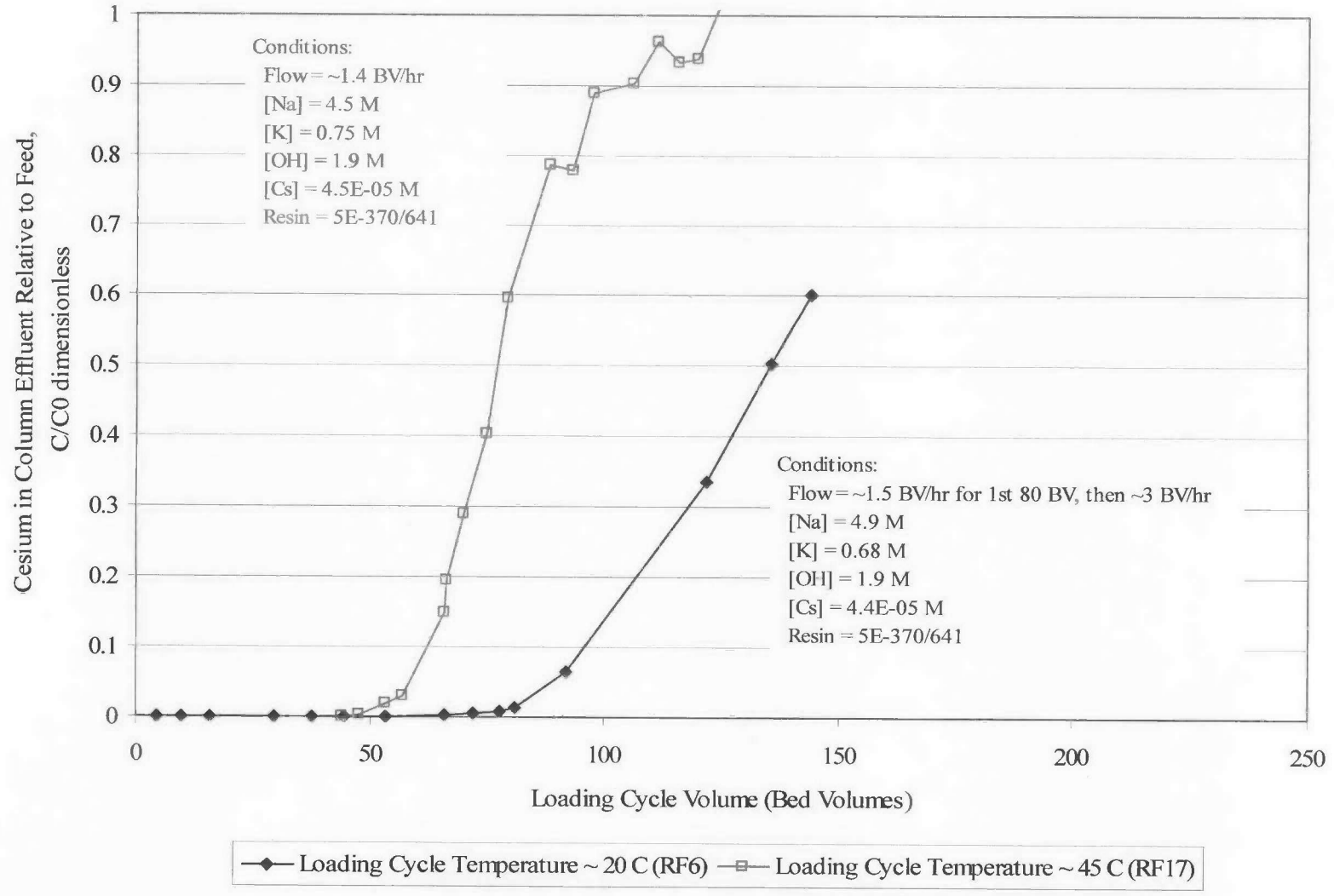
See Table 2.5-20 for data source based on Column Test ID.

Figure 2.5-30 Predicted Variation of Cs Breakthrough with Waste Feed Flow Rate



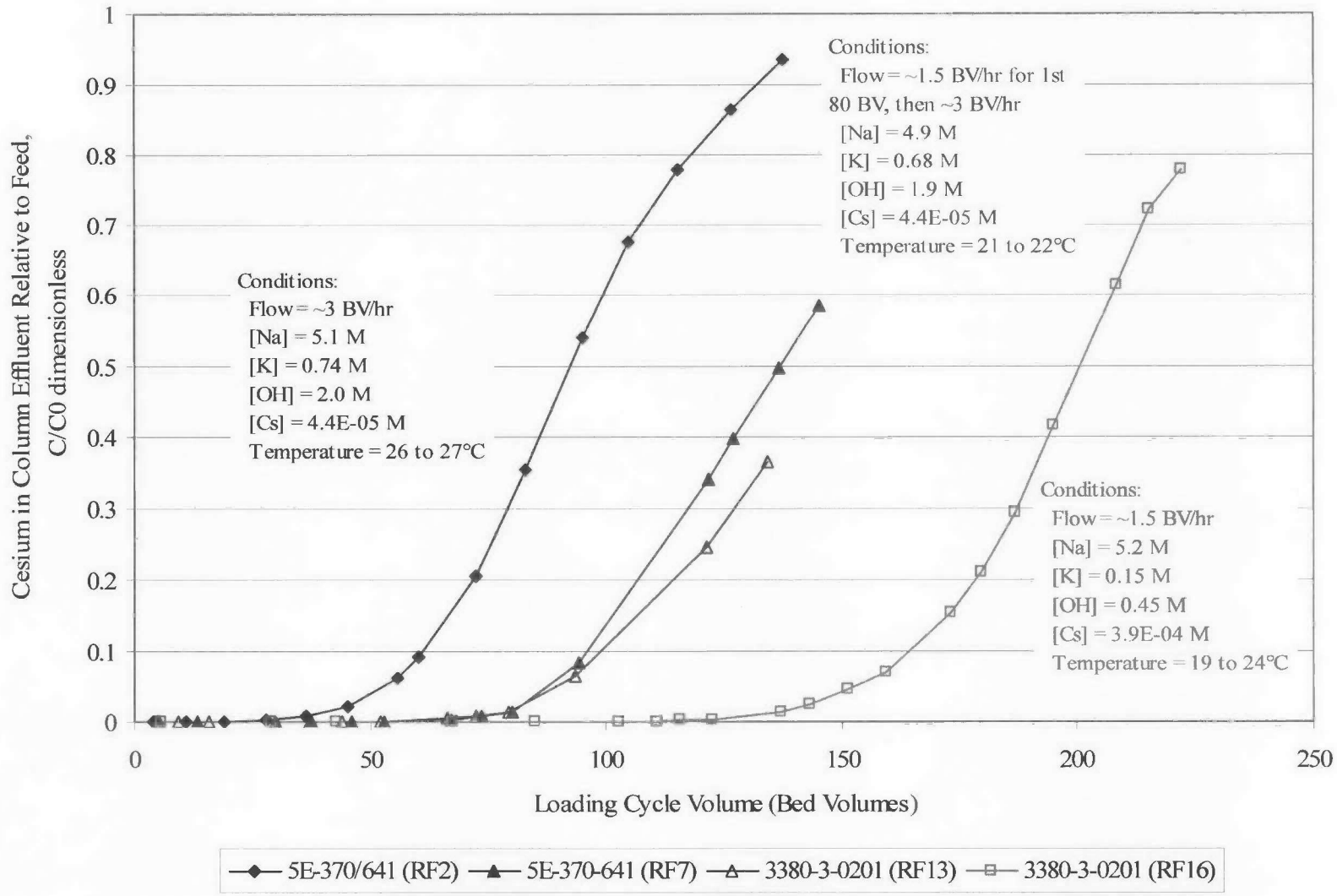
Source: SCT-M0SRLE60-00-05-00004, Rev 00A, *Ion Exchange Modeling of Cs Removal from Hanford Waste using Spherical Resorcinol-Formaldehyde Resin* (Figure 10-65).

Figure 2.5-31 Influence of Feed Temperature on Observed Cs Breakthrough Curve



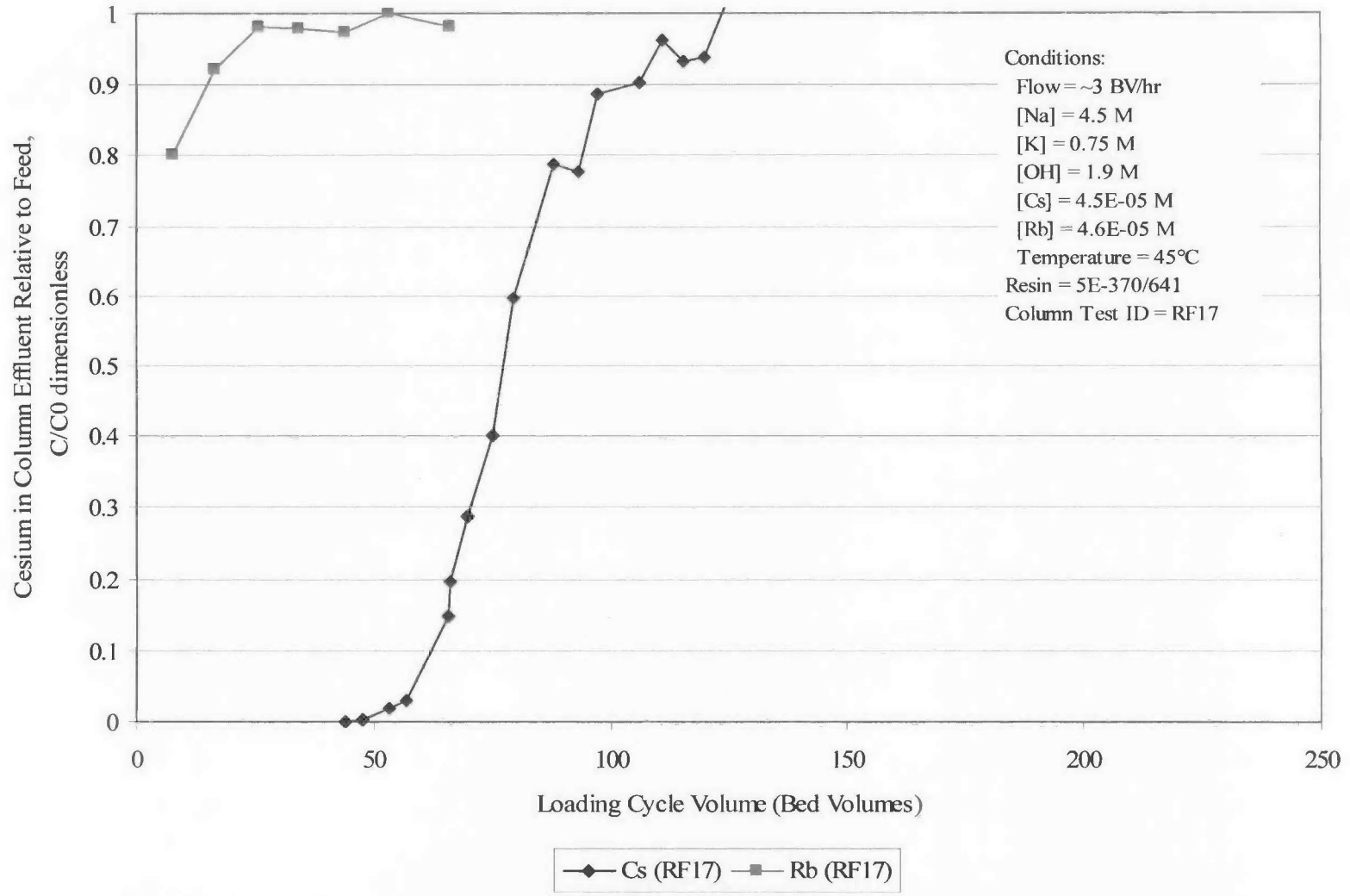
See Table 2.5-20 for data source based on Column Test ID.

Figure 2.5-32 Influence of Feed Potassium Concentration on Observed Cs Breakthrough Curve



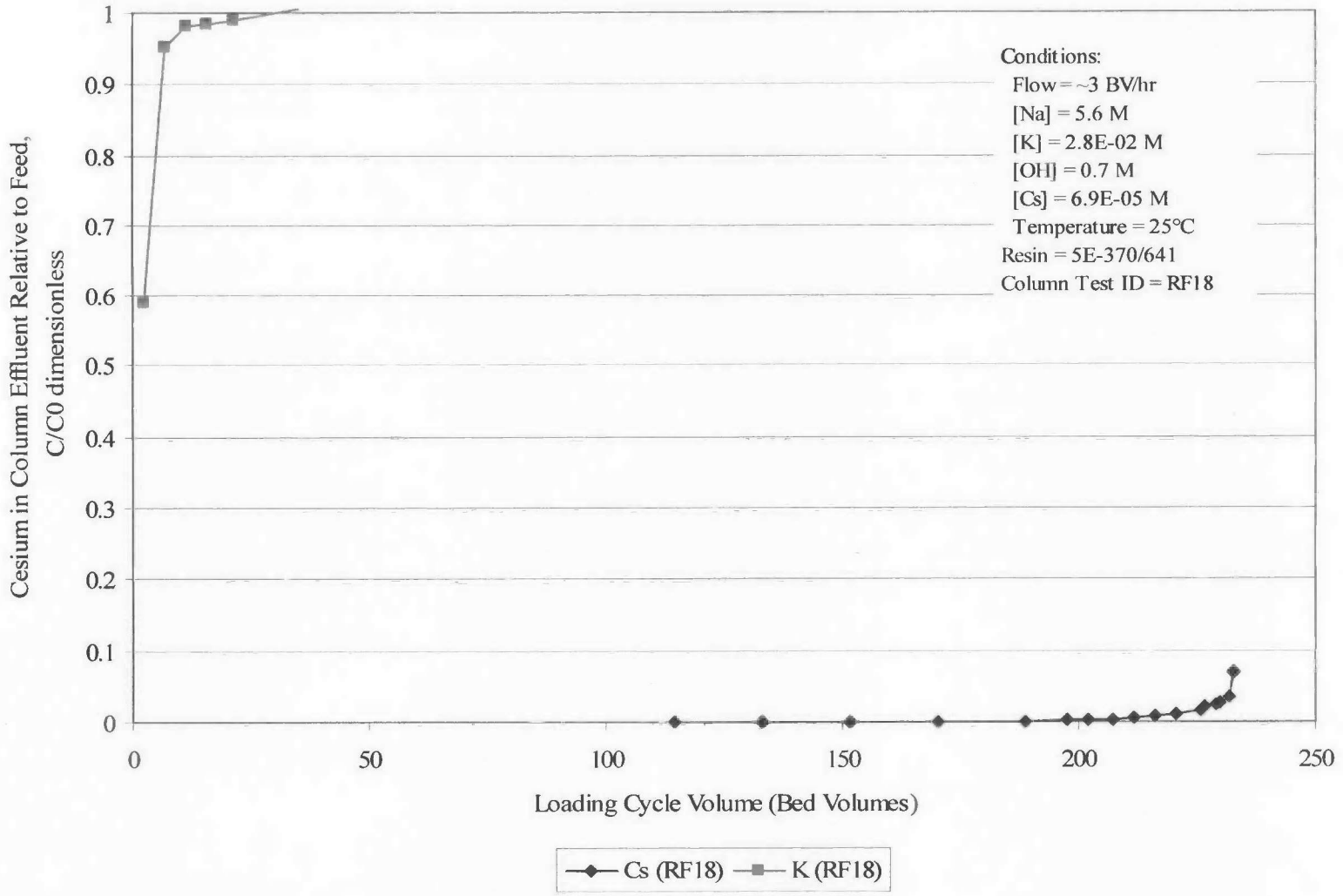
See Table 2.5-20 for data source based on Column Test ID.

Figure 2.5-33 Comparison of Observed Cs and Rubidium Breakthrough Curves



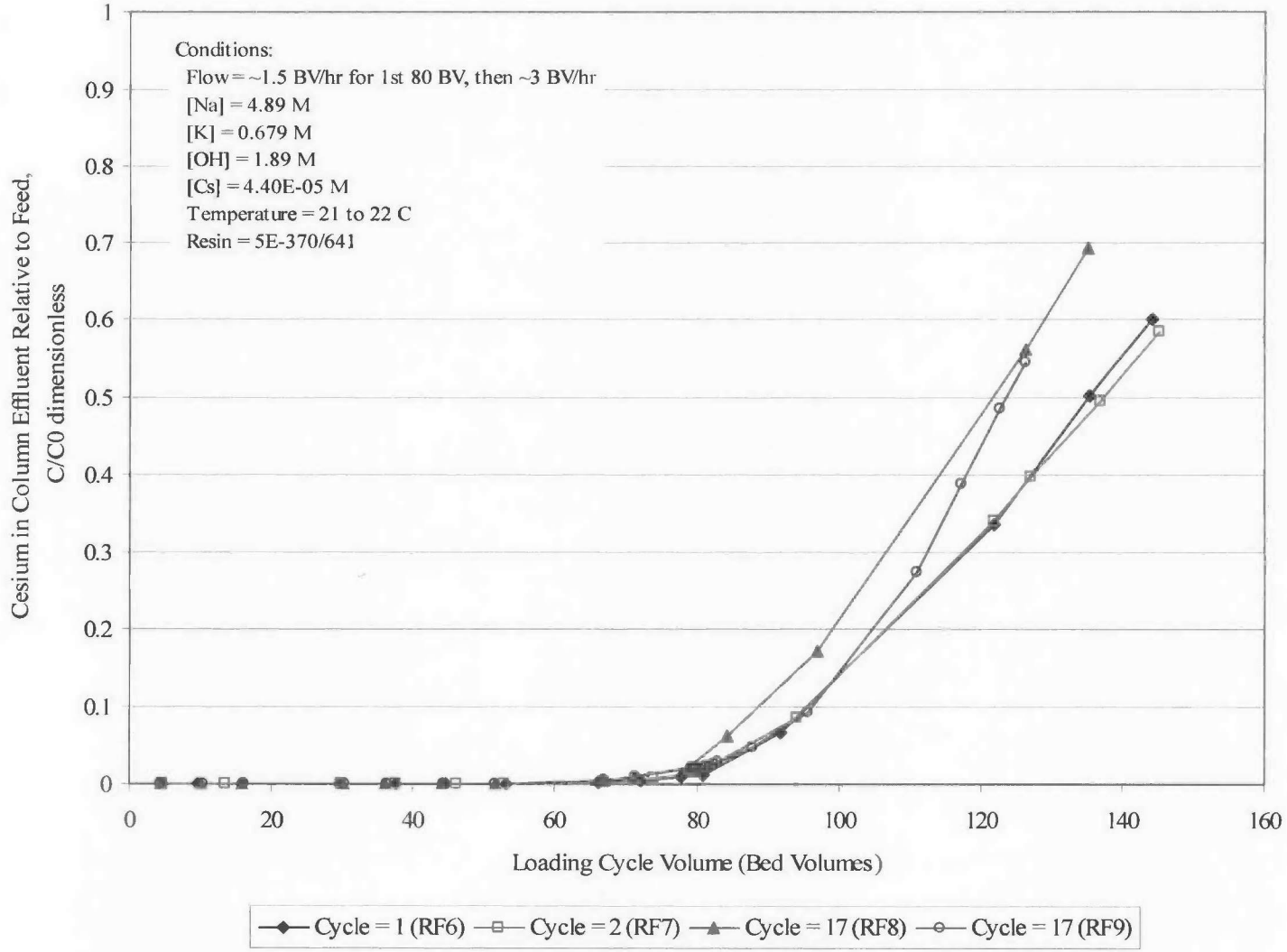
Source: SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin.* Data obtained using material from resin lot 5E-370/641.

Figure 2.5-34 Comparison of Observed Cs and Potassium Breakthrough Curves



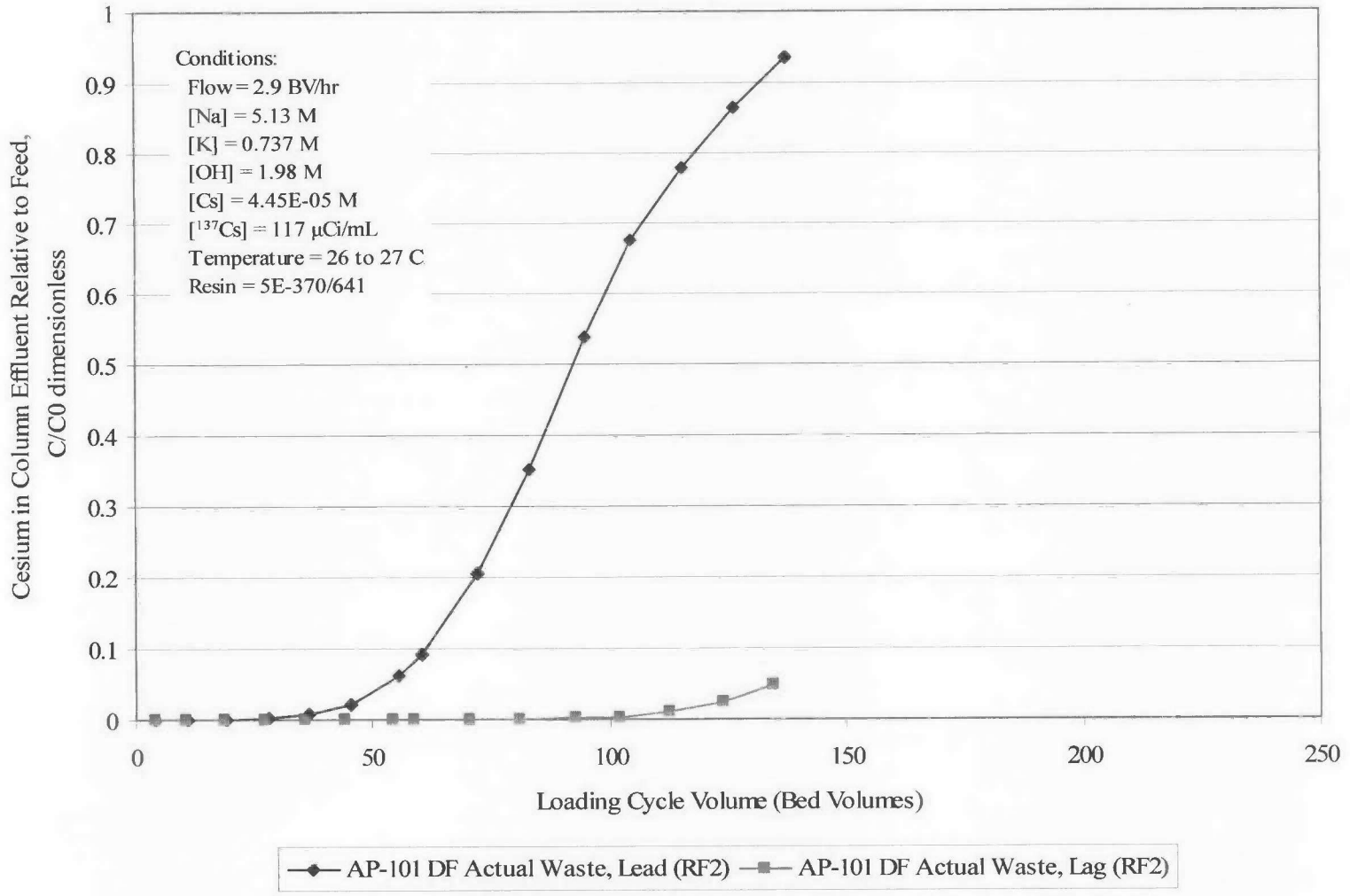
Source: SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin.* Data obtained using material from resin lot 5E-370/641.

Figure 2.5-35 Influence of Chemical Degradation on Observed Cs Breakthrough Curve



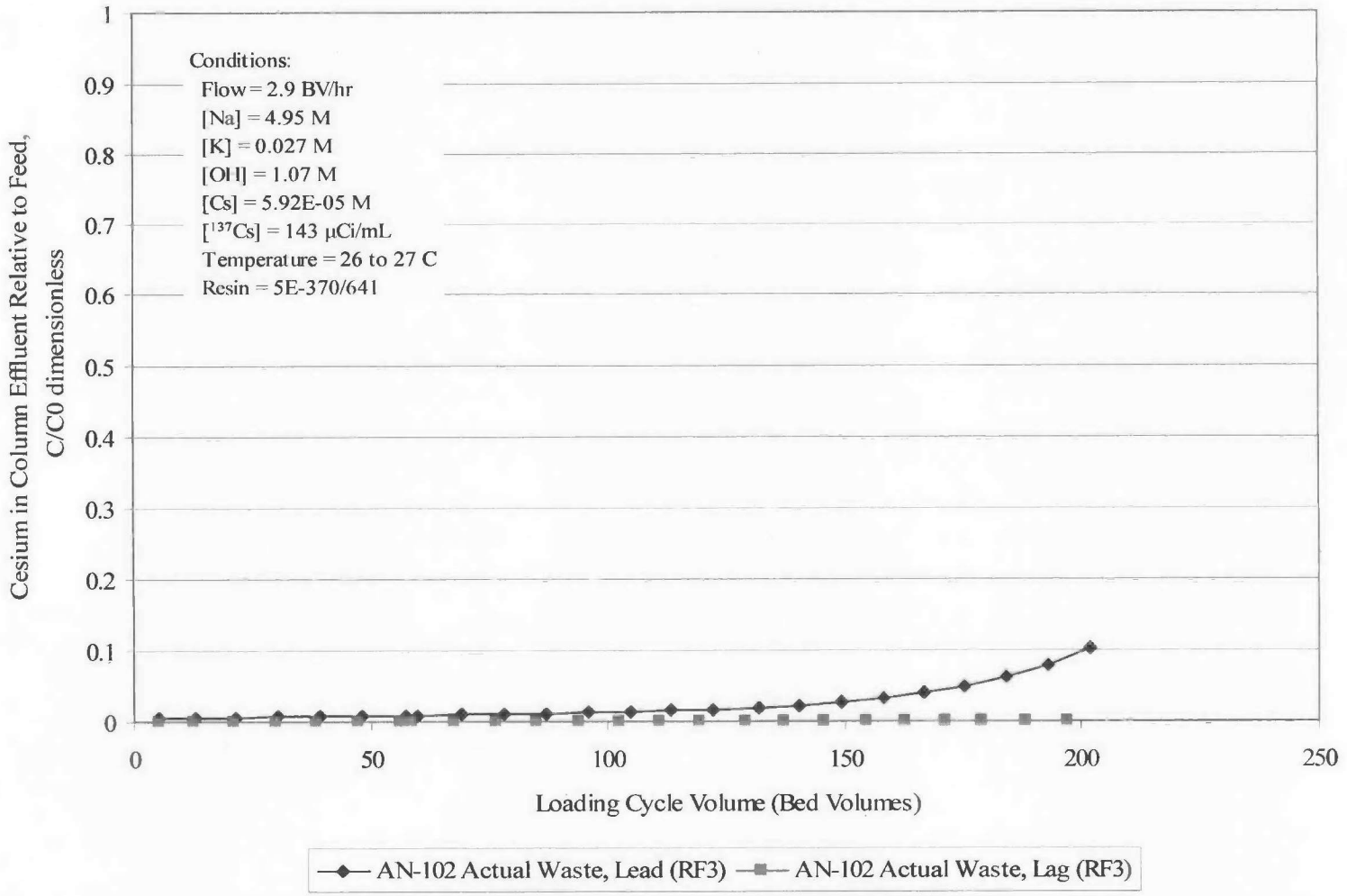
See Table 2.5-20 for data source based on Column Test ID.

Figure 2.5-36 Lead/Lag Column Cs Breakthrough Curves Processing AP-101 Actual Waste



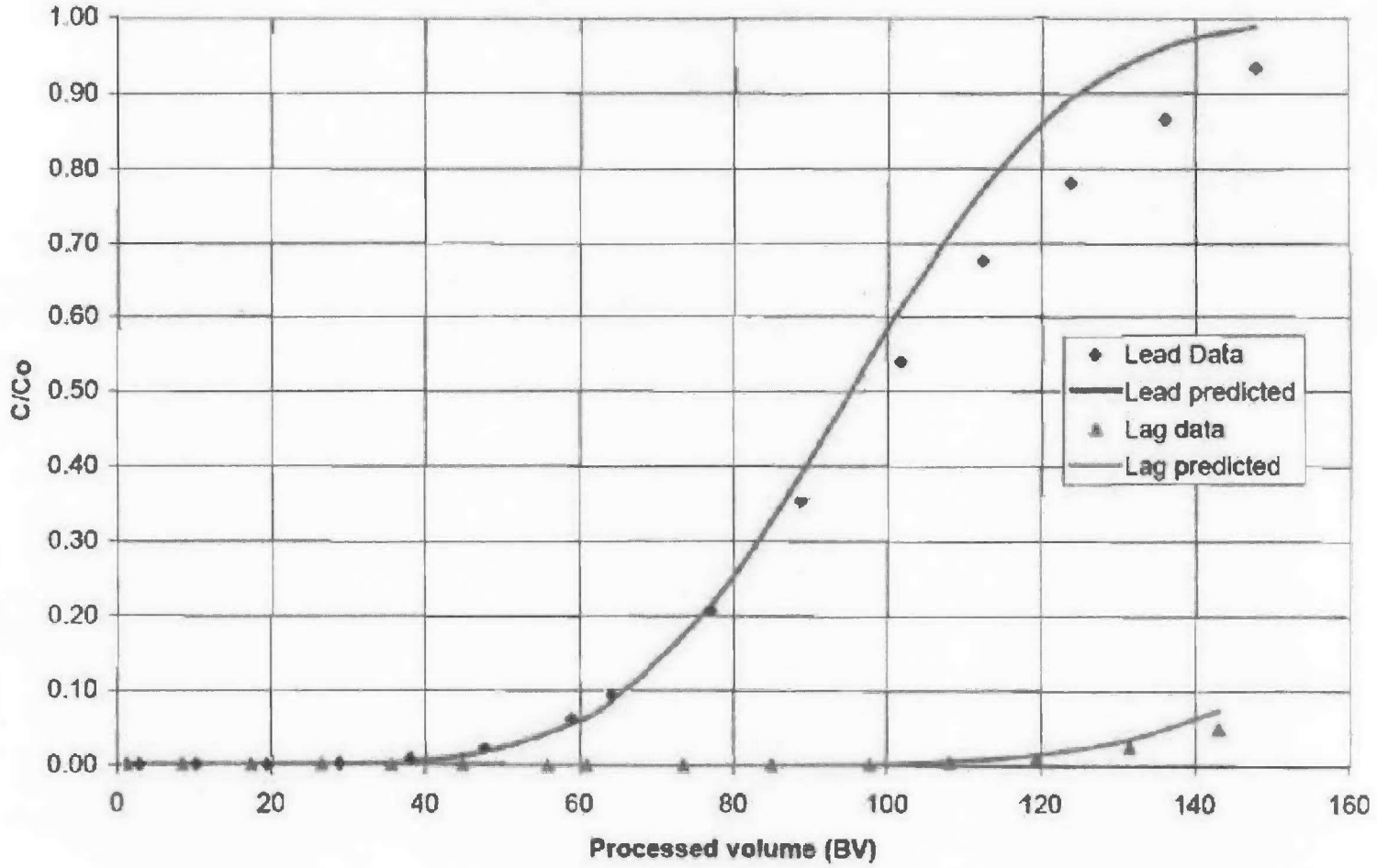
See Table 2.5-20 for data source based on Column Test ID.

Figure 2.5-37 Lead/Lag Column Cs Breakthrough Curves Processing AN-102 Actual Waste



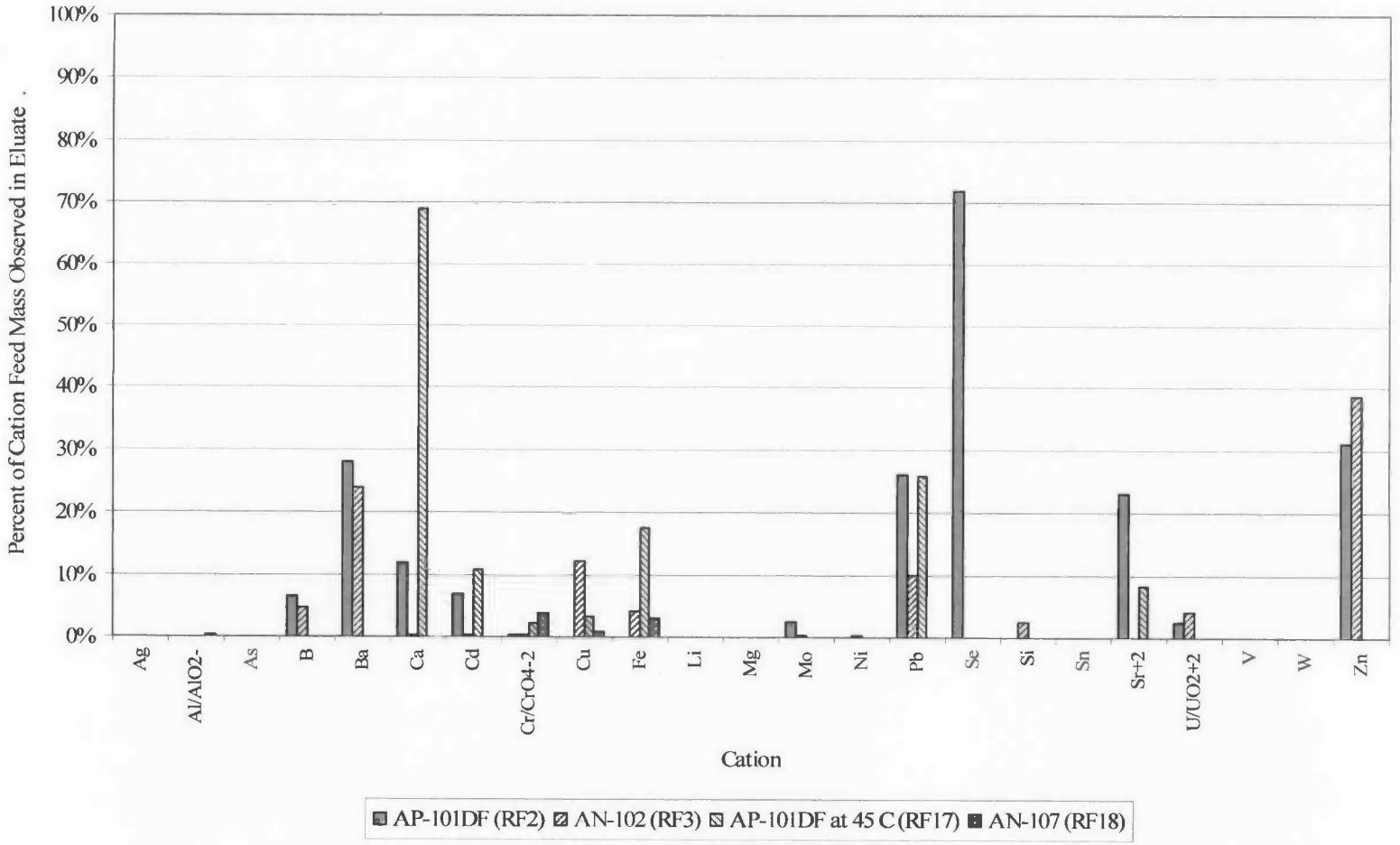
See Table 2.5-20 for data source based on Column Test ID.

Figure 2.5-38 Ion Chromatography Prediction to Loading Cycle Benchmark Test Data



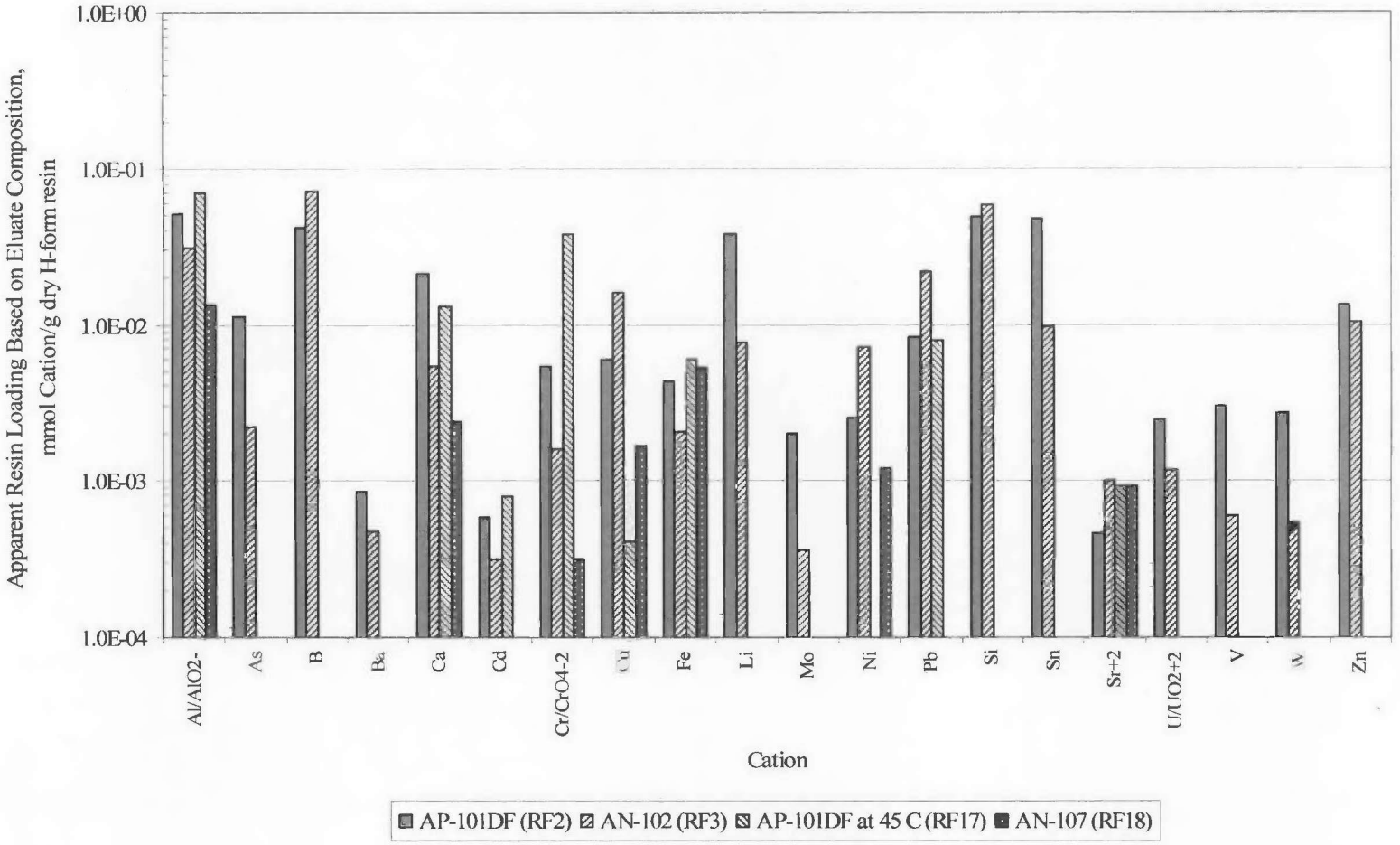
Source: Figure 20 of 24590-WTP-RPT-RT-07-005, *Basis of Recommendation for Use of Spherical Resorcinol Formaldehyde Resin as the Primary Cesium Ion Exchange Resin in the WTP*. Data from Column Test ID RF2 (see Table 2.5-20).

Figure 2.5-39 Cations Observed in Column Test Eluate as Fraction of Feed Mass



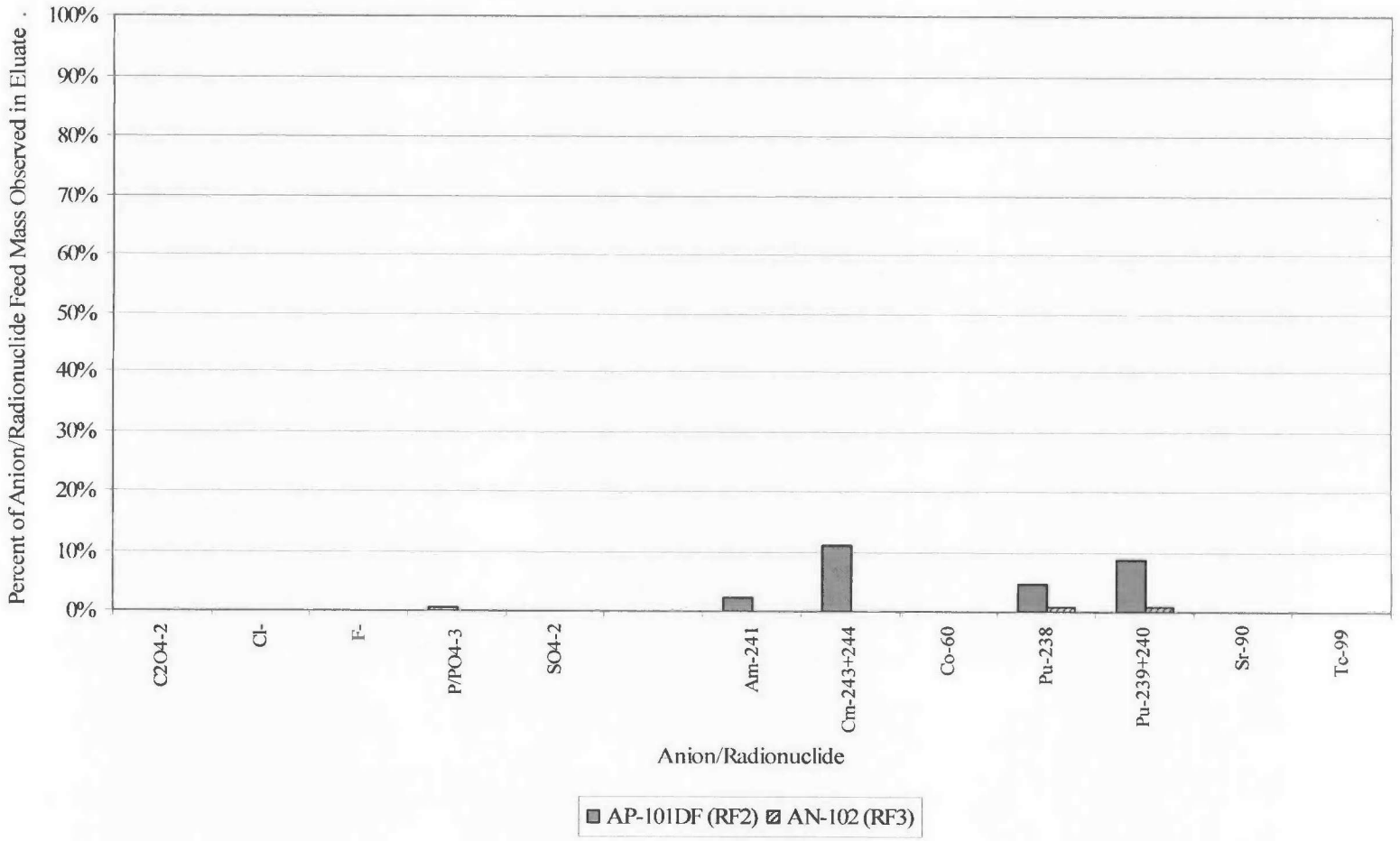
See Table 2.5-20 for data source based on Column Test ID. Omits sodium, potassium, and Cs ions.

Figure 2.5-40 Cations Observed in Column Eluate Relative to Resin Bed Mass



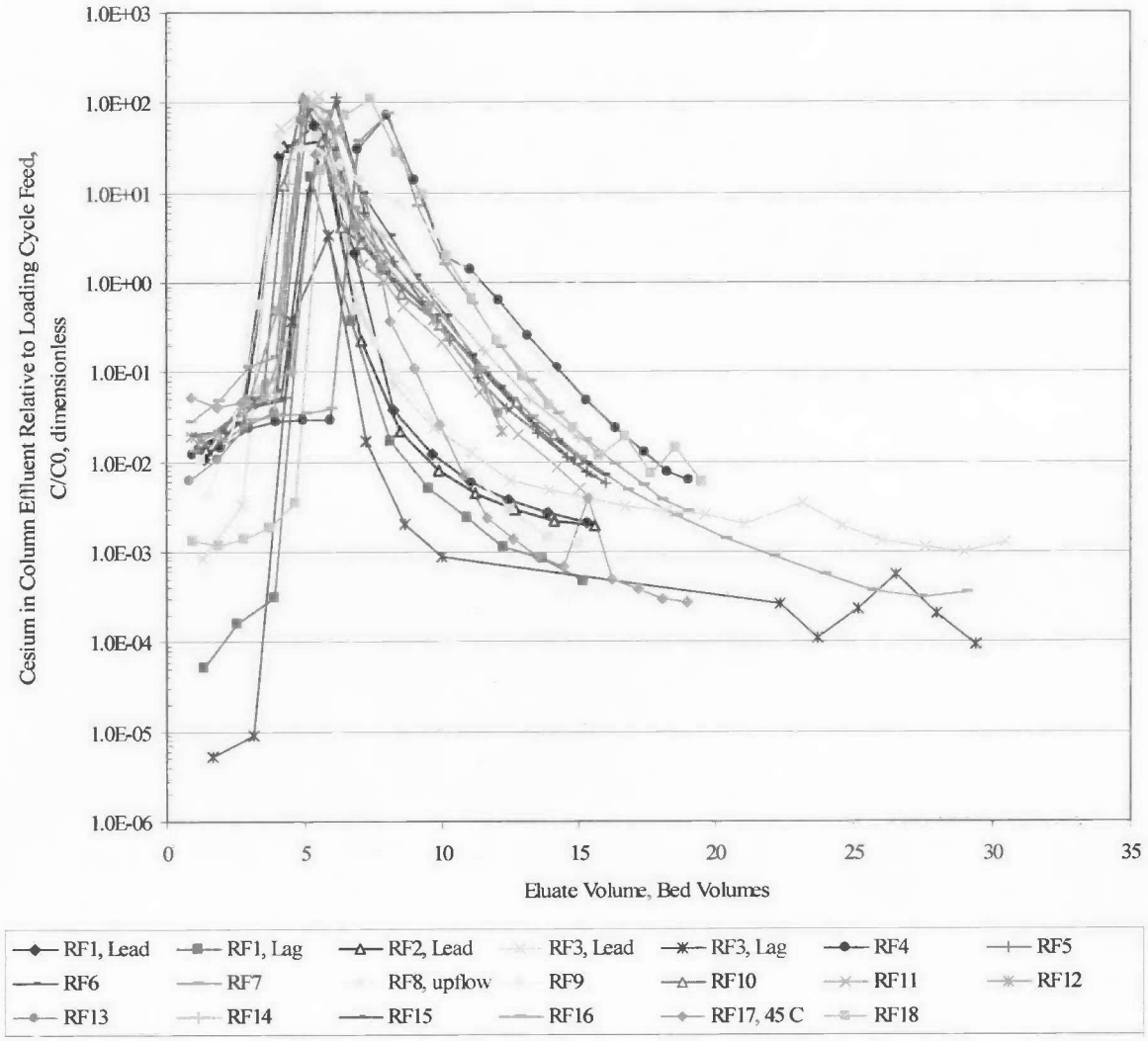
See Table 2.5-20 for data source based on Column Test ID. Omits sodium, potassium, and Cs ions.

Figure 2.5-41 Anions and Radionuclides Observed in Column Test Eluate



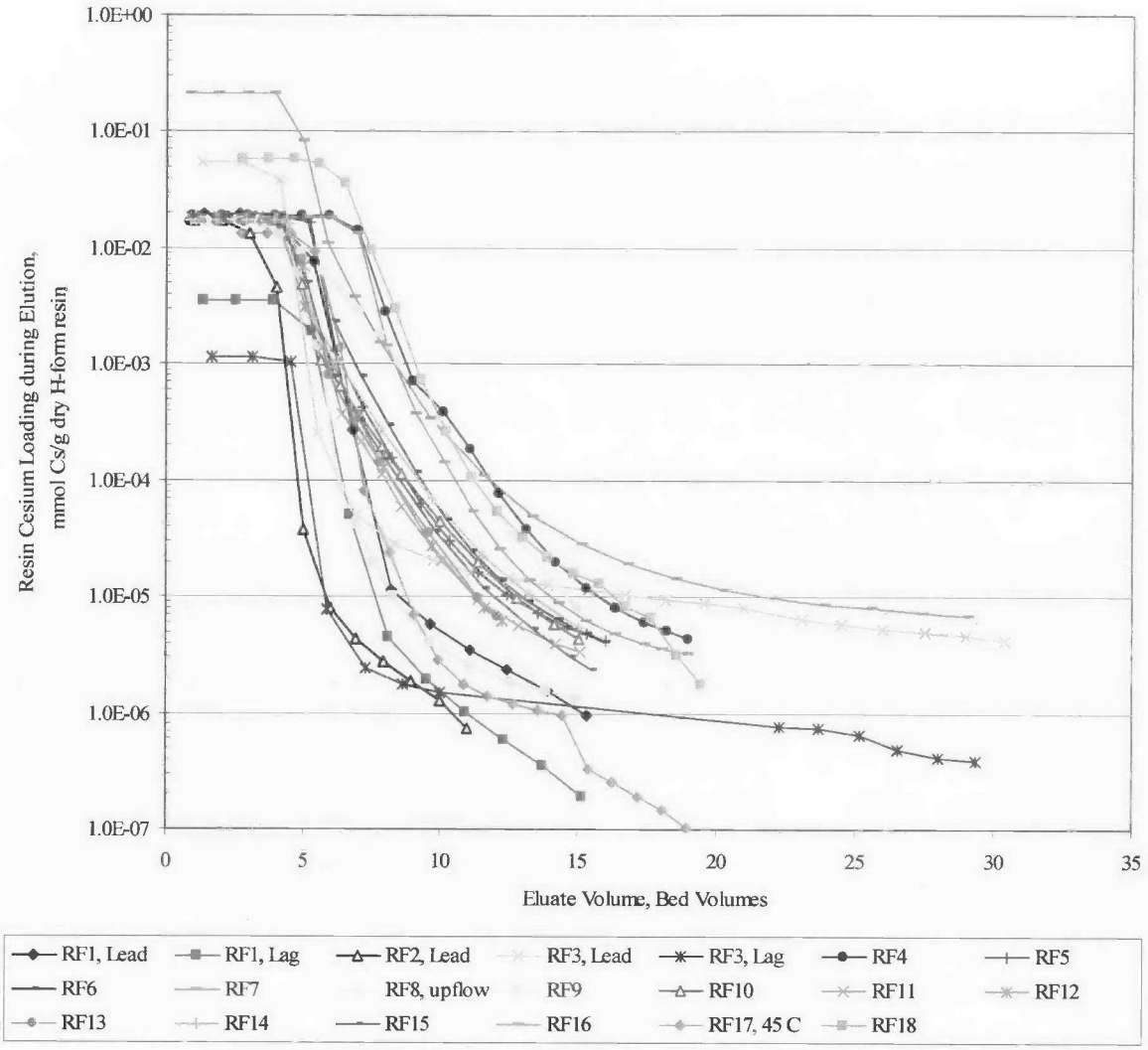
See Table 2.5-20 for data source based on Column Test ID. Omits nitrate ion and Cs isotopes.

Figure 2.5-42 Summary of Cs Elution Profiles from Test Data



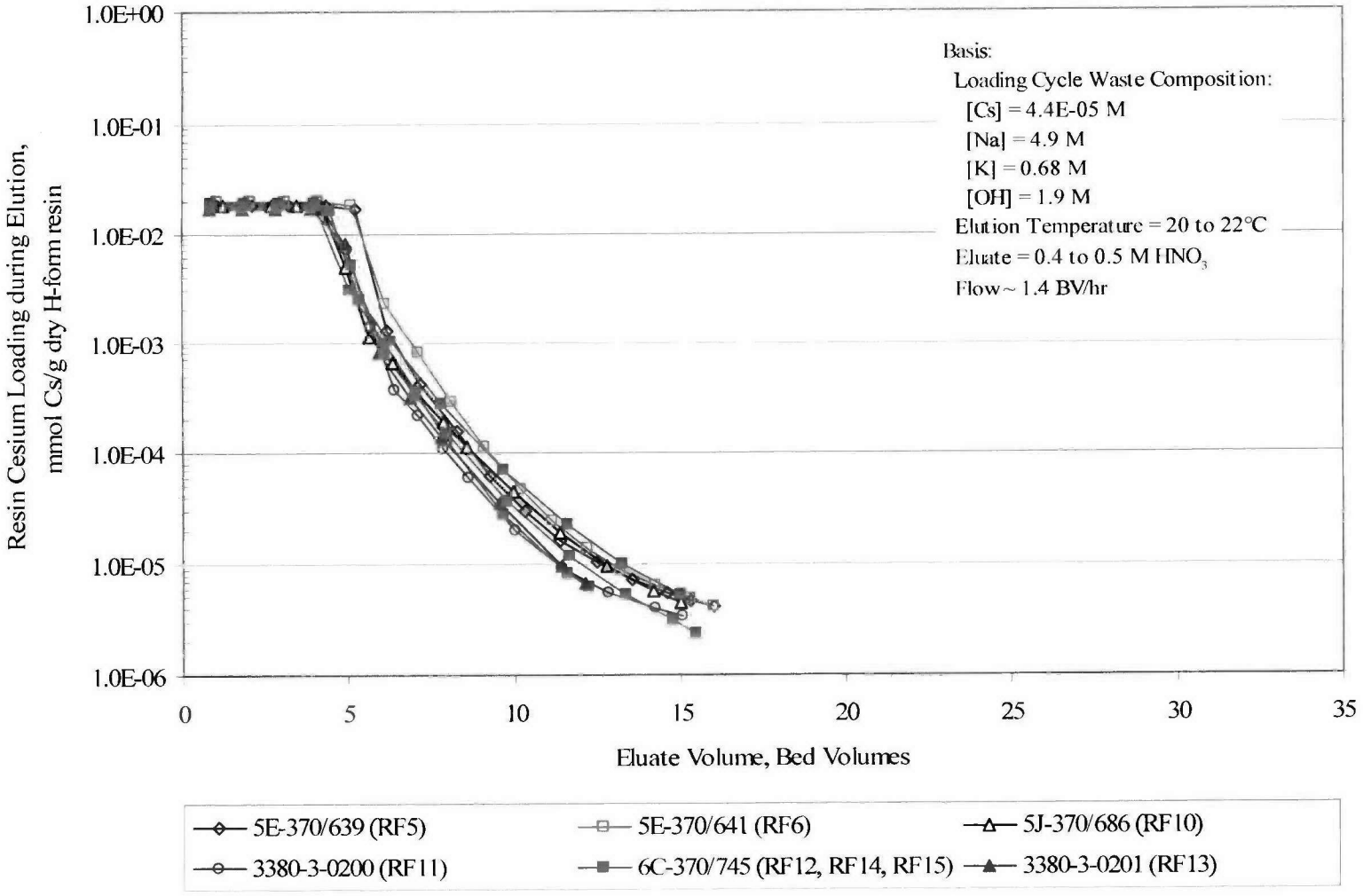
See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-43 Summary of Resin Cs Loading Variation Observed during Elution



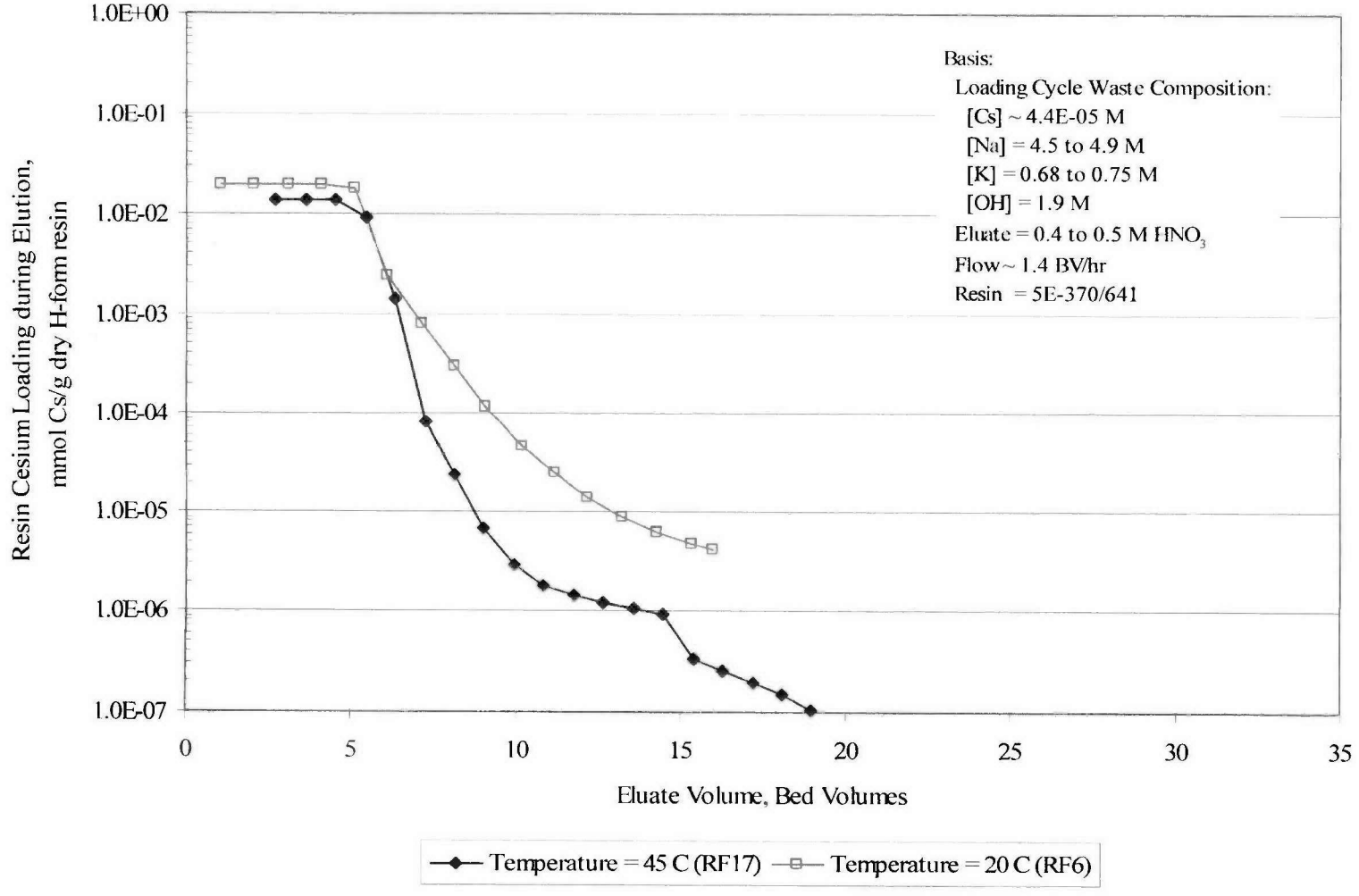
See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-44 Variation of Elution Curve with Resin Batch at Similar Conditions



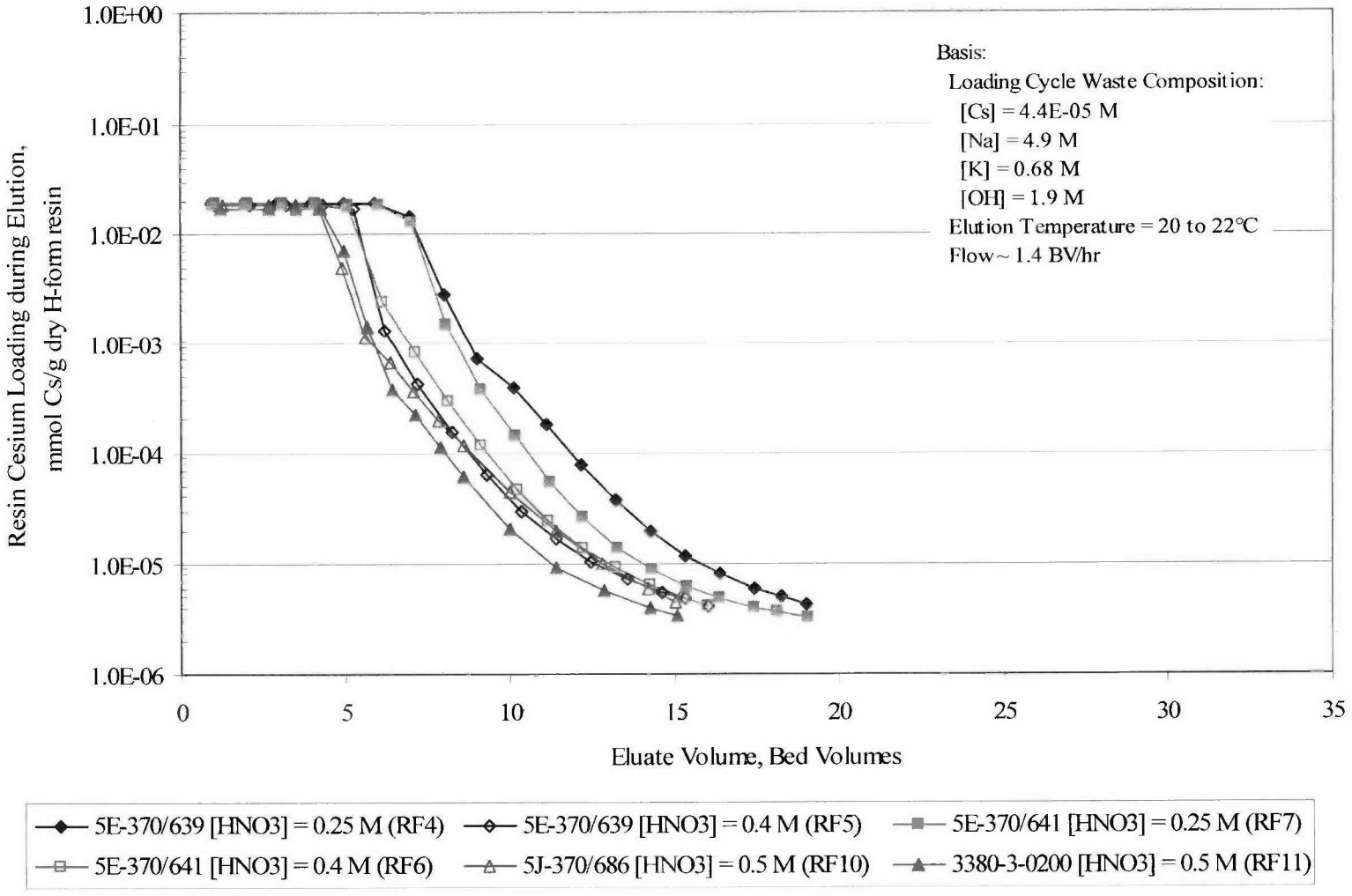
See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-45 Influence of Temperature on Observed Elution Curve



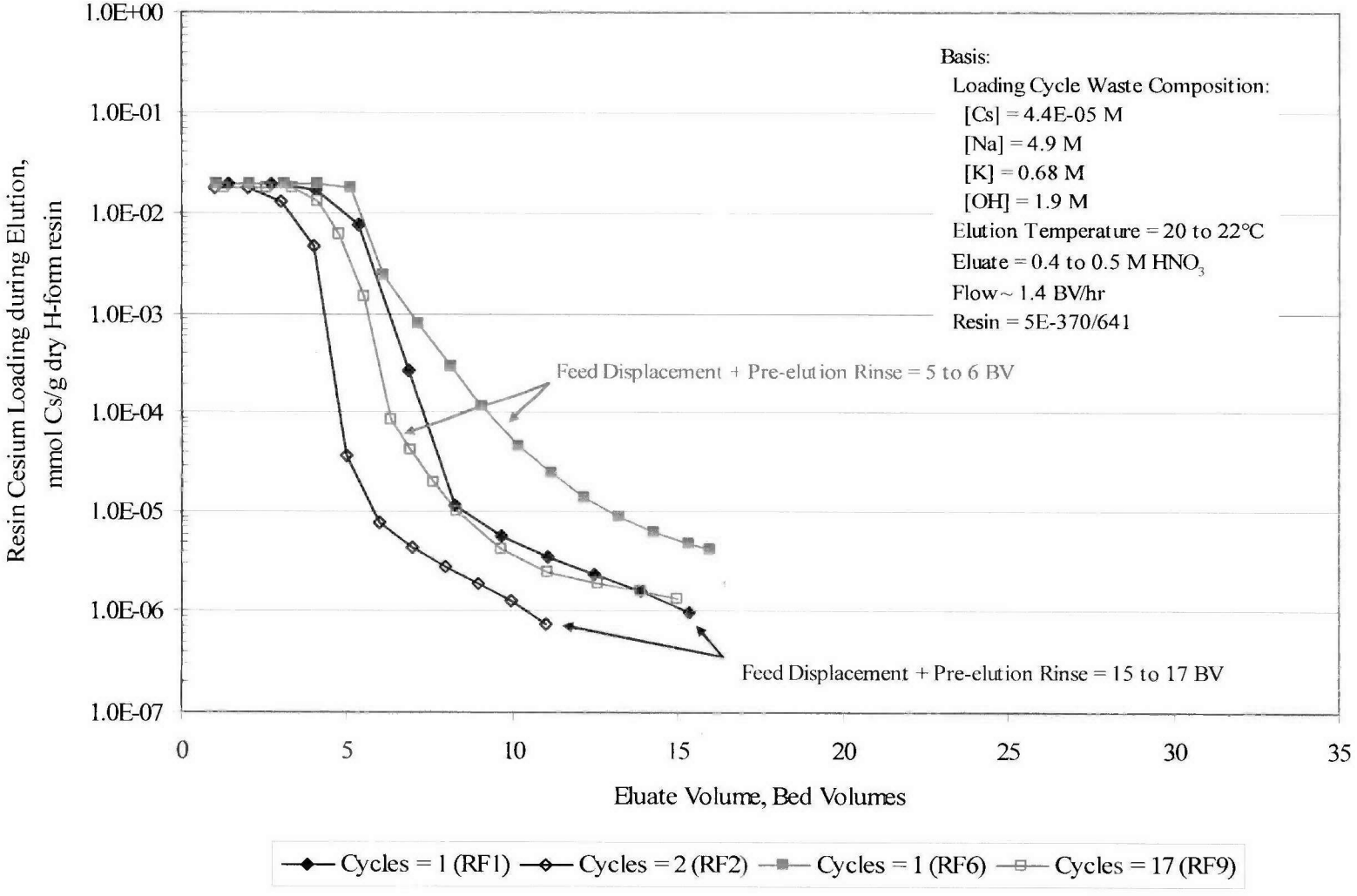
See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-46 Influence of Nitric Acid Concentration on Resin Elution



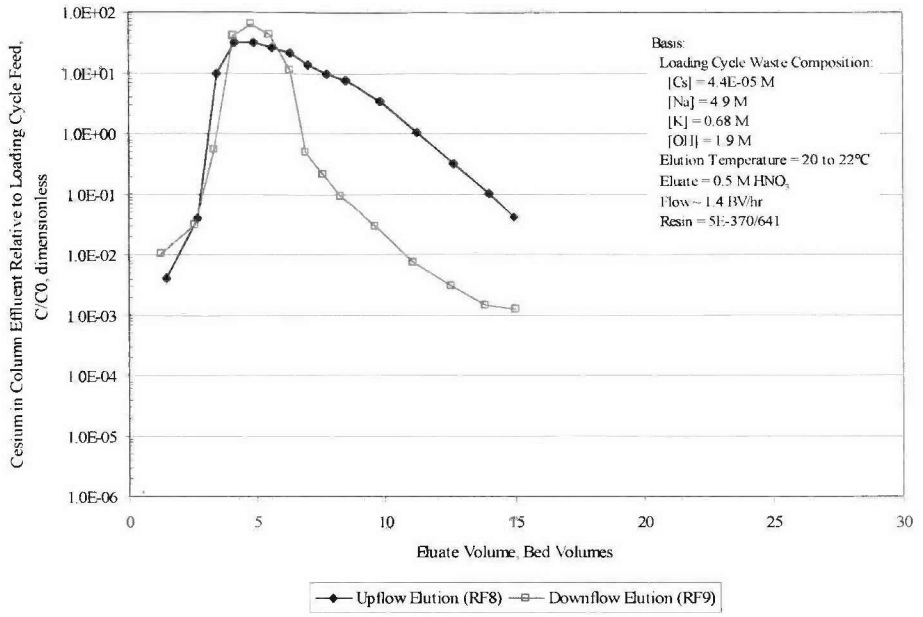
See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-47 Influence of Degradation on Resin Elution

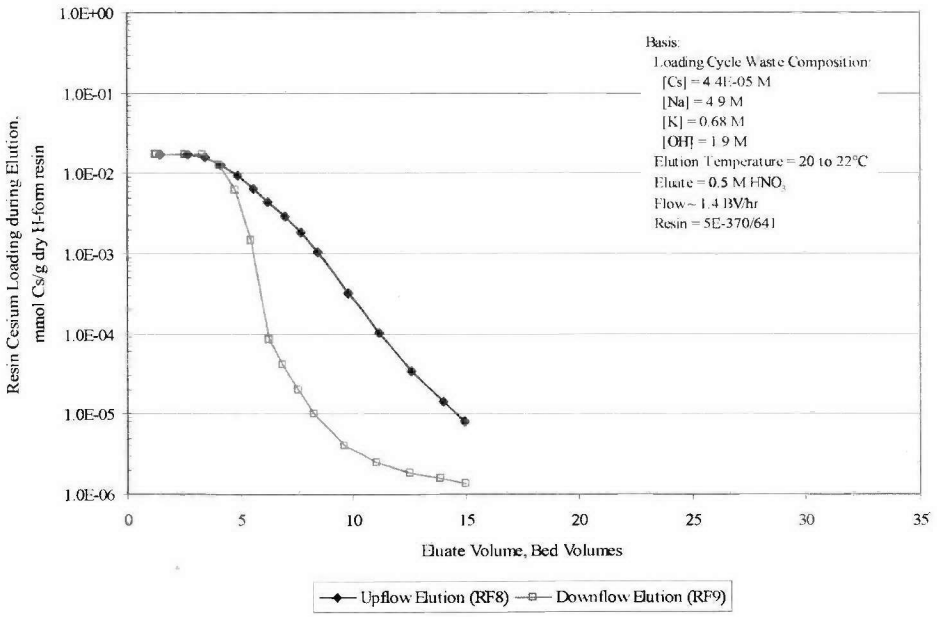


See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-48 Comparison of Up-Flow and Down-Flow Elution



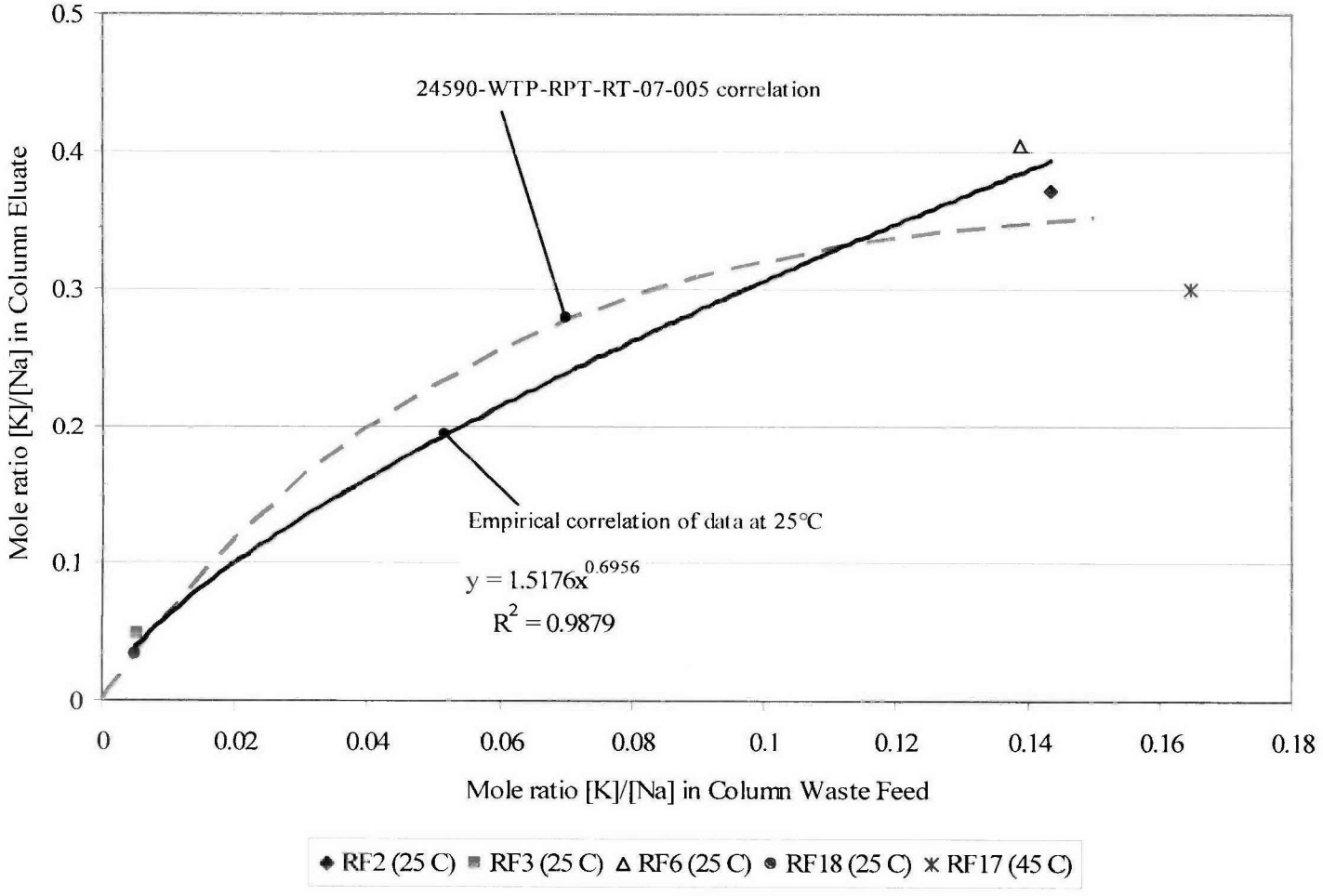
(a) Eluate Cs Concentration Relative to Loading Cycle Cs Feed



(b) Estimated Resin Cs Loading Variation based on Cs in Eluate

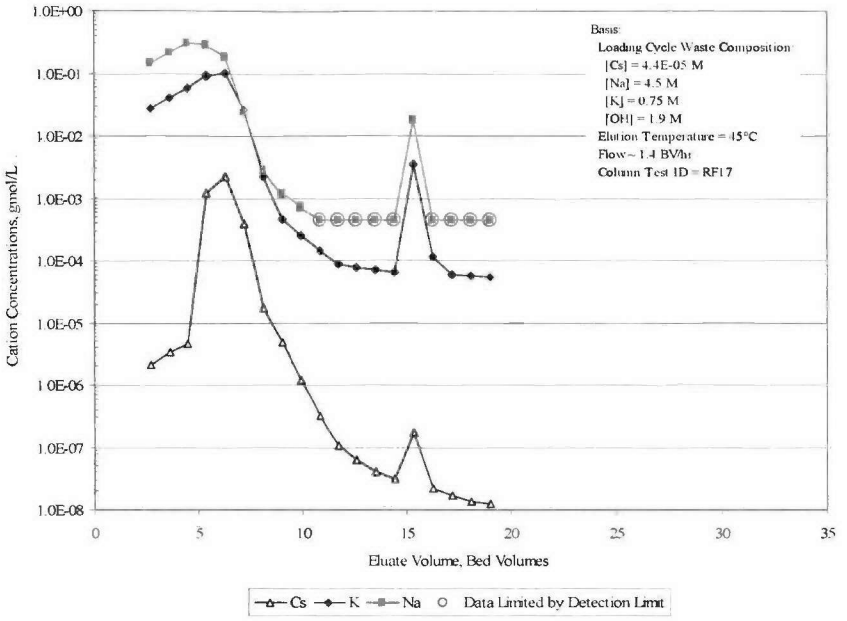
See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-49 Estimated Potassium Ion in Eluate

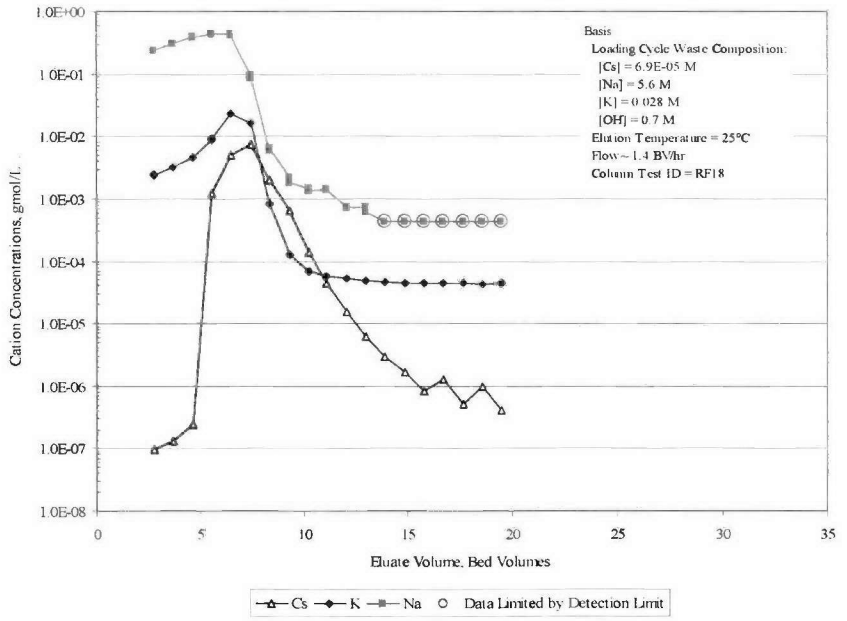


See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID. Correlation from 24590-WTP-RPT-RT-07-005, Rev 0, *Basis of Recommendation for Use of Spherical Resorcinol Formaldehyde Resin as the Primary Cesium Ion Exchange Resin in the WTP* is shown based on Equation 2.5-38.

Figure 2.5-50 Variation of Dominant Cation Concentrations in Eluate



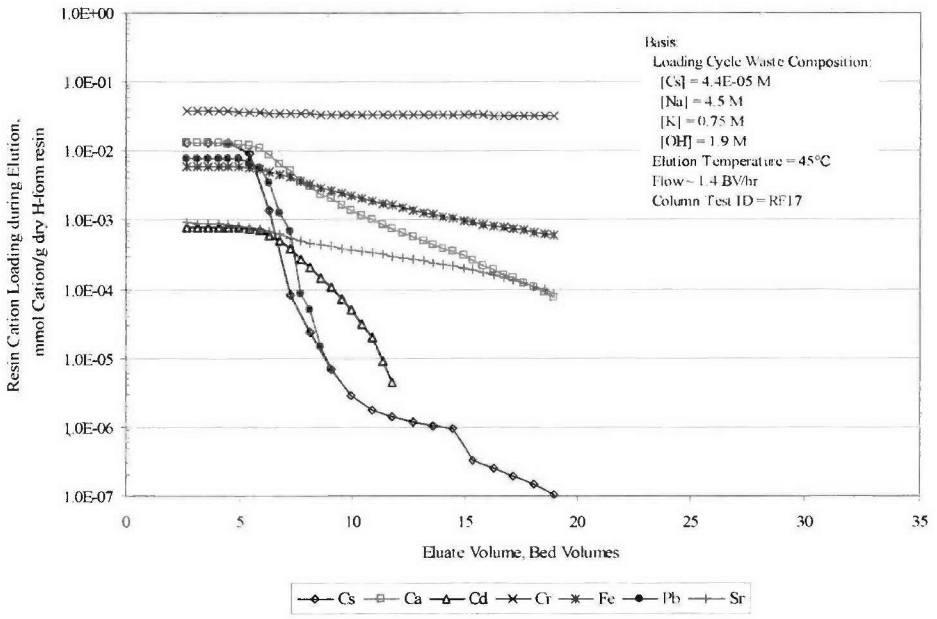
(a) Elution after High Potassium Waste Loading (AP-101)



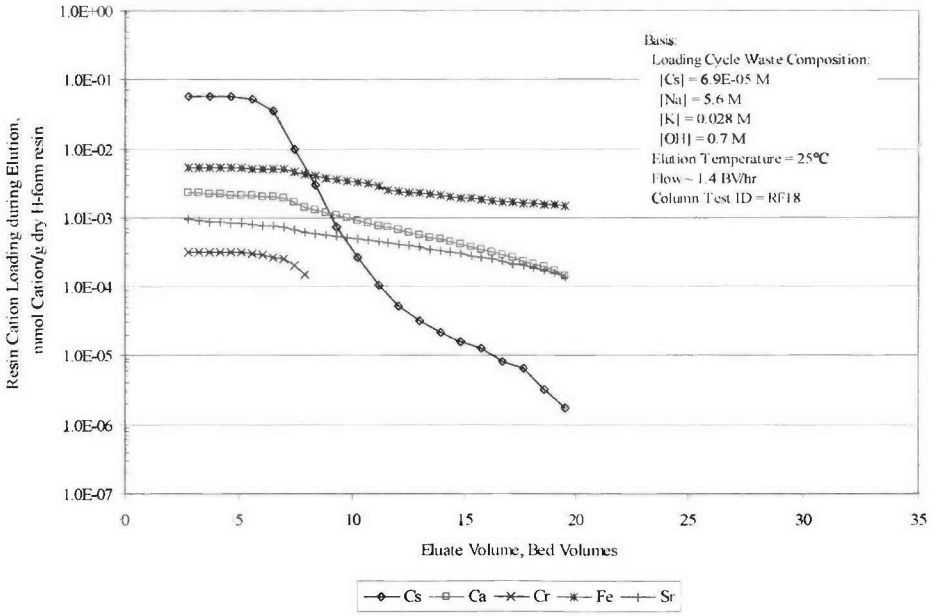
(b) Elution after Low Potassium Waste Loading (AN-107)

See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-51 Elution Characteristics of Trace Ions



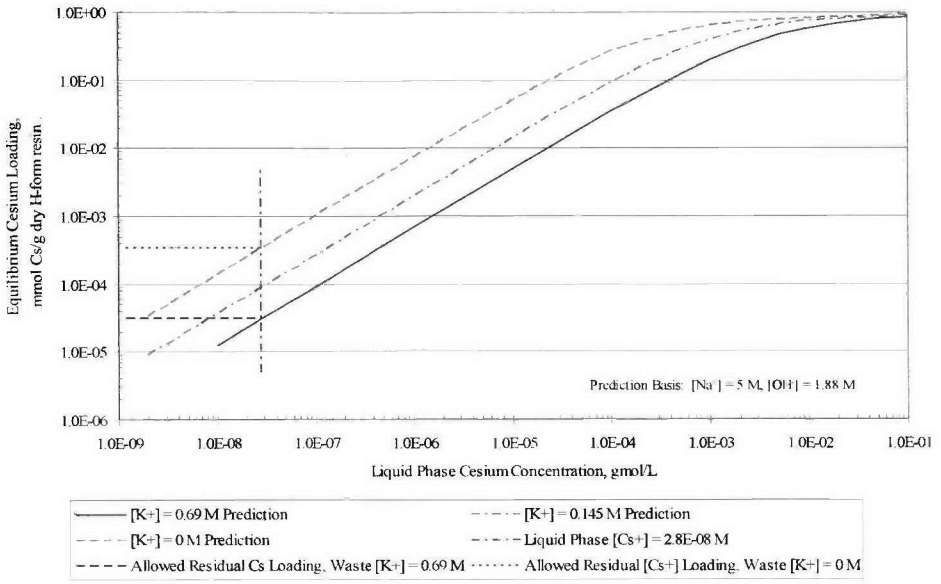
(a) Eluate from High Potassium Waste Loading (AP-101)



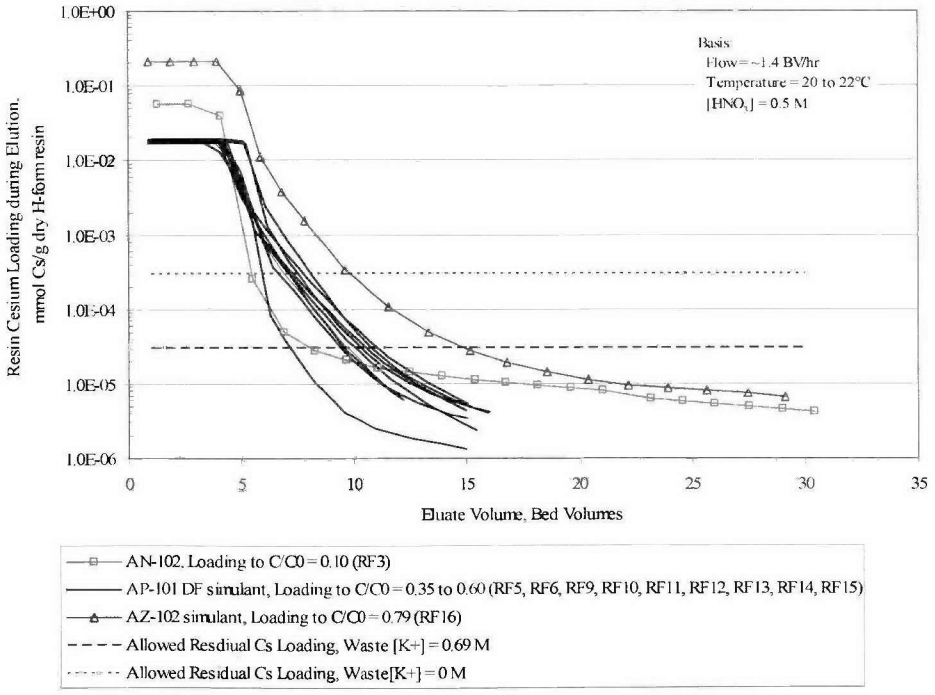
(b) Eluate from Low Potassium Waste Loading (AN-107)

See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-52 Elution Volume Basis



(a) Goal Resin Cs Loading at End of Elution Cycle



(b) Observed Resin Cs Loading Compared to Goal

See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-53 Sensitivity of Resin Cs Loading to Hydroxide Ion Concentration at Elution Cycle Conditions

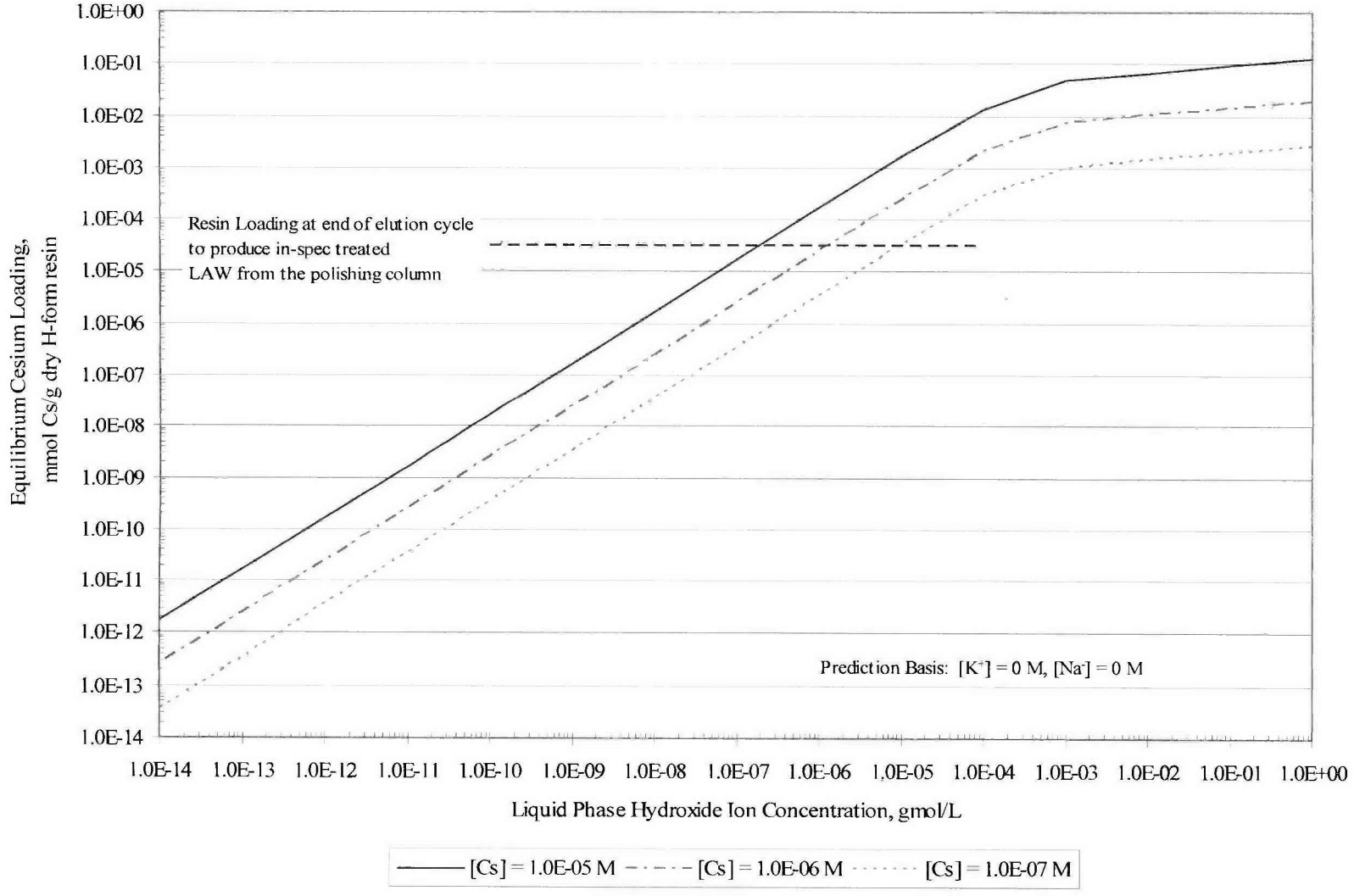
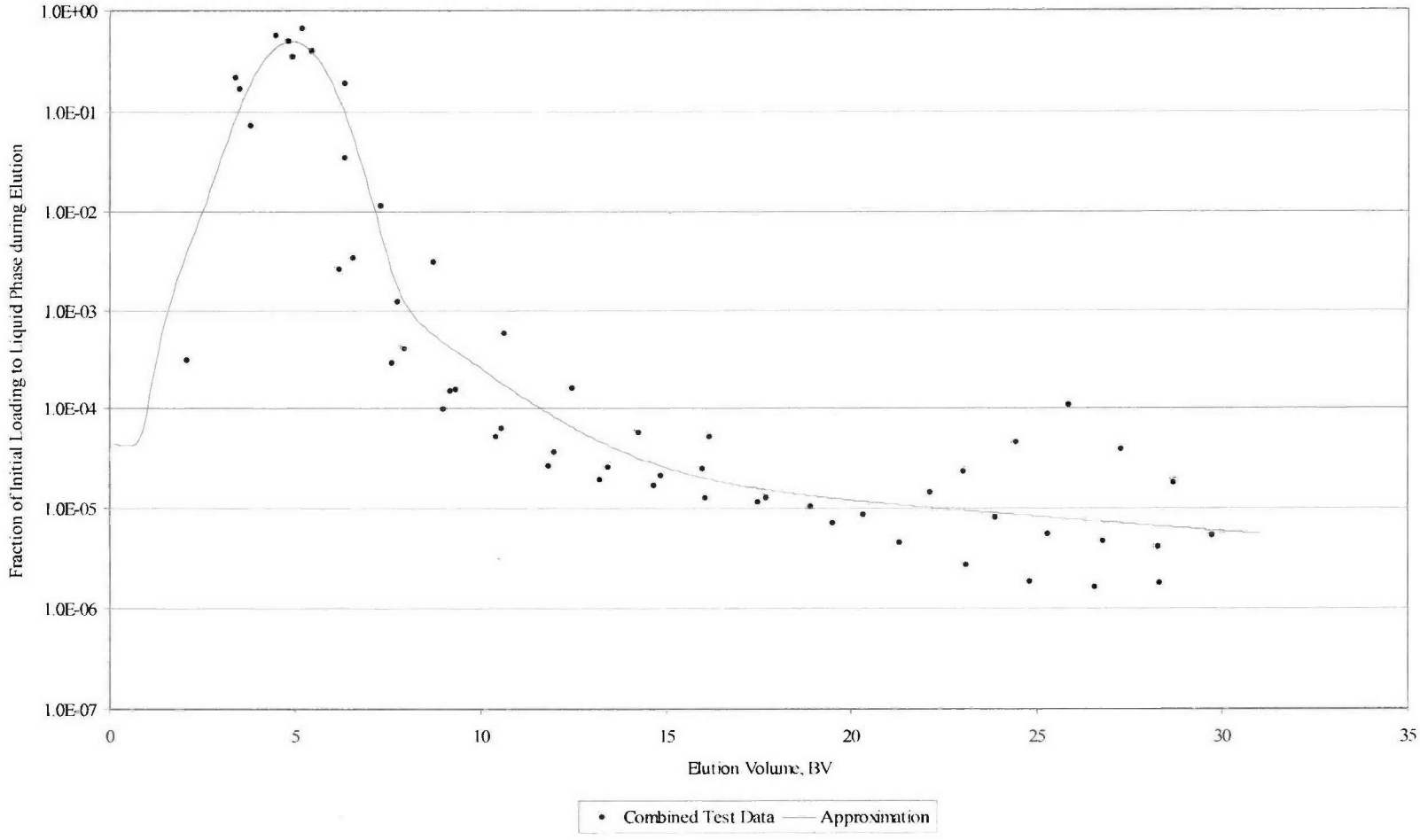
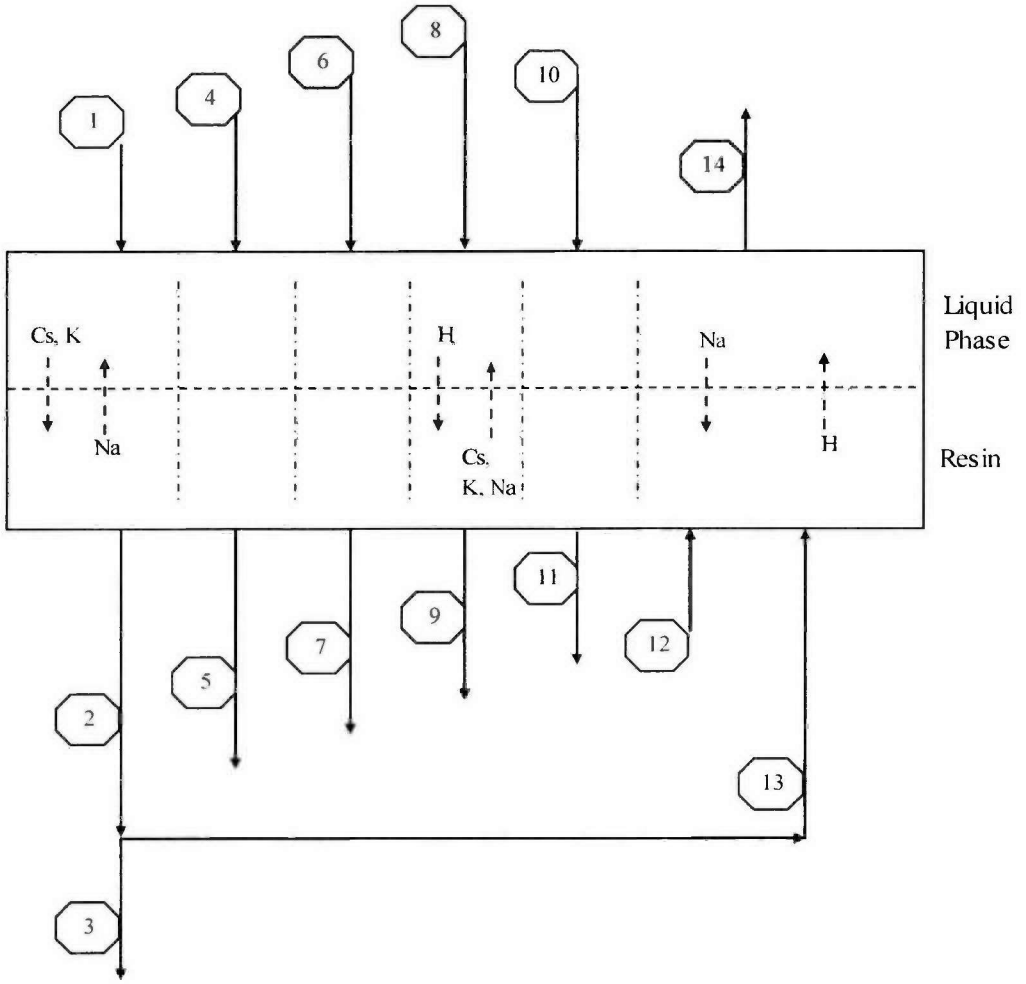


Figure 2.5-54 Elution Cycle Prediction Comparison to Benchmark Data



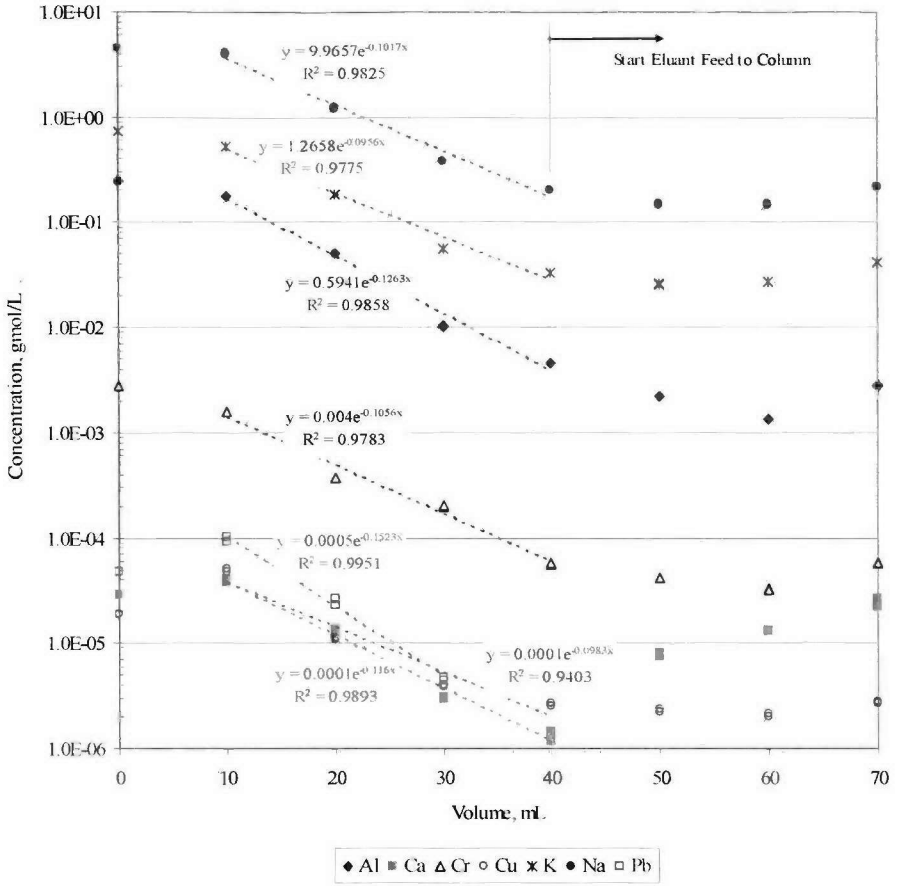
Combined test data from Column Test IDs RF2, RF3 Lead Column, RF3 Lag Column, and RF16. See Table 2.5-20 and Table 2.5-21 for data source based on Column Test ID.

Figure 2.5-55 Primary Resin/Liquid Phase Ion Transfers during Ion Exchange Cycles



Stream	Description	Stream	Description
1	Loading Cycle Feed	8	Elution Cycle Feed
2	Loading Cycle Effluent	9	Elution Cycle Effluent
3	Treated LAW to Vitrification	10	Post-Elution Rinse Cycle Feed
4	Feed Displacement Cycle Feed	11	Post-Elution Rinse Cycle Effluent
5	Feed Displacement Cycle Effluent	12	Regeneration Cycle Feed
6	Pre-Elution Rinse Cycle Feed	13	Regenerant Displacement Feed
7	Pre-Elution Rinse Cycle Effluent	14	Composite Regeneration Cycle Effluent

Figure 2.5-56 Cation Concentrations Observed in Displacement Solution Samples during Column Tests with AP-101 Simulant



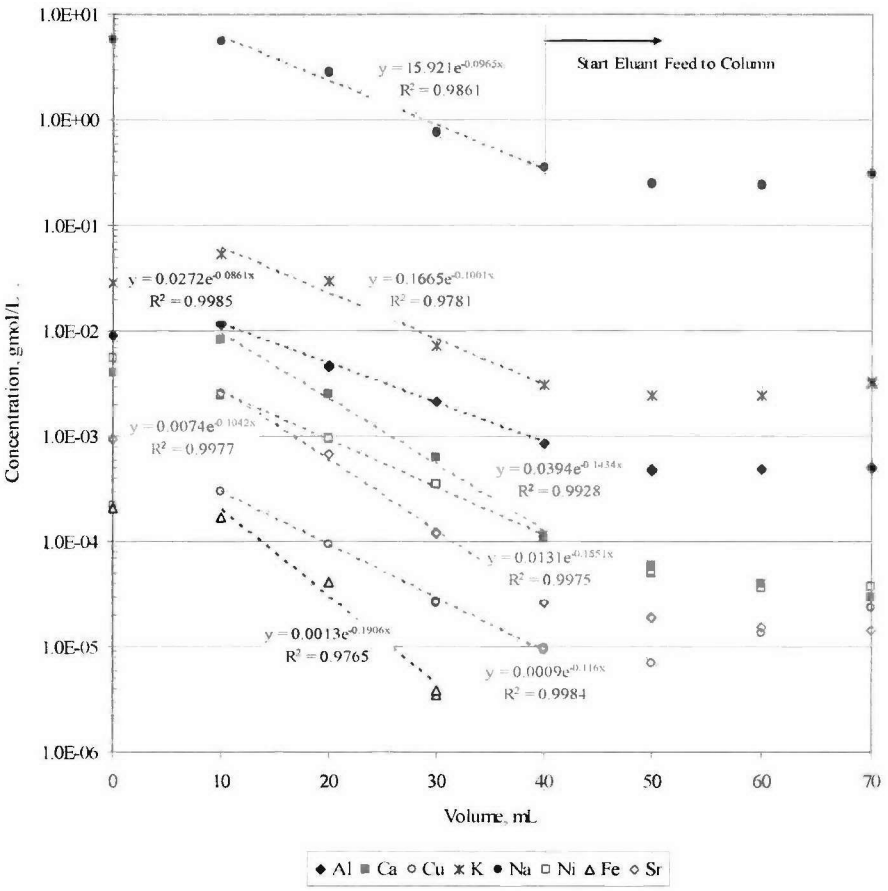
Cation	Trend Line Exponent[1]	Apparent Void Volume, mL[2]	Apparent Void Volume/ Head Space Volume[3]	Apparent Void Volume/ Dead Space Volume[4]
Na	-0.1017	9.83	0.91	0.38
K	-0.0956	10.46	0.96	0.40
Al	-0.1263	7.92	0.73	0.30
Cr	-0.1056	9.47	0.87	0.36
Pb	-0.1523	6.57	0.60	0.25
Ca	-0.1160	8.62	0.79	0.33
Cu	-0.0983	10.17	0.94	0.39
	Average	9.01	0.83	0.34

Notes:

1. From figure.
2. Based on Equation 2.5-50, Apparent Void Volume = -(1/ trend line exponent).
3. Reported test column head space volume = 10.9 mL.
4. Dead space volume = 26.2 mL (Liquid volume from feed tank dip tube to end of column discharge line. Includes head space volume, but excludes ~ 8 mL in collection funnel and tube from funnel to sampler.

Source: Data from SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin*, Appendix A and Appendix C. Waste feed concentrations shown at Volume = 0 for comparison purposes. First displacement sample is arbitrarily assigned to Volume = 10 mL and samples represent composition of column effluent in 10 mL increments.

Figure 2.5-57 Cation Concentrations Observed in Displacement Solution Samples during Column Tests with AN-107 Simulant

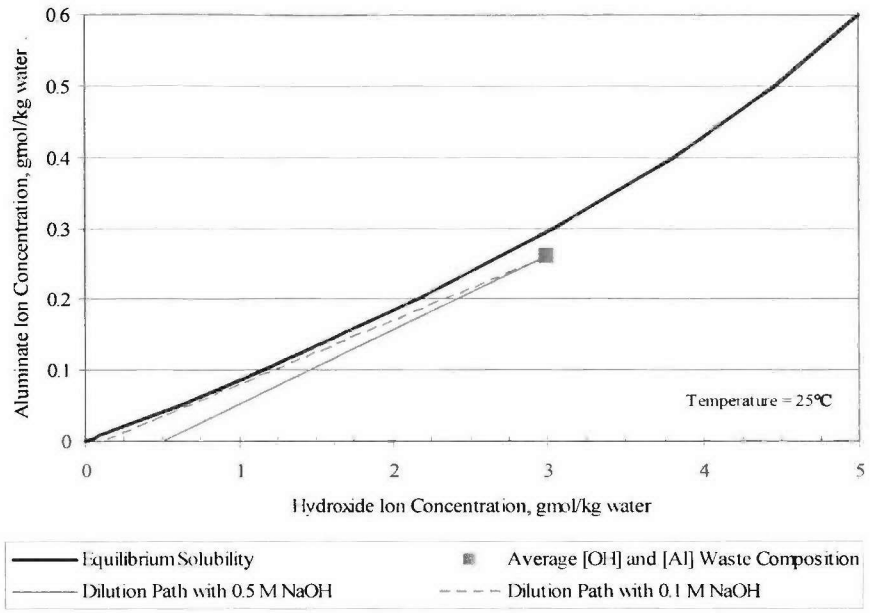


Cation	Trend Line Exponent[1]	Apparent Void Volume, mL[2]	Apparent Void Volume/ Head Space Volume[3]	Apparent Void Volume/ Dead Space Volume[4]
Na	-0.0965	10.36	0.98	0.36
K	-0.1001	9.99	0.94	0.35
Al	-0.0861	11.61	1.09	0.40
Ca	-0.1434	6.97	0.66	0.24
Ni	-0.1042	9.60	0.90	0.33
Sr	-0.1551	6.45	0.61	0.22
Cu	-0.1160	8.62	0.81	0.30
Fe	-0.1906	5.25	0.49	0.18
	Average	8.61	0.81	0.30

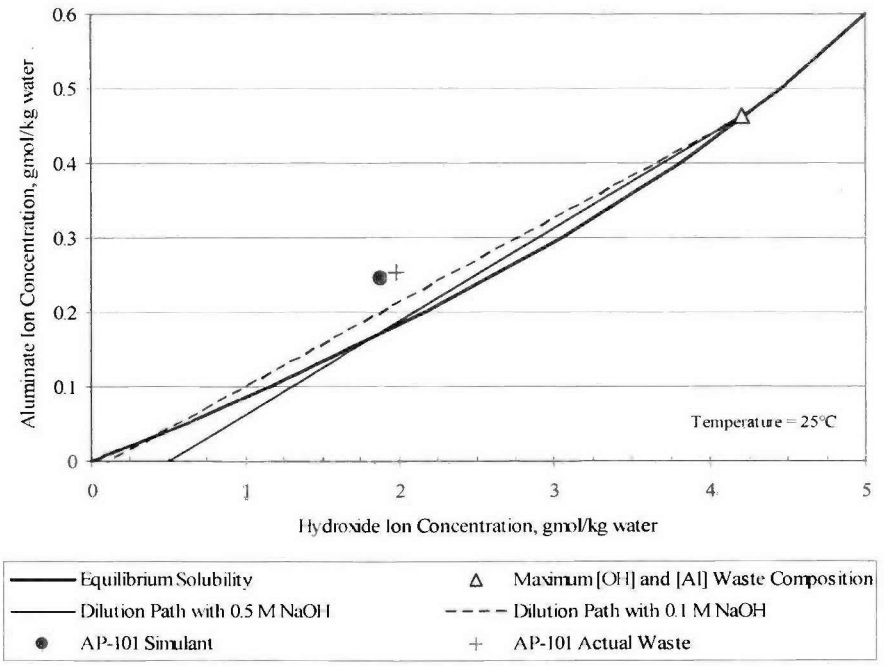
Notes:
1. From figure.
2. Based on Equation 2.5-50, Apparent Void Volume = -(1/trend line exponent).
3. Reported test column head space volume = 10.6 mL.
4. Dead space volume = 28.7 mL (Liquid volume from feed tank dip tube to end of column discharge line. Includes head space volume, but excludes ~ 8 mL in collection funnel and tube from funnel to sampler.

Source: Data from SCT-M0SRLE60-00-110-00029, *Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin*, Appendix A and Appendix C. Waste feed concentrations shown at Volume = 0 for comparison purposes. First displacement sample is arbitrarily assigned to Volume = 10 mL and samples represent composition of column effluent in 10 mL increments.

Figure 2.5-58 Potential for Aluminum Precipitation during Feed Displacement and Regeneration

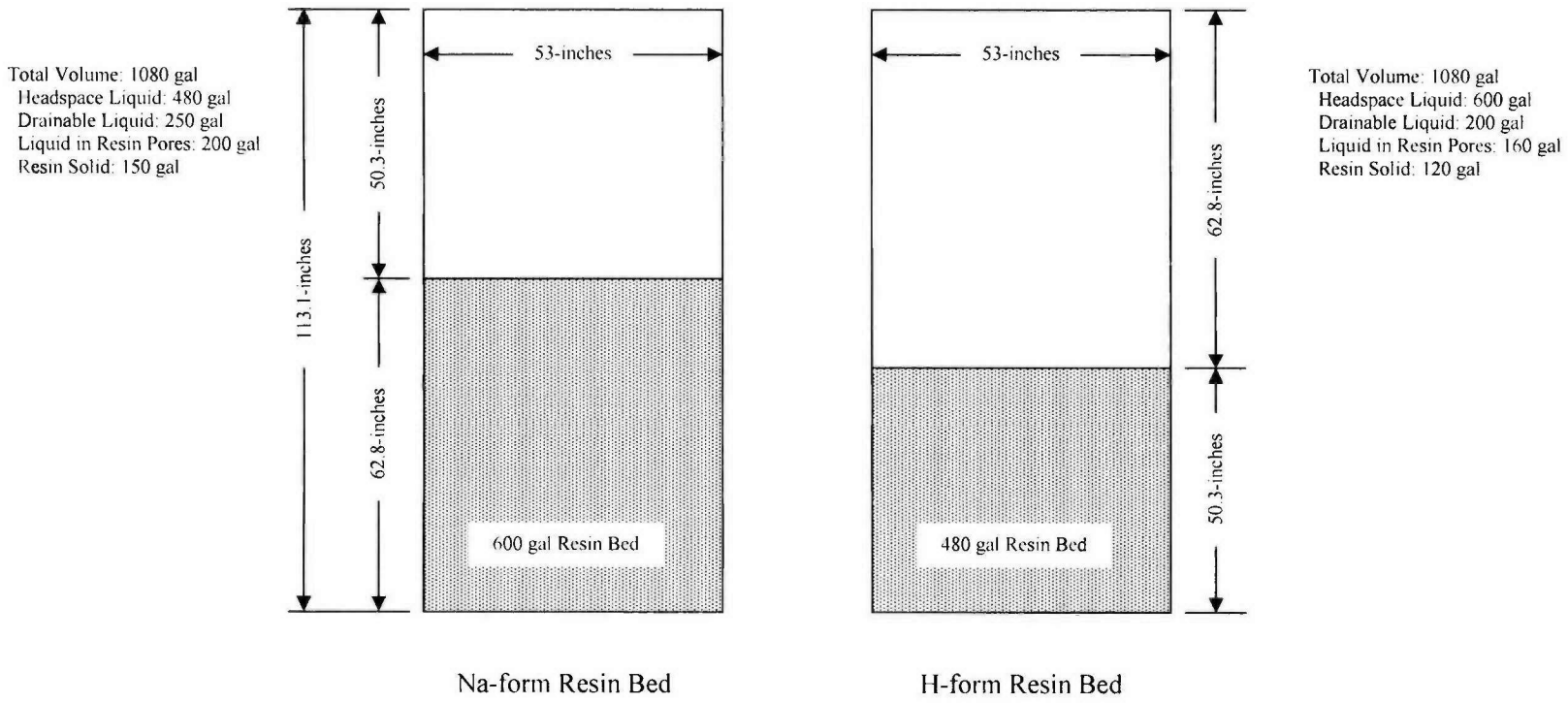


(a) Average Waste Hydroxide and Aluminate Ion Concentrations



(b) Maximum Waste Hydroxide and Aluminate Ion Concentrations

Figure 2.5-59 Description of Plant Scale Resin Bed Volumes



Na-form Resin Bed H-form Resin Bed

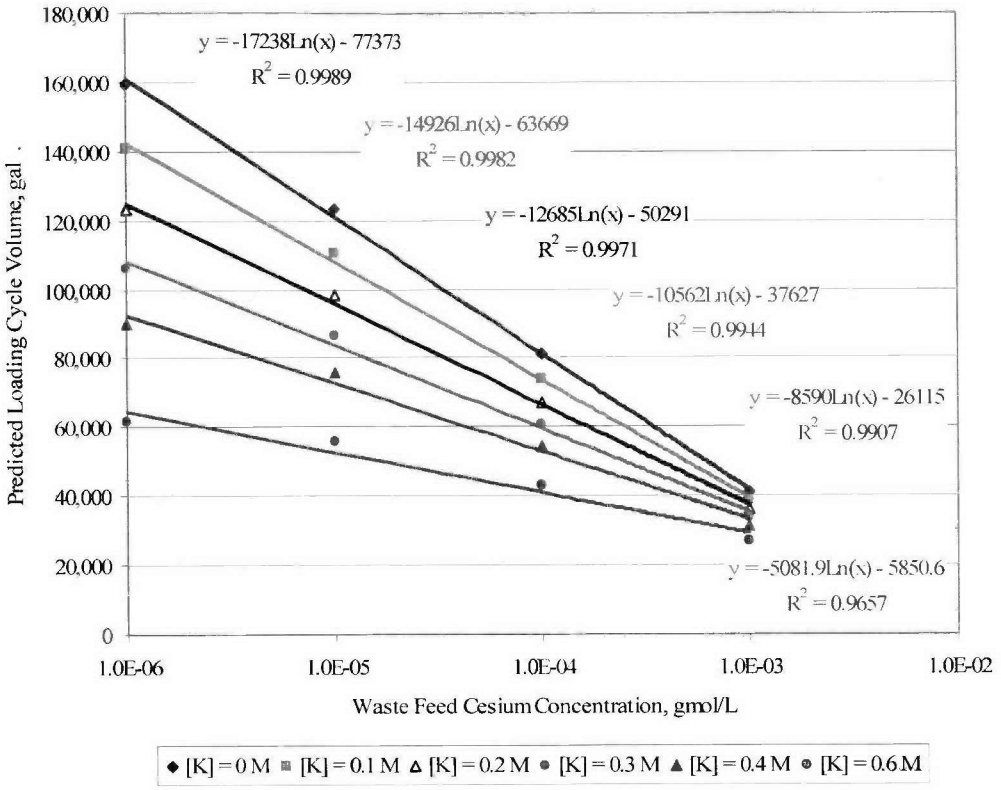
Resin Inventory: 680 kg dry H-form resin
(Equivalent to 375 gal as-received resin)

General Dimensions from 24590-QL-POA-MWD0-00001-04-00006, *IXC Weldment*:
Inside Diameter = 53-inches
Total Internal Working Volume = 1080 gal

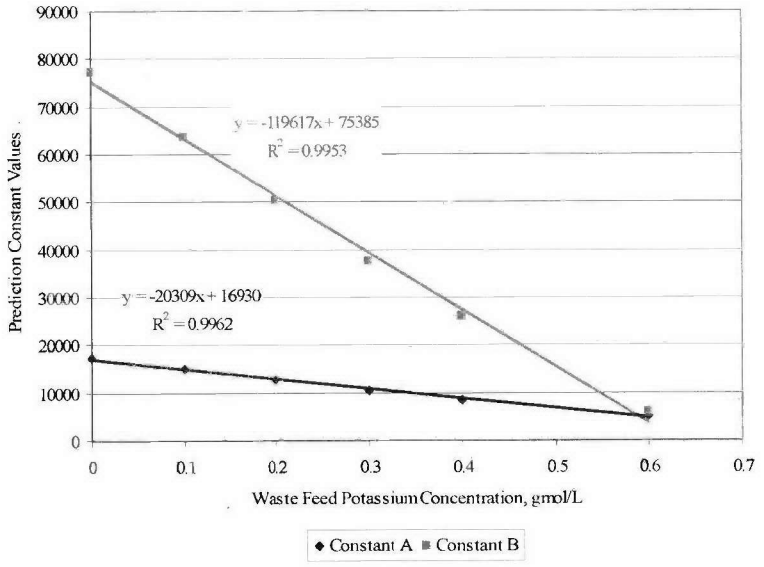
Volume Bases:

- 0.3 g dry H-form resin/mL wet Na-form resin
- 0.8 mL wet H-form resin/mL wet Na-form resin
- Total resin bed porosity = 0.75
- Bed porosity = 0.42
- 1.6 mL wet Na-form resin/mL as-received H-form resin

Figure 2.5-60 Algebraic Equation for Estimating Loading Cycle Volume



(a) Variation of Loading Cycle Volume Predictions with Cs and Potassium Concentration



(b) Variation of Correlation Constants with Potassium Concentration

Figure 2.5-61 Variation of Sodium Ion Adsorbed by Resin with Regeneration Caustic Volume

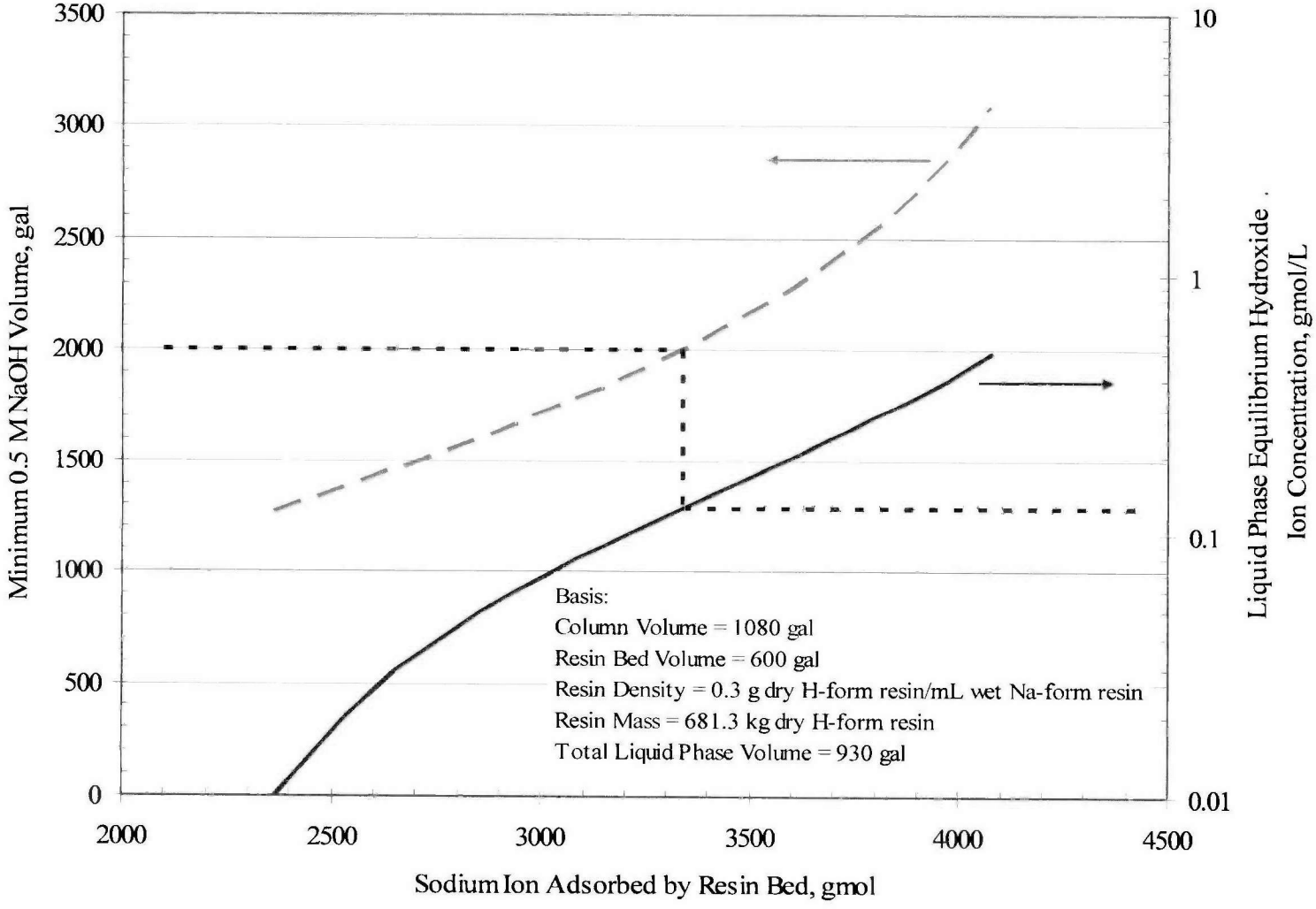
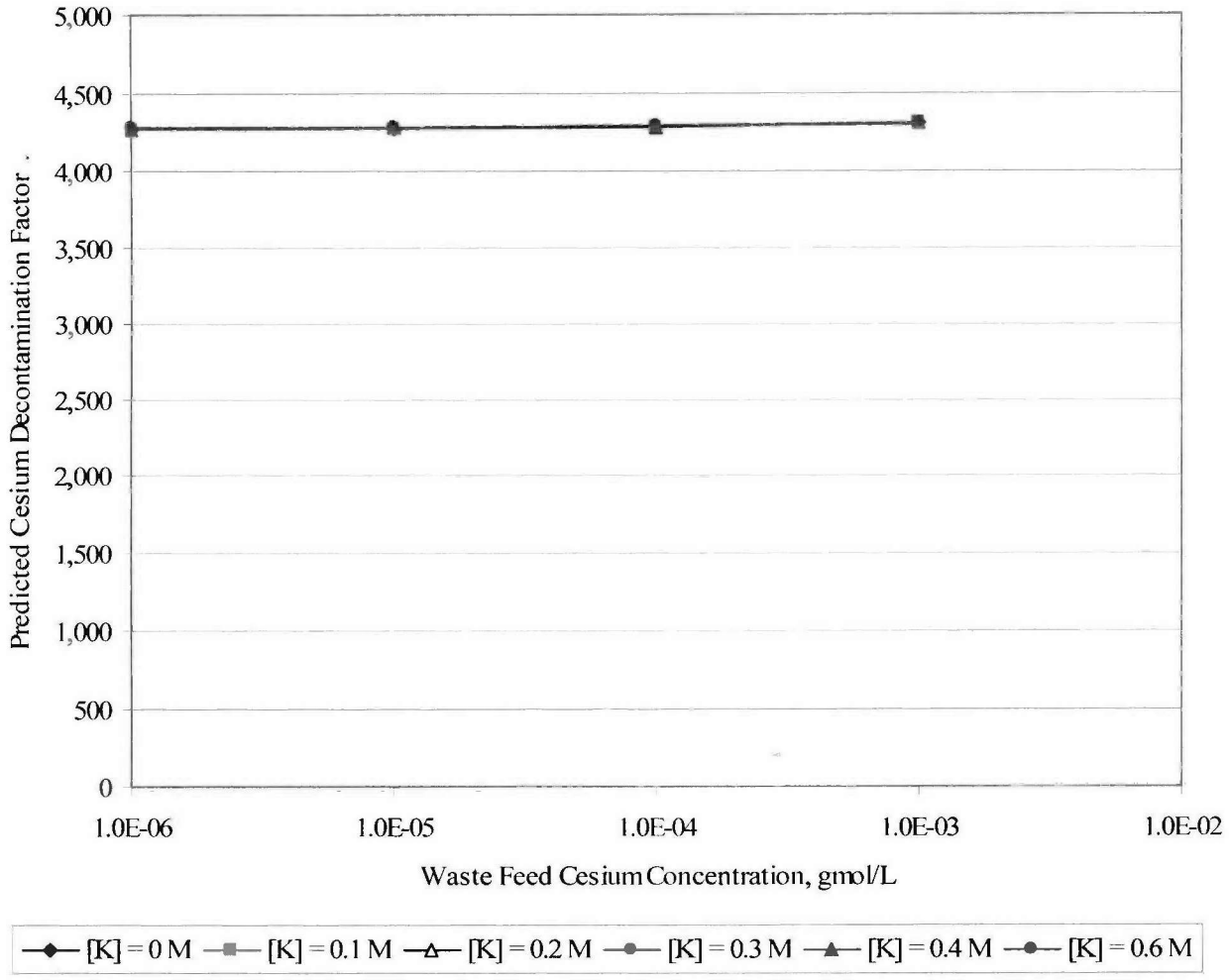


Figure 2.5-62 Variation of Predicted Cs Decontamination Factor with Waste Feed Cs and Potassium Concentration



Note: Based on an elution volume of 15 BV and assumes all residual Cs at the end of elution is transmitted to the treated LAW when a column is placed in the polishing position.

Figure 2.5-63 Variation in Loading Cycle Feed Rate to Avoid Limiting Throughput by the Restoration Cycle Time

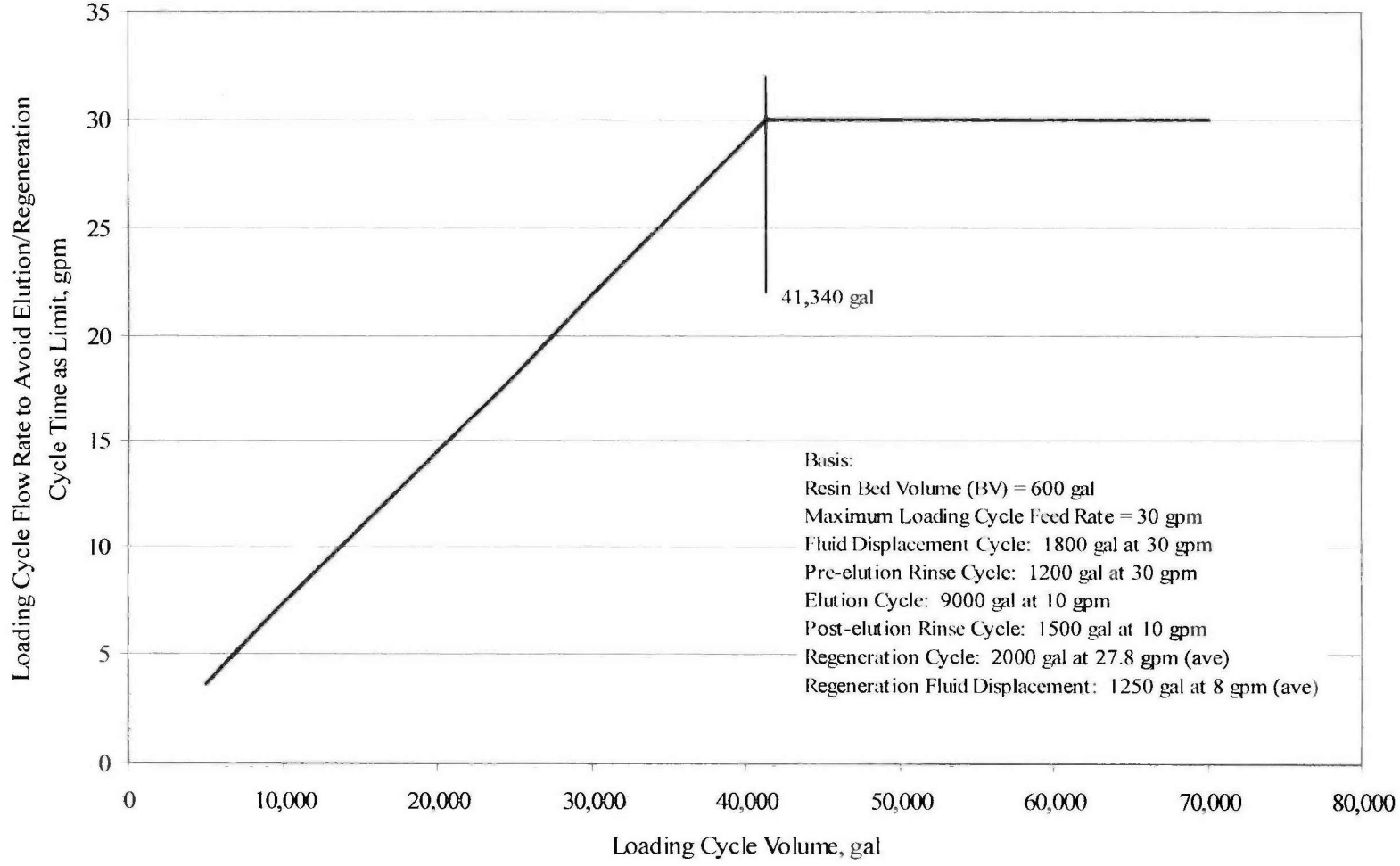
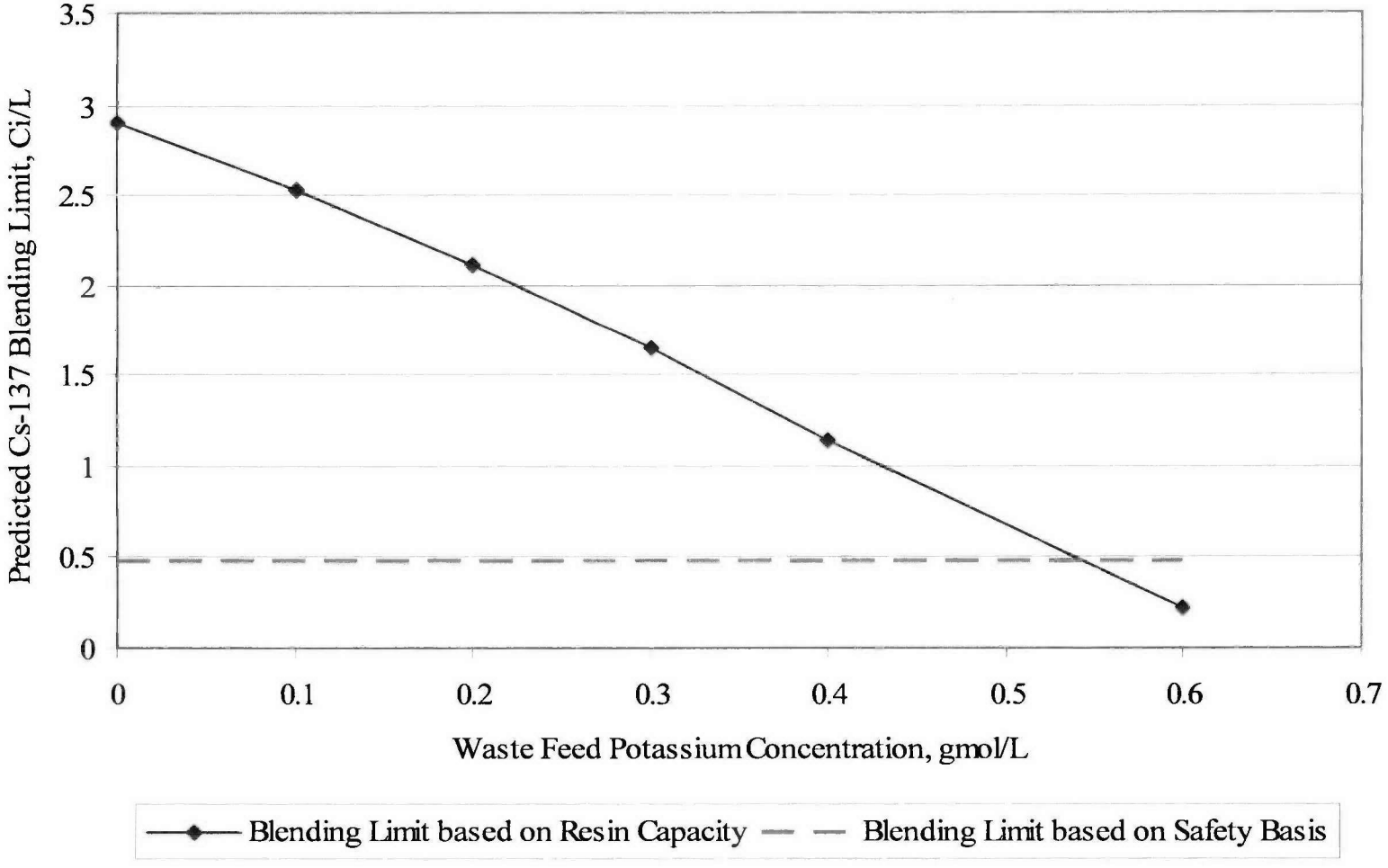
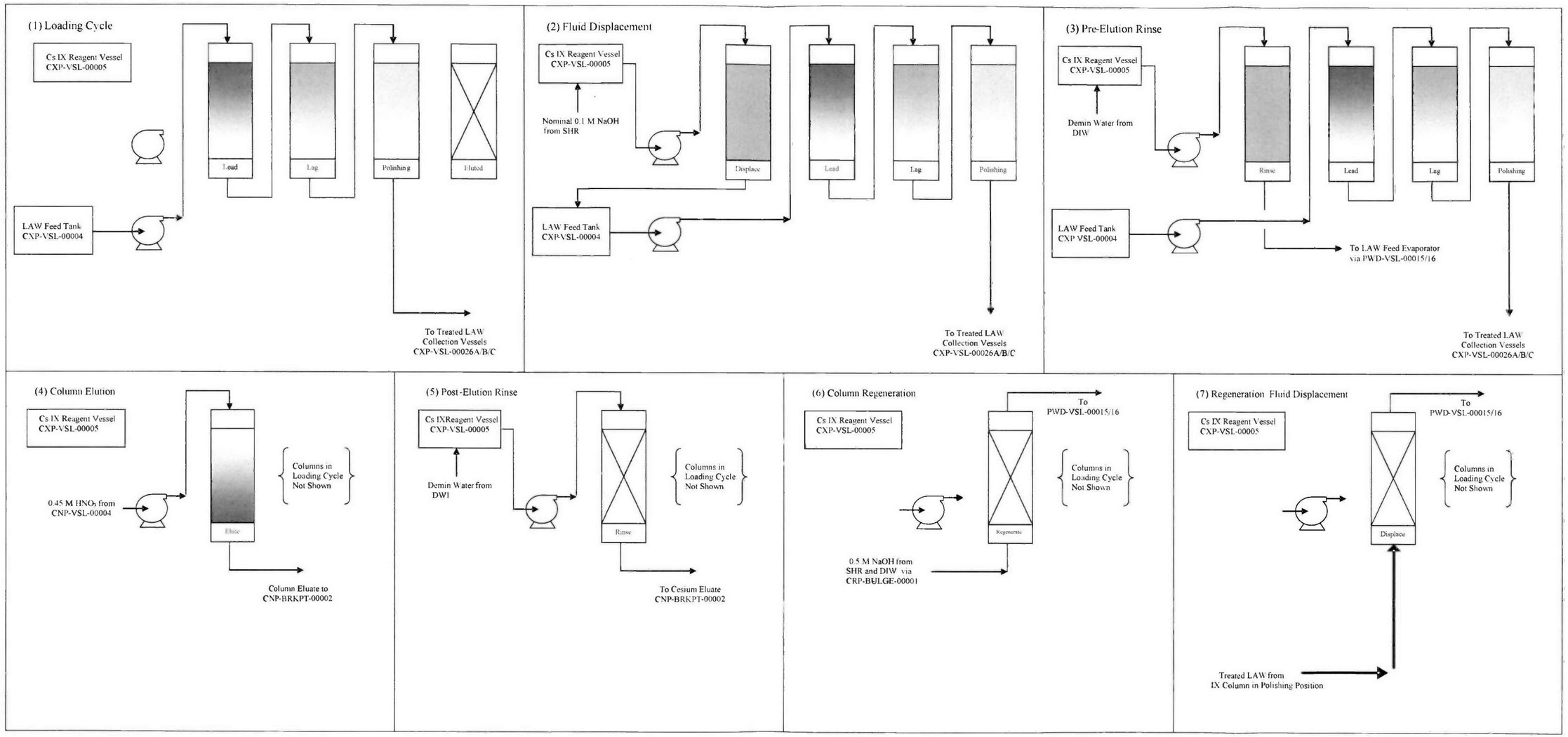


Figure 2.5-64 Comparison of Waste Blending Limits for Cs Ion Exchange



Note: Based on a minimum loading cycle volume of 41,400 gal.

Figure 2.5-65 Cs Ion Exchange Column Cycle Description



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2.6 System CNP: Cesium Nitric Acid Recovery Process

2.6.1 Functions and Requirements

The Cesium (Cs) Nitric Acid Recovery Process System (CNP) reduces the volume of the Cs eluate stream from the Cs ion exchange (IX) process. A Cs concentrate product is produced and nitric acid (HNO_3) is recovered for reuse as a Cs eluant.

2.6.2 Process Description

Process Flow Diagram - Cesium Nitric Acid Recovery Process-System CXP, 24590-PTF-M5-V17T-00014, referenced in Appendix A, shows the process flow for the CNP system. Figure 2.6-1 provides a schematic indicating the major equipment pieces in the CNP system. The eluate returned from the ion exchange columns (CXP-IXC-0001-4) is concentrated in a forced circulation, reduced-pressure evaporator (CNP-EVAP-00001). Cs eluate from the IX columns is routed to the Cs evaporator breakpot (CNP-BRKPT-00002), where it flows into the Cs evaporator separator vessel. The evaporator is a forced circulation concentrator. The evaporator bottoms recirculate through the evaporator recirculation pump (CNP-PMP-00001) to the evaporator reboiler (CNP-HX-00001), and then to the evaporator vessel, where the vapor and liquid disengage. The concentrated liquid stream is mixed with fresh eluate, heated, and again cycled through the evaporator vessel. The concentrated bottoms are periodically transferred to the high-level waste (HLW) blend vessel (HLP-VSL-00028) via a steam jet. The evaporator is then refilled with fresh nitric acid and is ready to resume the concentration of additional eluate solution.

The evaporator overheads pass through a demister in the evaporator vessel before entering the rectifier column (CNP-DISTC-00001). The rectifier column produces a ~0.5 M HNO_3 bottoms product and a water overheads product. The recovered nitric acid is accumulated in the recovered nitric acid vessel (CNP-VSL-00004). The rectifier operation is supported by a primary condenser (CNP-HX-00002), which returns some of the condensed vapors as reflux to the rectifier column, and sends the excess condensate to the plant wash and disposal system (PWD).

A two-stage steam eductor is used to control the operating pressure of the Cs evaporator and rectifier column. Steam condensate from the eductors is condensed in an inter- and after-condenser (CNP-HX-00003/4) and combined with excess condensate from the primary condenser. Condensates from the CNP system are routed to PWD-VSL-00015/16 for recycle. The operating pressure allows for control of the vapor-liquid equilibrium in the system so a rectifier bottoms product of 0.5 M HNO_3 can be realized.

A contingency vessel (CNP-VSL-00003) in the CNP system is available to temporarily store Cs concentrate before transfer to the HLW lag storage and feed blending process system (HLP) is unavailable. A maximum CNP transfer of 2615 gallons of concentrate can be accepted into HLP-VSL-00027B or HLP-VSL-00028 at one time. A minimum of 100 hours must elapse for cooling before a single HLP vessel can accept a second CNP concentrate transfer.

2.6.3 Basis

2.6.3.1 Eluate Concentration

The CNP system flowsheet is based on concentrating eluate received from the cesium IX columns on a semi-batch basis. The evaporator is initially charged with 5 to 8 M HNO_3 before receiving eluate solutions. The charge acid provides nitric acid in the evaporator concentrate to maintain the system at the desired vapor-liquid equilibrium point. This produces a relatively uniform concentration of nitric acid in

the evaporator overheads from the point of initial acid charge until the pot is emptied. The charge is depleted of acid over a concentration cycle, transferring acid to the eluant. This means the charge solution acid concentration (initially 5 to 8 M HNO_3) is reduced over time as salt concentrations increase.

The evaporator is operated at a reduced pressure which lowers the boiling point, thus minimizing vessel corrosion. An operating pressure of approximately 0.10 bar (1.5 psi) results in an operating temperature of 50 to 55 °C, producing a vapor with condensed acid concentration of approximately 0.5 M HNO_3. Therefore, these operating conditions have been selected as the flowsheet basis. Baich (2000) performed preliminary bench-scale tests concentrating simulated eluate with compositions based on observed eluate from column tests processing waste from tanks AN-107 and AW-101. These tests confirmed that the batch concentration of Cs eluate produces an overheads condensate with relatively uniform composition of approximately 0.5 M HNO_3.

The evaporator feed solution is primarily a dilute nitric acid solution containing $NaNO_3$, KNO_3, and $CsNO_3$ eluted from the IX resin, with $NaNO_3$ representing the dominant solute. Table 2.5-21 provides a summary of the concentrations of these cations observed in composite eluate samples from IX tests using actual waste. However, it should be recognized that the composite eluate composition is influenced by the elution volume used in a particular test. In addition, the eluate composition entering the evaporator can vary significantly over the elution cycle compared to composite compositions. Cs eluate concentration profiles, shown in Figure 2.5-50, indicate the potential variation of solute concentrations that can be experienced within an elution cycle. Evaporator evaluations performed to date have been based on an average eluate composition fed to the evaporator.

Eluate fed to the evaporator is projected to contain small concentrations of a variety of additional cations and anions based on test experience. Pierce (2001) provides a summary of IX test eluate compositions observed in composite sample analyses. Cations observed at detectable concentrations include Al, Si, Cr, Ni, Pb, Ca, Cu, Fe, Mg, Zn, B, and U, ranging from on the order of 1 to 100 µg/mL. Anions observed at detectable levels are generally limited to chloride ion. Other anions, including NO_2^-, F^-, PO_4^{-3}, SO_4^{-2}, and $C_2O_4^{-2}$, are reported to be less than detection limits; however, the detection limit for anions in the analyses was significantly higher than that for cations. Detectable concentrations of total organic carbon (120 to 13,500 µg/mL) and total inorganic carbon (< 20 to 215 µg/mL) were also reported in test eluates. The presence of these ions (such as uranium) in the eluate can, in some cases, be attributed to a limited affinity of the resin to capture ions. In other cases, the ions are present in the eluate as a result of non-ideal rinsing between the loading and elution cycles. Independent of source, the observed concentrations of the inorganic ions relative to sodium are not at levels that have a major impact on the eluate concentration process itself.

A semi-batch operating mode for removing concentrated product from the Cs evaporator has been selected because of the small volume of Cs concentrate generated from elution of each column. The evaporator bottoms concentration of Cs and associated salts (such as sodium and potassium) increases as the products of multiple column elutions accumulate in the evaporator. A concentrate endpoint of 80 % of the saturation limit for the solution, when held at 25 °C, has been selected as the basis for determining the frequency of transferring Cs concentrate to the HLW blend tank and restarting the concentration process with a fresh charge of nitric acid.

Preliminary calculations in Choi (2001) indicate that this endpoint is projected to occur at a $NaNO_3$ concentration of 2.64 M for a feed eluate composition derived from AN-107 IX test observations and charge acid concentration of 7.9 M HNO_3. Subsequent to these preliminary calculations, test data reported in the document *Cesium Eluate Evaporation Solubility and Physical Property Behavior* (SCT-M0SRLE60-00-99-03) describe the solubility limit and other physical characteristics (density, viscosity,

heat capacity, and thermal conductivity) of simulant solutions modeling concentrated eluate. The report develops a correlation of the solubility limit based on a statistical evaluation of the simulant data and relative mole fraction of cations in solution. This results in an endpoint prediction for the semi-batch concentration process that varies with the eluate evaporator feed composition. It further describes two bench-scale evaporation tests using eluate generated by operation of a pilot-scale IX system. Solubility limits observed in the bench-scale testing were consistent with the solubility limit predicted by the correlation derived in the report (SCT-M0SRLE60-00-99-03). The correlation developed indicates that the eluate concentrate solubility limit is influenced by nitric acid concentration. Therefore, the evaporator nitric acid balance is an important factor in determining the frequency of transferring concentrated eluate to the HLP blend tank and recharging the evaporator with acid.

An evaluation of the bench-scale evaporation tests is described in the following reports: *Cesium Eluate Evaporation Solubility and Physical Property Behavior*, (SCT-M0SRLE60-00-32-03) and *Cesium Eluate Semi-Batch Evaporation Performance* (SCT-M0SRLE60-00-185-01). The tests were performed using a batch concentration material balance model to estimate the variation in the nitric acid activity coefficient with solute composition from test observations at 55 °C (24590-WTP-RPT-PT-02-019, *Cesium Eluate Concentrator Reconciliation of Test Data*). The evaluation uses the nitric acid activity coefficient to relate the acid composition of concentrate to the acid composition of overheads in the form shown as Equation 2.6-1.

Equation 2.6-1

$$x_o^a = \frac{\gamma_a \, x_c^a \, P_A^{sat}}{P}$$

where: γ_a = acid activity coefficient relating vapor-liquid equilibrium for the concentrate solution
P = total concentrator operating pressure, torr
P_A^{sat} = saturation pressure of nitric acid at the evaporator operating temperature, torr
x_c^a = mole fraction of acid in the evaporator concentrate, dimensionless
x_o^a = mole fraction of acid in the evaporator overheads, dimensionless

Table 2.6-1 provides a summary of the test data for Experiments 1 and 2 (SCT-M0SRLE60-00-32-03). Data for Experiment 1 were limited to analysis of the concentrate at the conclusion of the evaporation test accompanied by frequent sampling of the condensate composition. Therefore, it could not be used to evaluate semi-batch concentration performance.

A series of seven follow-on bench scale eluate evaporation tests are described in SCT-M0SRLE60-00-185-01. Four different eluate compositions, described in Table 2.6-2, were used in these follow-on tests. Six of the follow-on tests were performed at the projected plant operating conditions of 70 torr and ~55 °C. Four of these tests were performed using the different eluate simulant compositions shown in Table 2.6-2 and a charge acid concentration of approximately 7.5 M HNO_3. Two tests were performed using the AN-102 eluate simulant composition and varying the charge acid composition to approximately 5.25 and 4 M HNO_3. A final (seventh) test was performed at atmospheric pressure and an operating temperature of approximately 108 °C. Table 2.6-3 provides a summary of the follow-on test data that are used to estimate the effect of solutes on nitric acid activity coefficient in the Cs eluate evaporator.

Test data obtained at 55 °C are used in report 24590-WTP-RPT-02-019, *Cesium Eluate Concentrator Reconciliation of Test Data*, to determine the effect of solutes on vapor-liquid equilibrium. The

evaluation results in Equation 2.6-2 as an estimate for variation of acid activity coefficient with concentrate solute, with the constant representing an average from seven tests.

Equation 2.6-2

$$\frac{\gamma_a}{\gamma_{AW}} = 1 + 7.812\, x_c^n$$

where: γ_{AW} = acid activity coefficient in the binary HNO_3-H_2O system
x_c^n = mole fraction of all solutes in the concentrate (characterized by sodium as the dominant solute), dimensionless

The acid activity coefficient estimate is supported by a correlation of literature data shown as Equation 2.6-3.

Equation 2.6-3

$$-\mathrm{Log}_{10}(\gamma_{AW}) = \left(\frac{1}{A\left(\frac{x_c^a}{x_c^w}\right) + B} \right)^2$$

$$A = 4.029672\, e^{\frac{444.877899}{T}}$$

$$B = 0.002114\, T - 0.093403$$

where: T = solution temperature, K

Figure 2.6-2, Figure 2.6-3, and Figure 2.6-4 provide a comparison of the predicted variation of eluate concentrate nitric acid and sodium ion concentrations with test observations. These comparisons indicate the impact of charge acid concentration on evaporator performance. The relationship between nitric acid activity coefficient and solute composition is combined with the solubility limit correlation from SCT-M0SRLE60-00-99-03, *Cesium Eluate Evaporation Solubility and Physical Property Behavior*, to define batch concentration cycles as shown in 24590-WTP-RPT-PT-02-019 and forms the basis for describing the Cs eluate evaporator dynamic operation.

Steady-state material balances require development of a time-averaged estimate of the semi-batch concentration process. The steady-state approximation should have the following characteristics in order to provide an adequate representation of the semi-batch process.

1 The volumetric flow rate of feed relative to the volumetric flow rate of concentrate must be consistent with the equivalent ratio determined by the batch concentration dynamic material balance when the concentrator reaches 80 % of the saturation limit.

2 The composition of concentrate must reflect the concentrate composition predicted by the batch concentration dynamic material balance at 80 % of the saturation limit.

3 The composition of overheads must reflect a time-averaged overheads over the batch concentration time period.

4 The time-averaged volumetric flow rate of charge acid must equal the time-averaged volumetric flow rate of concentrate, reflecting the operating step where charge acid is used to refill the concentrator after concentrate is transferred to the HLW blend vessels.

An estimate with these characteristics was developed for the steady-state flowsheet based on inputs that determine the volume reduction factor (or cumulative feed volume concentrated relative to the concentrate volume) and concentrate nitric acid concentration upon reaching 80 % of the saturation limit. Parametric evaluations were performed using the dynamic material balance described in 24590-WTP-RPT-PT-02-019 to predict volume reduction factor and concentrate nitric acid concentration at the operating endpoint as a function of eluate feed composition. The parametric evaluation simplified the chemical system to the dominant components of an aqueous solution containing 0.005 to 0.2 M $NaNO_3$ and 0.2 to 0.5 M HNO_3. The predictions were reduced to an algebraic form by correlating the regression parameters. The predictions were developed for a charge acid of both 5 and 6 M HNO_3 shown as Equation 2.6-4 and Equation 2.6-5.

For 5 M charge acid:

Equation 2.6-4

$$\frac{1}{VRF} = b_1 [Na_e]^{b_2}$$

$$b_1 = 0.1656 + 0.8241\ [HNO_{3,e}]$$

$$b_2 = 1.0348 - 0.031[HNO_{3,e}]$$

$$[HNO_3]_c = 2.638 + 6.332[HNO_{3,e}] + 3.102[Na_e] - 7.554[Na_e]^2$$

For 6 M charge acid:

Equation 2.6-5

$$\frac{1}{VRF} = b_1 [Na_e]^{b_2}$$

$$b_1 = 0.1426 + 0.8066\ [HNO_{3,e}]$$

$$b_2 = 1.0025 - 0.046[HNO_{3,e}]$$

$$[HNO_3]_c = 2.579 + 6.31[HNO_{3,e}] + 2.631[Na_e] - 1.718[Na_e]^2$$

where:

$[HNO_3]_c$ = concentration of HNO_3 in concentrate at 80 % of saturation, M
VRF = volume reduction factor at 80 % of saturation, dimensionless
$[HNO_{3,e}]$ = concentration of HNO_3 in eluate fed to evaporator, M
$[Na_e]$ = concentration of sodium in eluate fed to evaporator, M. In actual waste, this is the concentration of the sum of all cations.

The transfer of solutes from the concentrate to overhead vapor is defined by a decontamination factor (DF) to model the performance of the evaporator demister. The evaporator is vendor-designed equipment which is currently in procurement. A specific design is not available for analysis, nor is equipment available for testing. Therefore, the design specification limiting the mass rate of Cs in

condensate to a factor of 10^{-7} of the mass rate of Cs in the feed is used to describe the transmission of all solutes to the overhead vapor (24590-PTF-3PS-MEVV-T0002, *Engineering Specification for Cesium Nitric Acid Recovery System and Technetium Eluant Recovery System*). The design specification requires that the vendor perform a test to confirm that this requirement is achieved by the plant equipment.

A sensitivity evaluation was performed using the batch concentration model to estimate the effect of selected charge acid compositions on eluate concentration system characteristics (24590-WTP-RPT-PT-02-019). The results indicate that higher charge acid concentrations reduce the concentrate transfer frequency and reduce the time-averaged mass rate of acid in concentrate sent to the HLP system blend tanks. Lower charge acid concentrations reduce the potential for generating excess eluant that would be transferred to waste recycle and reduce the potential for generating an overheads vapor that causes operating instabilities in the rectifier. Limiting the charge acid composition to a maximum of ~6 M HNO_3 results in a monotonic concentrate density increase over the evaporation cycle, which may simplify control schemes. While a formal optimization was not completed, a charge acid composition of 5 M HNO_3 was judged to represent a balance between the competing desirable attributes for the CNP system and is used as the basis for material balances. However, flexibility to modify the charge acid concentration should be maintained to allow operations to respond to variations in the importance of competing attributes.

Data from an additional eluate concentration test are reported in SCT-M0SRLE60-00-183-02, *Validation and Application of Concentrated Cesium Eluate Physical Property Models*. These data were obtained by concentrating a simulant based on eluate compositions observed during actual AW-101 waste IX column tests. The observed IX eluate composition was diluted by a factor of four to formulate feed for the concentration test, which was performed at ~70 torr and ~55 °C with a charge acid concentration of 7.5 M. An evaluation of the additional test data, analogous to that performed for other tests in 24590-WTP-RPT-PT-02-019, is described by CCN 167389, *Letter: Reconcile Cesium Eluate Concentration Data from SCT-M0SRLE60-00-183-02; Subcontract No. 24590-CM-HC4-HXYC-00013*. The evaluation indicated that modification of the average for the empirical constant in Equation 2.6-2 to include the additional test does not significantly change predictions of concentrator performance. Therefore, material balance inputs continue to be based on data from the first seven evaporation tests.

Correlations for estimating concentrated eluate solution density, viscosity, heat capacity, and total dissolved solids solubility are reported in SCT-MOSRLE60-00-183-02. The correlations estimate eluate concentrate property variations with temperature and dominant eluate cation (Al, Ca, Cs, H, K, and Na) concentrations, assuming an initial charge acid concentration of 7.5 M. Variation of the correlations over the range of applicability indicates the eluate concentrate properties at 55 °C is approximated by density ~1.34 to 1.45 g/mL, viscosity ~1.5 to 2.5 cP, heat capacity ~0.5 to 0.7 cal/g-°C, and solute solubility limit ~0.6 to 0.8 g/mL. A correlation predicting the volume reduction factor for eluate at 80 % of the solubility limit is also indicated in SCT-M0SRLE60-00-183-02. The volume reduction factor correlation could not be validated by comparison to test observations and use of this correlation was not recommended.

2.6.3.2 Recovered Nitric Acid Rectifier

The operating pressure controls the concentration of the nitric acid vapor stream, in combination with the initial charge concentration. The rectifier (CNP-DISTC-00001) removes nitric acid from the vapor and produces an acidic bottom product. Also, some of the post-elution rinse water is routed to the CNP system, so that more water returns to the CNP system than is sent to the IX columns as eluant. The rectifier performs a binary distillation of nitric acid and water that separates excess water entering the system for recycle as process condensate.

The simplified sketch of the rectifier column system shown in Figure 2.6-1 was used to develop a mass balance model to describe the system as a binary distillation. The model is based on the following general assumptions:

- Evaporator operation is controlled such that the nitric acid concentration in evaporator overheads is less than the desired nitric acid concentration in recovered acid.
- The condensers are assumed to operate as total condensers.
- Entrainment estimates based on sieve trays and nominal column operation at 80 % of flooding describe the distribution of solutes to the rectifier distillate.

The flowsheet uses the following as known inputs to calculate the rectifier system outputs:

1. Specified concentration of nitric acid in recovered acid is the HNO_3 concentration specified for cesium IX eluant in Section 2.5. This is based on the composition required to reuse recovered acid as IX eluant.
2. Rectifier column design recovery efficiency for nitric acid = 99.9 %. This is an assumed input that will be dependent on vendor design results.
3. Number of trays in the column = 3 sieve trays. This is an assumed input that will be dependent on vendor design results.
4. Henry's Law constant for trace volatile components in the rectifier feed. See Section 7 for listing.
5. Operating pressure = 1.45 psia. This is an assumed value consistent with the evaporator operating conditions.
6. Operating temperature = 130 °F (55 °C). This is an assumed value consistent with the evaporator operating conditions. This value is also consistent with the CNP equipment parameters in 24590-WTP-RPT-ENG-07-007, *Process Stream Properties*.

Based on overall and component mass balances, Equation 2.6-6 calculates the rectifier system outputs.

Equation 2.6-6

$$x_D^{HNO3} = \frac{(1-\alpha)\,x_F^{HNO3}}{\left(1-\alpha\,\frac{x_F^{HNO3}}{x_B^{HNO3}}\right)}$$

$$D = \frac{(1-\alpha)\,x_F^{HNO3}}{x_D^{HNO3}}\,F$$

$$B = F - D$$

$$x_D^j = \frac{x_F^j}{df^j}$$

$$x_D^{H2O} = 1 - x_D^{HNO3} - \sum_{\forall\, j,\, \text{except}\, H2O\, \text{and}\, HNO3} x_D^j$$

$$x_B^j = \frac{F\,x_F^j - D\,x_D^j}{B}$$

where:

F is molar flow rate of vapor fed to column from the Cs evaporator, kmol/hr

D is molar flow rate of distillate produced by the column, kmol/hr

B is molar flow rate of recovered acid produced by the column, kmol/hr

x_i^j is mole fraction of component j in stream i, dimensionless

df^j is decontamination factor for component j, dimensionless

α is fraction of feed nitric acid recovered, dimensionless

DFs are used to estimate the distribution of all components other than nitric acid and water to the distillate and bottoms streams of the rectifier. The DFs are estimated based on an entrainment analysis for non-volatile components and gas absorption for volatile components, resulting in the following alternate modeling equations. The non-volatile DF modeling equation will be used for all components where Henry's Law constant data are unavailable.

DF estimates for non-volatile components fed to the rectifier column are based on a tray tower entrainment correlation presented in Perry and Chilton (1973; see Figure 18-20, pg 18-13). The correlation associates the fraction of entrained liquid with respect to the gross liquid downflow (entrainment factor, Ψ) to the liquid/gas mass flow rate, liquid/gas density, and approach to flooding for bubble-cap plate and sieve plate towers. The relationship is presented in a graphical format by Perry and Chilton (1973). To simplify calculations, points from the graph presented in Perry and Chilton (1973) were correlated to provide a mathematical expression for the entrainment factor assuming sieve trays will be used in the rectifier column design and normal operation will be performed at approximately 80 % of flooding. The entrainment factor was assumed to be constant for each tray. Tray-by-tray material balances, using the entrainment factor, result in Equation 2.6-7 as an estimate for non-volatile solute DF.

Equation 2.6-7

$$df^j = \frac{\left(\sum_{k=0}^{N} f^k\right) D + B}{f^N F}$$

where:

$$f = \frac{\Psi}{1-\Psi}$$

$$\mathrm{Log}_{10}\Psi = -3.15224 - 1.89062\,\mathrm{Log}_{10}z - 0.30617(\mathrm{Log}_{10}z)^2$$

$$z = \frac{B}{F}\left(\frac{\rho_g}{\rho_l}\right)^{0.5} \approx \frac{B}{F}\left(0.018\frac{P_T}{RT}\right)^{0.5}$$

ρ_l is liquid density $\approx$ 1000 g/L

ρ_g is vapor density $\approx 18 \times P_T/RT$ g/L

N is number of sieve trays in rectifier

Figure 2.6-5 indicates the predicted variation in non-volatile solute DF with distillate to feed mass rate ratio for a rectifier containing three sieve trays.

DFs for volatile components are evaluated assuming the rectifier performs like a tray absorber using linear equilibrium relationships for the volatile components (applies Henry's Law constants). It is assumed that the gas and liquid flows through the rectifier are constant (volatile components modeled by DFs are trace constituents in the feed stream).

Henry's Law constants are assumed to be available to relate the partial pressure of a component in the vapor phase to the mole fraction of a component in the liquid phase on each tray. This results in Equation 2.6-8 for estimating the equilibrium relationship.

Equation 2.6-8

$$y^{i}_{eq} = \frac{H_i}{P_T} x^i = \gamma_i x^i$$

where:

y_{eq}^{i} is vapor phase mole fraction of component i in equilibrium with solution

x^i is mole fraction of component i in the liquid phase on a tray

H_i is Henry's Law constant for volatile component i, atm/mole fraction

P_T is column operating pressure, atm

γ_i is $\frac{H_i}{P_T}$, dimensionless

Tray-by-tray material balances are used to develop Equation 2.6-9 as an estimate of the DF for volatile components that is dependent on the number of trays in the rectifier.

Equation 2.6-9

$$df^j = \frac{x^j_F}{x^j_D} = 1 + (1 - \gamma_j)\sum_{k=1}^{N}\left(\frac{B}{\gamma_j F}\right)^k$$

2.6.3.3 Energy Contributions

The major utilities used in the CNP system are low-pressure steam and plant cooling water. The Cs evaporator concentrate reboiler (CNP-HX-00001) operates continuously at a boil-off rate of 7 to 10 gpm to supply recovered eluate to the IX columns. Low-pressure steam is used in the reboiler. The Cs evaporator primary condenser (CNP-HX-00002) uses plant cooling water and operates continuously to condense the boil-off from the evaporator. Two vacuum ejectors between the primary, inter, and after condensers require 300 lb/hr of high-pressure steam to provide a vacuum on the CNP system. The discharge from the vacuum ejectors flows to the secondary and tertiary condensers, where plant cooling water condenses the steam. These ejector/condenser systems operate continuously.

2.6.3.4 Vessel Volumes

The CNP evaporator, CNP-EVAP-00001, has a working volume of 2131 gal. It is currently assumed that there will be a 130 gal heel, leaving a batch volume of approximately 2000 gal. The Cs evaporator

recovered nitric acid vessel, CNP-VSL-0004, has a batch volume of 6000 gal. The eluate contingency storage vessel, CNP-VSL-00003, has a batch volume of 12,500 gal.

2.6.4 Ongoing Work and Potential Changes

There are still two open issues regarding the technical readiness of the CNP system. The first item involves performing bench-scale composition testing to confirm that solids precipitation in the CNP evaporator can be controlled for various design feed envelopes. The second item requires an analysis of operating procedures to mitigate the effects of inadvertent solids formation during process upsets.

A more detailed thermodynamic model of the eluate concentration process is ultimately planned to replace the batch concentration model described above. Completion of the evaporator vendor design and acceptance test results have the potential to result in modifying the DFs used to estimate transmission of solutes to the evaporator overheads. As the design of the rectifying column is finalized, calculations assuming sieve trays will be updated to reflect either valve trays or packing, depending on which is ultimately chosen.

Report SCT-M0SRLE60-00-99-03 noted that the presence of oxalate (at 500 mg/L), DBP (dibutylphosphate, at 350 to 700 mg/L), and EDTA (ethylenediaminetetraacetic acid, at 500 mg/L) significantly reduced the solubility limit for solutes in the test matrices at 3 and 5 M HNO_3. Solute solubilities were reduced by 50 to 95 % as compared to systems that were not spiked with these organics. The predicted path of organic compounds in the evaporator system, and potential for modifying the frequency of concentrate transfers to the HLW blend tanks, is expected to be improved upon implementation of the detailed thermodynamic model.

The influence of inorganic components expected to exhibit a relative volatility to nitric acid, such as HCl and HF, has not been incorporated into the evaporator model. This results in treating these types of components as solutes and potentially overestimating their concentration in the concentrate and underestimating their concentration in recovered acid. Implementation of the detailed thermodynamic model may modify the halide concentration of recovered acid used as IX eluant.

To lower the ultimate acid concentration in the evaporator, the following elution method is being investigated: The first 4 bed volumes (BV) of the nitric acid elution will be performed with 0.5 M fresh HNO_3 and will be added via CXP-VSL-00005 and the Cs Ion Exchange Process System (CXP) pumps. The resin bed requires about 3.5 to 4 BV of 0.5 M HNO_3 to titrate the resin, that is, convert all of the adsorption sites from sodium to hydrogen form. For new resin, the acid requirement is about 1.6 g-moles of acid per liter of Na-form resin. The exact acid concentration for the last 21 BV of the 25 BV acid elution cycle is not critical and may vary from 0.5 M down to 0.1 M (pH = 1) without any reduction in the Cs elution rate. This means the recovered acid concentration is not critical.

2.6.5 References

24590-PTF-3PS-MEVV-T0002, Rev 5, *Engineering Specification for Cesium Nitric Acid Recovery Forced Circulation Vacuum Evaporator System.*

24590-PTF-DCA-PR-03-005, Rev 0, *Design Basis Modification for the Eluant Recovery Evaporator Systems.*

24590-PTF-M5-V17T-00014, Rev 2, *Process Flow Diagram Cesium Nitric Acid Recovery Process System CNP.*

24590-WTP-RPT-ENG-07-007, Rev 00A, *Process Stream Properties.*

24590-WTP-RPT-PT-02-019, Rev 1, *Cesium Eluate Concentrator Reconciliation of Test Data.*

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CCN 211821, memorandum, JG Brown (WTP) to JW Olson (WTP), *Closure of Technical Issue 2008-0012: "CNP Open Issues".* 28 July 2010.

Choi AS. 2001. *Estimation of Physical Properties of AN-107 Cesium and Technetium Eluate Blend*, SRT-RPP-2000-00061 (WSRC-TR-2000-00527), February 2001. Westinghouse Savannah River Company, Aiken, SC.

Perry RH and Chilton CH. 1973. *Chemical Engineers' Handbook.* McGraw-Hill Book Company, New York, New York. SCT-M0SRLE60-00-32-02, Rev D, *Cesium Eluate Analytical Data Evaluation*, (WSRC-TR-2001-00594).

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SCT-M0SRLE60-00-183-02, Rev 00A, *Validation and Application of Concentrated Cesium Eluate Physical Property Models.*

SCT-M0SRLE60-00-185-01, Rev 00B, *Report - Cesium Eluate Semi-Batch Evaporation Performance* (WSRC-TR-2003-00135, Rev B).

SCT-M0SRLE60-00-99-03, Rev 00D, *Report -Cesium Eluate Evaporation Solubility and Physical Property Behavior* (WSRC-TR-2002-00273, Rev 1).

Table 2.6-1 Summary of Cs Eluate Evaporation Test Data Used to Estimate Effect of Solutes on Nitric Acid Activity Coefficient

Analyte	Average Feed	Process Volumes Fed to Evaporator				
		10	20	30	40	50
		Concentrate Composition (mg/L)				
[Na], mg/L	1494.7	14100	30900	45400	63100	70700
[Al], mg/L	3.7	47.8	78.2	115.3	148.3	163.4
[Ca], mg/L	6.5	58	135	197	274	304
[Cr], mg/L	58.9	571	1200	1800	2520	2750
[Cu], mg/L	2.9	30.7	61.9	87	124	135
[Fe], mg/L	5.3	50	106	164	231	250
[K], mg/L	25.2	219	520	760	1070	1210
[Cs], mg/L	16.0	157	321	458	685	779
[HNO_3], M	0.52	4.47	6.18	5.21	5.44	4.66
Density, g/mL	1.0198	1.1732	1.2625	1.2730	1.3155	1.3372

	Composite Condensate Composition (mg/L)									
	Process Volumes to Evaporator									
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
[HNO_3], M	0.018	0.099	0.337	0.524	0.661	0.640	0.528	0.614	0.629	0.519

Notes:

1. Data from *Cesium Eluate Evaporation Solubility and Physical Property Behavior* (SCT-M0SRLE60-00-32-03), Tables 4-3 and 4-7.
2. Initial charge acid in evaporator was 7.25 M HNO_3 with observed density of 1.2287 g/mL.
3. Evaporator operating volume initially at 0.325 L, decreasing to 0.245 L as sampling was performed.
4. Evaporation performed at approximately 55 °C at a total pressure of approximately 70 torr.
5. Mist eliminator condensate accumulations were observed during processing of feed volumes 0 to 10, which is expected to impact the apparent vapor-liquid equilibrium observed between concentrate and condensate.

Table 2.6-2 Summary of Eluate Simulant Compositions Used in Follow-on Evaporation Tests

Eluate Simulant Basis	AN-103	AN-102	AW-101	AN-107
Composition, gmol/L[1]				
$CsNO_3$	8.65E-04	1.80E-04	1.11E-03	3.02E-05
KNO_3	1.84E-03	2.05E-03	1.95E-02	4.09E-04
$NaNO_3$	4.61E-02	6.43E-02	1.94E-01	3.08E-02
$Al(NO_3)_3$	2.19E-03	9.93E-03	1.04E-02	1.11E-04
$Ni(NO_3)_2$	0.00E+00	7.67E-05	1.02E-04	1.16E-03
$Ca(NO_3)_2$	7.23E-03	1.65E-03	9.97E-05	0.00E+00
$Cu(NO_3)_2$	1.26E-04	4.73E-04	1.61E-03	2.36E-04
$Fe(NO_3)_3$	5.04E-04	3.18E-04	5.65E-04	1.67E-04
$Mg(NO_3)_2$	5.35E-04	3.70E-04	0.00E+00	0.00E+00
$Zn(NO_3)_2$	3.21E-04	6.11E-05	4.15E-04	3.86E-05
HNO_3	0.24	0.28	0.29	0.36

Notes:

1. Calculated from simulant make-up data reported in Table 3-1 of *Cesium Eluate Semi-Batch Evaporation Performance* (SCT-M0SRLE60-00-185-01).

Table 2.6-3 Summary of Cs Eluate Evaporation Follow-on Test Data

Test Identifier	1			2			3			4		
Feed Composition	AW-101			AN-102			AN-103			AN-107		
Charge Acid/Volume	7.62 M / 250 cm^3			7.54 M / 250cm^3			7.64 M / 250 cm^3			7.64 M / 250 cm^3		
Operating Pressure	70 torr			70 torr			70 torr			70 torr		
Operating Temperature	~55°C			~55°C			~55°C			~55°C		
Reported Test Data	Concentration Factor[1]	Concentrate		Condensate	Concentration Factor	Concentrate		Condensate	Concentration Factor	Concentrate		Condensate	Concentration Factor	Concentrate		Condensate
		[H+], M	[Na+], M	[H+], M		[H+], M	[Na+], M	[H+], M		[H+], M	[Na+], M	[H+], M		[H+], M	[Na+], M	[H+], M
	0	7.62	0	No Data[2]	0	7.54	0	No Data	0	7.64	0	No Data	0	7.64	0	No Data
	4	6.82	0.77	0.556	4	7.06	0.26	0.622	4	No Data	No Data	0.365	4	No Data	No Data	0.398
	8	6.29	1.55	0.686	8	6.34	0.51	0.411	8	No Data	No Data	0.395	8	No Data	No Data	0.425
	12	5.59	2.32	0.253	12	6.09	0.77	0.391	12	6.61	0.55	0.32	10	7	0.31	No Data
	14	5.21	2.71	No Data	16	6.01	1.03	0.366	16	No Data	No Data	0.156	12	No Data	No Data	0.4
	16[6]	5.37	3.1	0.541	20	5.77	1.29	0.264	20	No Data	No Data	0.494	16	No Data	No Data	0.558
					24	5.85	1.54	0.402	24	No Data	No Data	0.56	20	No Data	No Data	0.387
					28	5.45	1.8	0.374	28	5.65	1.29	0.274	22	6.48	0.68	0.334
					32	5.21	2.06	0.313	32	No Data	No Data	0.35	26	No Data	No Data	0.303
					36	4.97	2.32	0.4	36	No Data	No Data	0.287	30	6.76	0.92	0.426
					40	4.97	2.57	0.34	40	4.94	1.84	0.289	34	No Data	No Data	0.399
					44[6]	5.13	2.83	0.398	44	No Data	No Data	0.257	38	No Data	No Data	0.538
					48[6]	5.05	3.09	0.346	48	4.42	2.21	0.341	42	6.2	1.29	0.411
									52	4.58	2.4	0.236	46	No Data	No Data	0.459
									56	4.46	2.58	0.338	50	No Data	No Data	0.494
									60[6]	4.46	2.77	0.252	52	5.48	1.6	No Data
									64[6]	4.54	2.95	0.248	54	No Data	No Data	0.325

Test Identifier	5			6			7[4]			58	No Data	No Data	0.511
Feed Composition	AN-102			AN-102			AN-102			62	No Data	No Data	0.322
Charge Acid/Volume	5.32 M / 250 cm^3			4.0 M / 250 cm^3			5.25 M / 50 cm^3			64	5.17	1.97	0.503
Operating Pressure	70 torr			70 torr			760 torr			68	No Data	No Data	0.272
Operating Temperature	~55°C			~55°C			~108°C			72	No Data	No Data	0.354
Reported Test Data	Concentration Factor	Concentrate		Condensate	Concentration Factor	Concentrate		Condensate	Concentration Factor	Concentrate		Condensate	74	5.13	2.28	No Data
		[H+], M	[Na+], M	[H+], M		[H+], M	[Na+], M	[H+], M		[H+], M	[Na+], M	[H+], M	76	No Data	No Data	0.321
	0	5.32	0	No Data	0	4	0	No Data	0	5.25	0	No Data	80	No Data	No Data	0.312
	4	5.51	0.26	0.228	4	4.28	0.26	0.22	4	5.39	0.26	0.227	82	5.37	2.52	No Data
	8	5.85	0.51	0.209	8	5.03	0.51	0.278	8	5.16	0.51	0.373	84	No Data	No Data	0.483
	12	6.02	0.77	0.207	12	4.97	0.77	0.289	12	4.7	0.77	0.481	86	5.17	2.65	0.464
	16	6.4	1.03	0.339	16	4.97	1.03	0.341	20	4.12	1.29	0.424	90[6]	5.56	2.77	0.203
	20	6.05	1.29	0.456	20	4.93	1.29	0.339	28	3.43	1.8	0.327	94[6]	5.92	2.89	0.335
	24	5.72	1.54	0.455	24	4.77	1.54	0.317	36	3.56	2.32	0.33				
	28	5.4	1.8	0.287	32	4.54	2.06	0.351	44	3.59	2.83	0.345				
	32	5.07	2.06	0.48	40	4.7	2.57	0.305								
	36	4.89	2.32	0.41	44	4.54	2.83	0.341								
	40	4.61	2.57	0.358	48[5]	4.97	3.09	0.406								
	44	4.34	2.83	0.425												
	48	4.31	3.09	0.263												
	52[6]	4.38	3.35	0.35												
	56[6]	4.64	3.6	No Data												

Notes:

1. Concentration factor = Eluate volume fed to evaporator relative to the constant concentrate volume maintained in the evaporator during the test run.
2. Data shown in this table represents a composite of test data reported in Tables 4-1, 4-2, 4-3, and 4-4 of *Cesium Eluate Semi-Batch Evaporation Performance* (SCT-M0SRLE60-00-185-01).
3. Atmospheric test performed in a smaller evaporator pot.
4. Test control problem may have influenced this data point.
5. Precipitate observed upon cooling sample to room temperature.

Figure 2.6-1 Cs Eluate Concentration and Nitric Acid Recovery Schematic

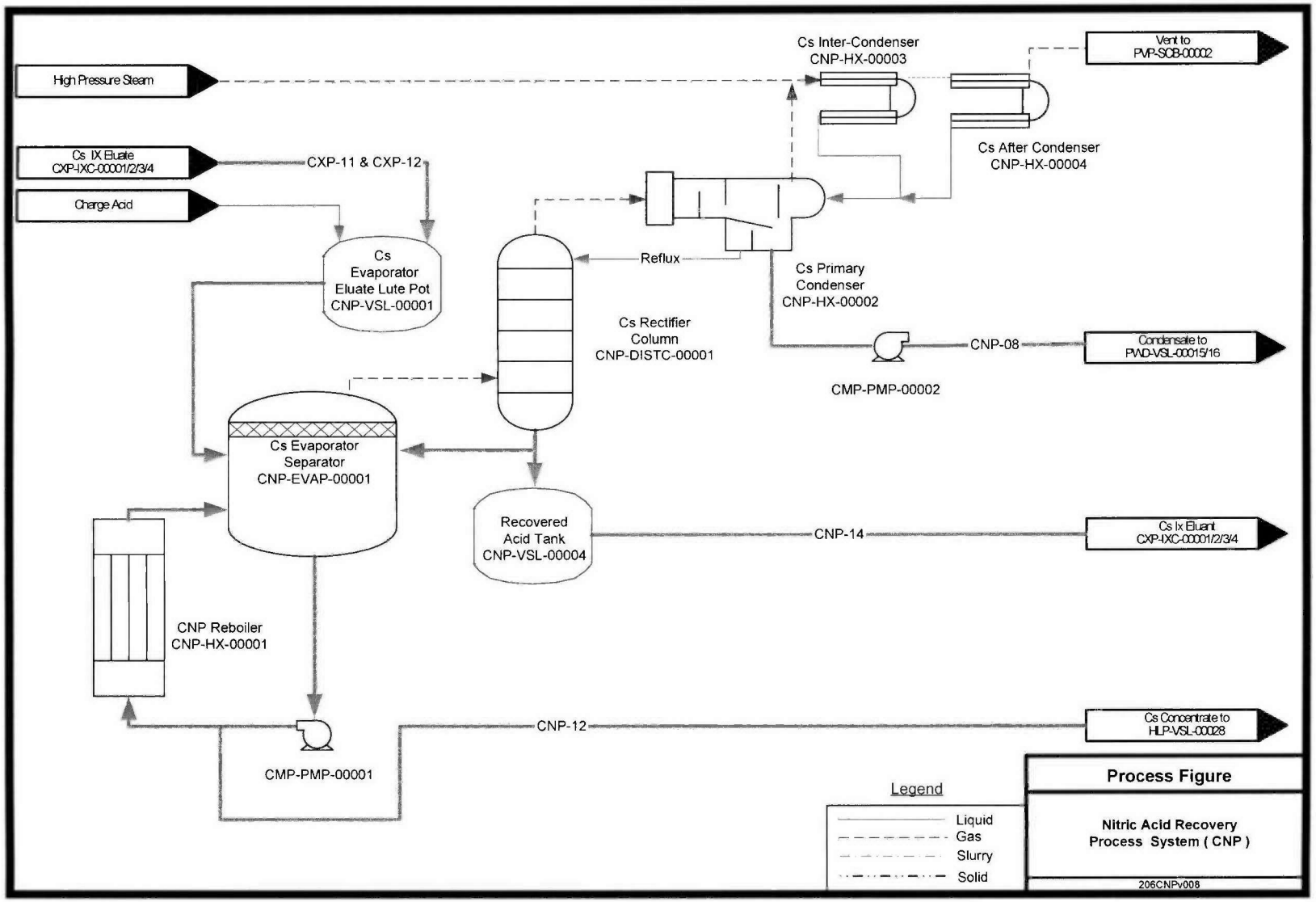
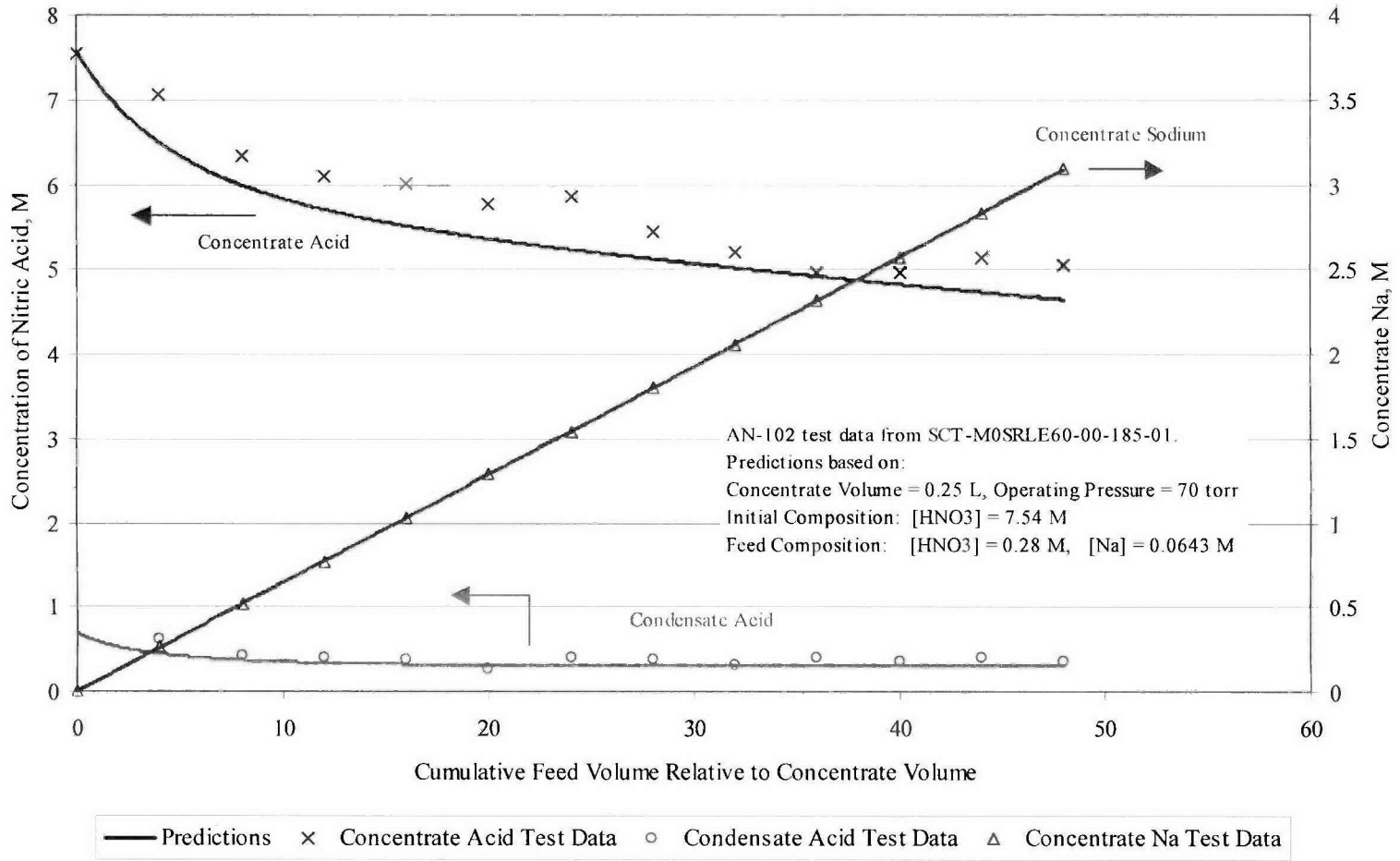


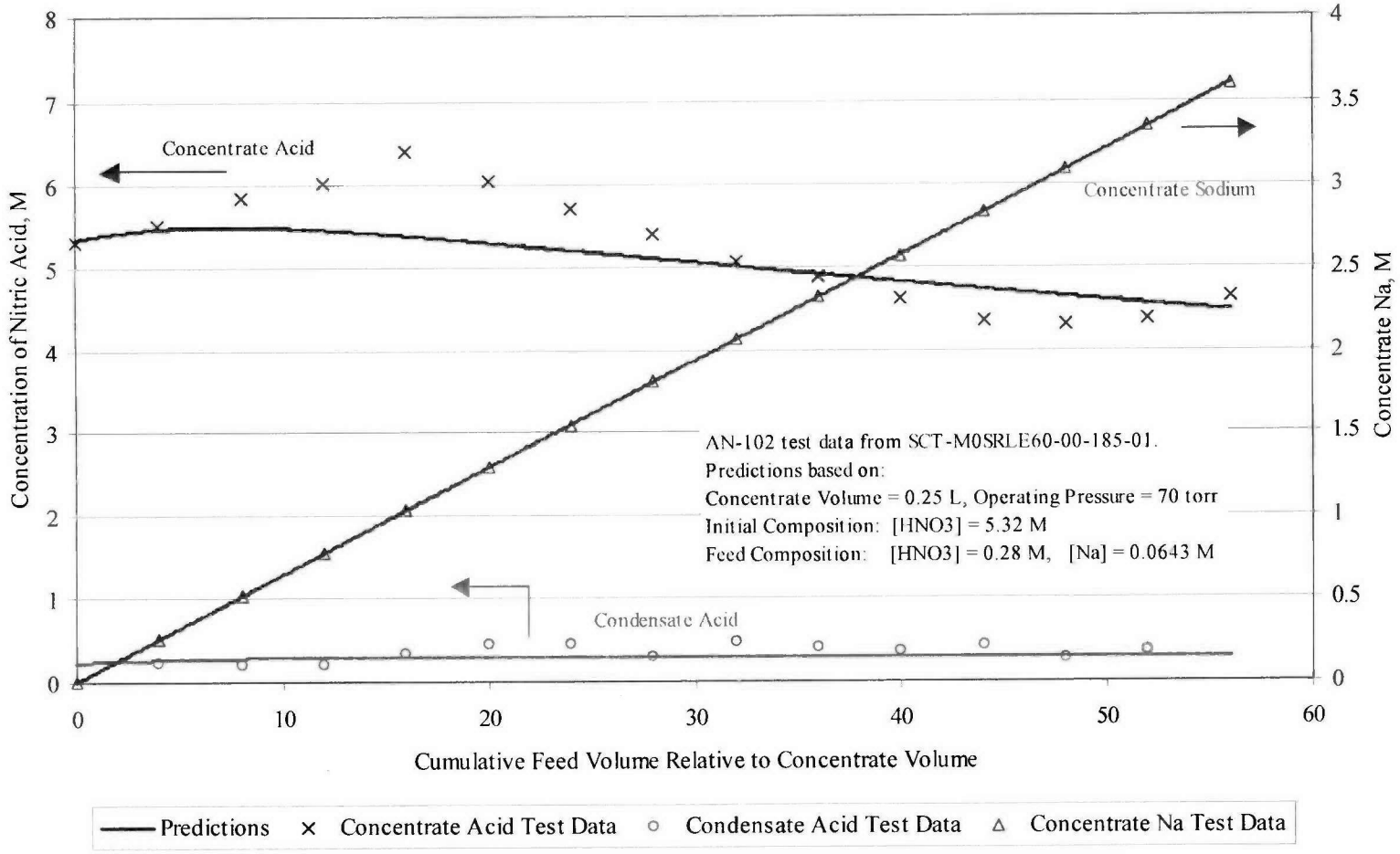
Figure 2.6-2 Comparison of Batch Concentration Prediction to Experimental Observations for 7.25 M Charge Acid



Notes:

1. From 24590-WTP-RPT-PT-02-019.
2. Evaporator feed composition based on AN-102 eluate described in Table 2.6-2.

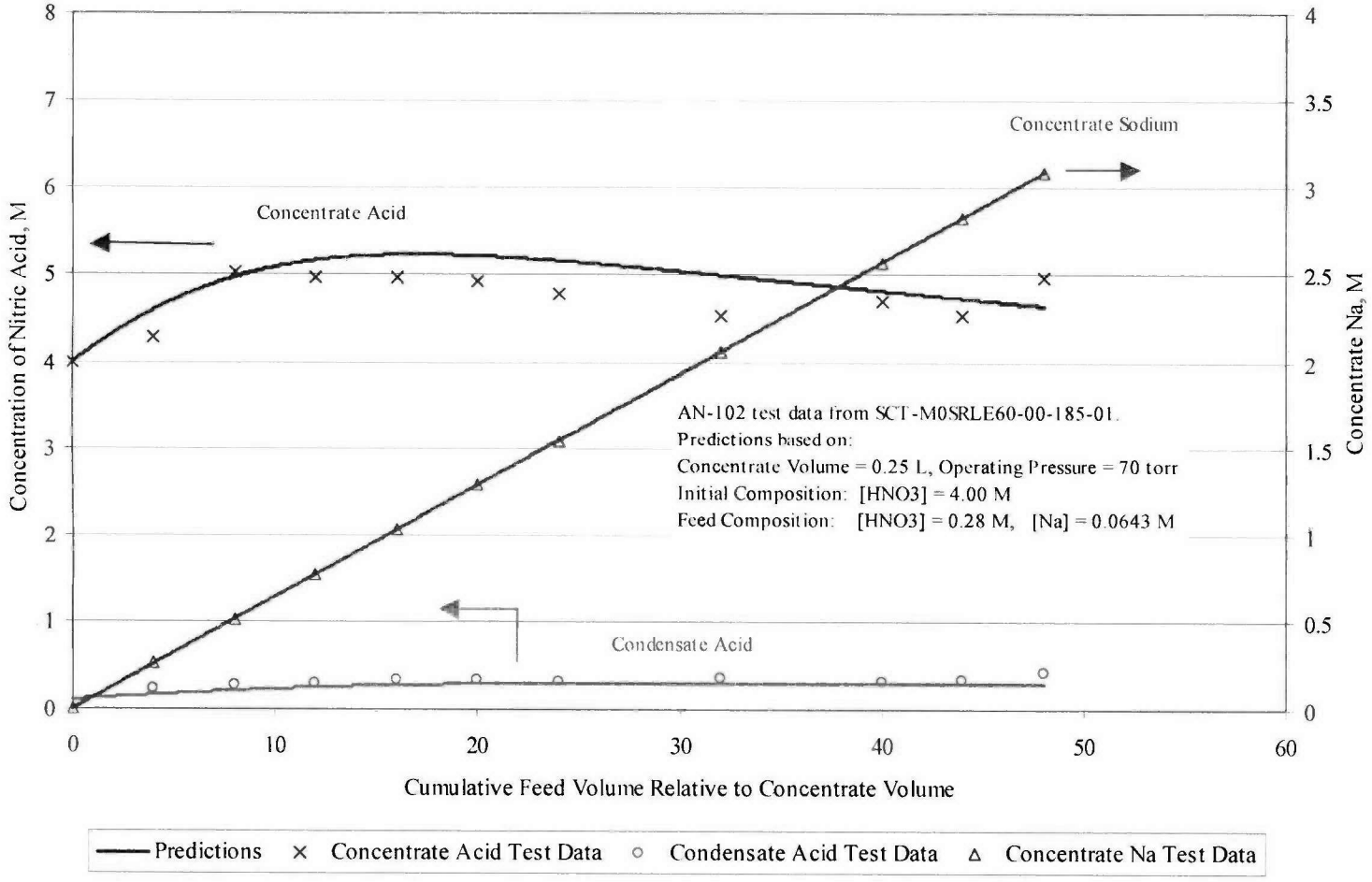
Figure 2.6-3 Comparison of Batch Concentration Prediction to Experimental Observations for 5.32 M Charge Acid



Notes:

1. From 24590-WTP-RPT-PT-02-019.
2. Evaporator feed composition based on AN-102 eluate described in Table 2.6-2.

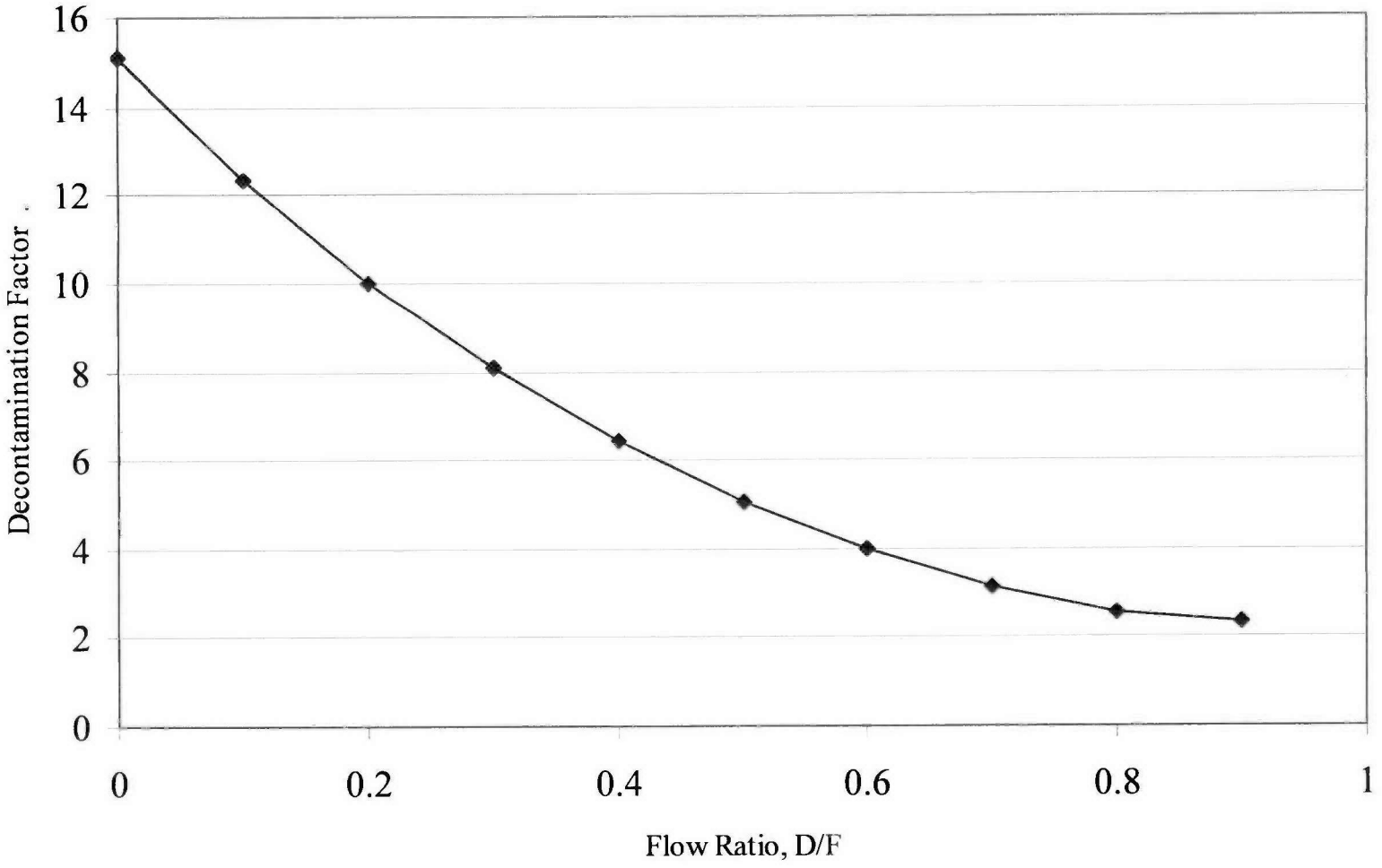
Figure 2.6-4 Comparison of Batch Concentration Prediction to Experimental Observations for 4.0 M Charge Acid



Notes:

1. From 24590-WTP-RPT-PT-02-019.
2. Evaporator feed composition based on AN-102 eluate described in Table 2.6-2.

Figure 2.6-5 Estimated Variation of Non-Volatile Component Decontamination Factors with Distillate to Feed (D/F) Mass Flow Ratio for a Column Containing Three Sieve Trays



2.7 System TXP: Technetium Ion Exchange Process (Deleted)

2.8 System TEP: Tc Eluant Recovery Process (Deleted)

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2.9 System CRP: Cesium Fresh Resin Addition Process

2.9.1 Function and Requirements

The primary purposes of the Cesium fresh resin addition process system (CRP) are to add fresh resin to the Cs ion exchange (IX) columns, provide hydrogen mitigation for IX columns, and provide pathways from clean systems to the Cesium IX system (CXP) (i.e., emergency elution for IX columns). The resin conditioning occurs before transfer and includes converting the resin beads from the hydrogen to the sodium form, removing resin fines, and adjusting the alkalinity of the transfer fluid.

2.9.2 Process Description

Fresh resin is assumed to be delivered in bins by the vendor in the H-form with diameters within 10 % of 380 microns (24590-CM-MRA-MWD0-00007). The wet, Na-form resin has 2.04 moles of cation sites per liter (Section 2.5.3.2.1). The as-received, fresh resin is educted via demineralized water into the resin addition vessel (CRP-VSL-00001), where it mixes with 1140 gal of water. The maximum batch volume of this tank is 2146 gal.

The resin addition vessel is agitated to distribute solids in the liquid. The slurry is then pumped through a 330 micron screen (CRP-SCN-00001A/B) in the vessel, through a bag filter (CRP-FILT-00001A/B), and back into the resin addition vessel. This slurry recirculation system removes fines from the as-received resin. Once fines removal is complete, the demineralized water is decanted to RLD-VSL-00017 A/B.

Two molar NaOH is then added to convert the resin from the as-delivered H-form to the Na-form. This is accomplished by adding 720 gal of demineralized water to CRP-VSL-00001, followed by 750 gal of 2.0 M NaOH. A 12-hour wait time is necessary for the hydrogen form resin to fully convert to the sodium form. After 40 loading cycles have been reached in an IX column (24590-PTF-MVC-CXP-00010), the slurry in CRP-VSL-00001 is transferred by gravity flow to an empty IX column (Section 2.11). The fresh resin is captured on the IX column resin screen and the transfer solution is sent with treated LAW to CXP-VSL-00026A/B/C.

The system description (24590-PTF-3YD-CRP-00001), along with the process flow diagram (24590-PTF-M5-V17T-00018), describe the fresh resin addition system. Part 2 of the system description has not yet been updated to reflect the use of resorcinol formaldehyde (RF) resin or address hydrogen mitigation and clean reagent pathways in CRP-BULGE-00001.

2.9.3 Basis

2.9.3.1 Resin Replacement Frequency

The resin replacement frequency is how often the Cs resin bed is removed for disposal and a new resin bed added. Radiation and chemical degradation can contribute to loss of resin performance, resulting in the need to replace the resin bed. In practice, the resin performance and capacity will be monitored by process control techniques to determine when replacement is required, but estimates of resin life are provided based on laboratory studies to predict resin use and waste generation. Sections 2.5.3.1.4 and 2.5.3.1.5 describe the current status of laboratory studies investigating resin radiation and chemical stability. Therefore, the current baseline material balance estimates are based on a Cs resin bed replacement frequency of 40 loading/elution cycles.

Assumption 2.9.2. The resorcinol formaldehyde resin will retain adequate performance and capacity stability for 40 loading and elution cycles.

2.9.3.2 Fresh Resin Addition

The particle size distribution of resin particles used to form a bed in the IX columns is controlled during fresh resin addition to provide a bed with known hydraulic properties. Therefore, the initial step of preparing resin for introduction into a column includes removal of fines that may have been generated by transportation of the resin material. Section 2.5.3.1.2 describes test data that define the particle size distribution of as-received RF resin batches. The amount of fines removed from RF resin is expected to be significantly less than the SuperLig resin.

Pilot-scale testing of RF resin column addition and removal has been performed (SCT-M0SRLE60-00-110-00028, Rev B). Using gravity and suction, the resin was easily pumped into the columns as a slurry consisting of 30 % resin in deionized water. Rheological calculations of the viscosity as a function of bead concentration yielded similar results for optimal slurry loading (CCN 147249). A slurry loading of 27 % resin by volume is used for the flowsheet.

The steps required for Cs resin pretreatment before use in waste processing are defined by manufacturer recommendations and laboratory test experience. The test experience is described in Section 2.5.3.3, indicating the pretreatment chemical treatment that resulted in successful decontamination of waste solutions.

2.9.3.3 Storage and Aging Effects

It is recommended that RF resin be stored in its as-received hydrogen form, under water, and in an inert atmosphere. Section 2.5.3.1.4 describes the adverse oxidative effects on RF resin, so it is recommended that the storage containers be pressurized. Adhering to the above conditions, no change in Cs capacity was noticed after 1 year in storage at 22 °C (72 °F) in tests. Storage at an increased temperature of 45 °C (113 °F) actually showed an increase in Cs capacity of 15 % after 1 year. Storage temperatures should stay in the range of 0 to 100 °C (32 to 212 °F) (24590-QL-HC9-WA49-00001-03-00001, Rev 00A).

2.9.4 Ongoing Work and Potential Changes

As RF resin becomes incorporated into the system description, minor changes to the process may occur. Specifically, calculation 24590-PTF-MVC-CRP-00004 assumes a CIX bed volume of 750 gallons. It is currently assumed that operations will occur with scaled-down batch volumes to adjust for a 600 gallon CIX bed. Because of the relatively low frequency of use of this system, changes are not expected to impact the overall results of the flowsheets.

2.9.5 References

24590-101-TSA-W000-0004-99-00013, Rev 00C, *Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project – Waste Treatment Plant.*

24590-CM-MRA-MWD0-00007, Rev 5, *Resorcinol Formaldehyde Spherical Resin (N167).*

24590-PTF-3YD-CRP-00001, Rev 1, *System Description for the Cesium Resin Addition Process System – CRP.*

24590-PTF-M5-V17T-00018, Rev 2, *Process Flow Diagram Cesium Resin Addition Process System CRP.*

24590-PTF-MLC-CRP-00003, Rev 00D, *Pressure Drop and Size for CRP-SCN-00001A/B.*

24590-PTF-MVC-CRP-00004, Rev A, *Batch Specification for the Cesium Resin Addition Vessel (CRP-VSL-00001).*

24590-PTF-MVC-CXP-00010, Rev B, *Key Design Parameters for the CXP System.*

24590-QL-HC9-WA49-00001-03-00001, Rev 00A, *Report - Storage and Aging Effects on Spherical Resorcinol-Formaldehyde Resin Ion Exchange Performance.*

CCN 147249, *An Equation that Accommodates the Calculation of Bead Slurry Viscosities as a Function of Bead Concentration.* 26 October 2006.

SCT-M0SRLE60-00-110-00028, Rev 00B, *Report - Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin.*

2.10 System TRP: Tc Ion Exchange Fresh Resin Addition Process (Deleted)

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2.11 System RDP: Spent Resin Collection and Dewatering Process

2.11.1 Function and Requirements

The cesium (Cs) ion exchange resin performance is expected to degrade over time with exposure to radiation and chemicals during waste processing. Sections 2.5.3.1.3 through 2.5.3.1.5 describe the testing that has been performed, and Equation 2.5-17 is the resultant equation estimating the combined impact of radiolysis and chemical oxidation on the initial resin capacity. The resin is removed from the column and fresh resin is added when the resin capacity limits production throughput or when removal performance is inadequate to satisfy immobilized low-activity waste specifications for glass. The purpose of the Spent Resin Collection and Dewatering Process System (RDP) is to provide the capability to temporarily store and sample spent resin removed from the ion exchange columns and to transfer the resin to a package suitable for solid waste disposal.

To permit disposal as a solid mixed waste, spent resin will be analyzed to demonstrate that the waste complies with the *Hanford Site Solid Waste Acceptance Criteria* (HSSWAC) (24590-WTP-ICD-MG-01-003, *Interface Control Document for Radioactive Solid Waste*).

2.11.2 Process Description

Initially, the spent resin slurry vessel A (RDP-VSL-00002A) will contain 7500 gal of transport liquid that had been recycled from previous fresh resin addition or resin removal activities. RDP-VSL-00002B initially will be empty. After the elution cycle (Section 2.5), if a resin change is necessary, the contents of RDP-VSL-00002A are pumped at 140 gpm through the spent column. The displaced material from the column is washed into RDP-VSL-00002B. The spent slurry solution is recirculated for at least 2 hr to evenly suspend particles before sampling to demonstrate compliance with the HSSWAC for disposal. After satisfactory results from sampling, the spent resin is transferred in a slurry to a disposable resin dewatering container, where the resin is captured. Most of the transfer solution is transferred through the dewatering container and accumulated in RDP-VSL-00002A for reuse. Pressurized air is used to complete the drying of spent resin for compliance with HSSWAC for residual liquid (24590-PTF-3YD-RDP-00001). Drawing 24590-PTF-M5-V17T-00020, referenced in Appendix A, provides a flow diagram describing the spent resin disposal process.

As fresh resin is added to the emptied column through the cesium resin addition process, the displaced liquor from the column is gravity drained into RDP-VSL-00002A at 60 gpm.

2.11.3 Basis

Section 2.9.3.1 describes the basis for Cs resin bed replacement frequency. It is currently assumed that each resin bed will be replaced after 40 loading/elution cycles.

The maximum capacities of the spent resin slurry vessels (RDP-VSL-00002A/B/C) are 7525 gal each, and they are interchangeable in their functions. After the spent resin flush-out and the fresh resin flush-in operations, RDP-VSL-00002B has a volume of 7085 gal. A final 432 gal addition of line flush water is then put in this vessel, resulting in a final volume of 7517 gal within RDP-VSL-00002B. The maximum volume of the spent resin dewatering moisture separation vessel (RDP-VSL-00004) is 79 gal (24590-PTF-3YD-RDP-00001).

Analyses on laboratory studies using resorcinol formaldehyde (RF) resin to process actual waste samples are summarized in Section 2.5.3.1.6, Spent Resin Properties, and Table 2.5-12. Analytes detected above

the minimum reportable quantity included Ag, As, Ba, Cr, Ni, and Pb. Spent RF resin is expected to contain 1/20 of the design basis for Cs content and 1/10 of the limit of transuranic elements (TRU) for non-TRU wastes.

A slurry loading of 27 % resin by volume in resin transfer solutions has been used for preparation of material balances. Resin removal tests are described in SCT-M0SRLE60-00-110-00028, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin*, for both 12- and 24-in. diameter pilot scale columns. The 24-in. diameter column test indicates that approximately 99.8 % of the resin bed (~170 L resin bed volume [BV] in the hydrogen form) was removed from the column after a total of 500 L flush solution was pumped through the column. The test results produce an average transfer solution resin loading of ~34 % by volume, bounding the material balance input. Observations during testing indicate that very little resin was removed by the last 100 L of flush solution pumped through the test column and removal slurries were approximately 50 % resin by volume at the beginning of the resin removal process. Tests concluded that greater than 99 % of a resin bed was sluiced out of the 24-in. column in less than 5 min with less than 2.5 BV of flush solution (average slurry resin loading of 40 % by volume).

The sampling performed in RDP-VSL-00002B is sample point 31b and has a laboratory turnaround time of 5.5 hr (CCN 254099, *Laboratory Sample Turnaround Times*). This is a model hold point, meaning the contents of RDP-VSL-00002B will not be released until the sample results are received.

2.11.4 Ongoing Work and Potential Changes

No further testing activities specific to the resin removal process are currently planned.

2.11.5 References

24590-PTF-3YD-RDP-00001, Rev 1, *System Description for Spent Resin Collection and Dewatering Process - System RDP.*

24590-PTF-M5-V17T-00020, Rev 2, *Process Flow Diagram Spent Resin Collection and Dewatering Process System RDP.*

24590-WTP-ICD-MG-01-003 Rev 3, *ICD 03 - Interface Control Document for Radioactive Solid Waste.*

24590-WTP-PL-PR-04-0001, Rev 2, *Integrated Sampling and Analysis Requirements Document (ISARD).*

CCN 254099, *Laboratory Sample Turnaround Times (WTP OR Model V7.0).*

SCT-M0SRLE60-00-110-00028, Rev 00B, *Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin.*

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2.12 Systems TLP/TCP: Treated LAW Evaporation and Concentrate Storage Process

2.12.1 Function and Requirements

The primary purpose of the treated low-activity waste (LAW) evaporation process system (TLP) is to concentrate the pretreated feed to the LAW melters. The TLP system also collects the offgas condensate from the LAW Facility, neutralizes the stream, and evaporates the recycle stream with the treated LAW feed.

General requirements from the WTP *Statement of Work* (SOW) (DE-AC27-01RV14136) that apply to evaporation are Facility Specification, Sections C.7 (d) (1) (v) and (vi).

The treated LAW concentrate storage process system (TCP) provides buffer storage capacity between the Pretreatment (PT) and LAW Facilities. This system is designed to provide lag storage for 7 days (at 60 metric tons per day immobilized LAW production) to allow for continuous operation of the LAW Facility if there is an outage in the PT Facility.

2.12.2 Process Description

The TLP system consists of a continuous, forced-circulation, vacuum evaporation system. The feed to the evaporator (TLP-SEP-00001) either comes from the LAW submerged bed scrubber (SBS) condensate receipt vessels (TLP-VSL-00009A/B) or the ion-exchange system treated LAW collection vessels (CXP-VSL-00026A/B/C). The evaporator system consists of a separation vessel, recirculation pump and pipe loop, reboiler, slurry product pump, vacuum eductor system, primary condenser, intercondenser, and aftercondenser. The condensate from the condensers is collected in the condensate collection vessel (TLP-VSL-00002). The evaporated product is collected in TCP-VSL-00001 before being sent forward to the LAW concentrate receipt process and any supplemental LAW processes.

The process flow diagrams (24590-PTF-M5-V17T-00005, *Process Flow Diagram; Treated LAW Evaporation, System TLP*, 24590-PTF-M5-V17T-00006, *Process Flow Diagram; Treated LAW Concentrate Storage, System TCP, and* 24590-PTF-M5-V17T-00025, *Process Flow Diagram; Cesium Ion Exchange Process Collection Vessels System CXP*) and the respective system descriptions (24590-PTF-3YD-TLP-00001 and -TCP-00001) provide more detailed information.

2.12.2.1 Material Transfer to TLP System

The TLP evaporator receives feeds from the following locations:

1 LAW SBS condensate receipt vessels (TLP-VSL-00009A/B)
   - LAW SBS purge liquor and condensate, as well as wet electrostatic precipitator (WESP) condensate (RLD-VSL-00005)
   - 5 M NaOH for neutralization
   - Effluent from the process condensate vessels (RLD-TK-00006A/B) that does not meet specifications
   - Effluent from the alkaline effluent vessels (RLD-VSL-00017A/B) that does not meet specifications
   - TCP recycle from the treated LAW concentrate storage vessel (TCP-VSL-00001)

2 Ion-exchange (IX) treated LAW collections vessels (CXP-VSL-00026A/B/C). This material has been treated in the CXP system and meets the Cs removal requirements specified in Section 2.5.

2.12.2.2 Evaporator Feed Properties

Simultaneous transfers are made from LAW SBS condensate and the IX treated LAW to TLP-SEP-00001. Transfers from CXP-VSL-00026A/B/C are fed continuously, with one vessel transferring to TLP-SEP-00001 while the second vessel is being sampled and the third vessel is being filled from the IX columns. Transfers from TLP-VSL-00009A/B are fed when neutralized LAW SBS condensate is available. Additional transfer logic may be employed by the individual flowsheets to optimize the TLP utilization (CCN 211796, *TLP Evaporator Pump Rate Updates For G2*).

The maximum TLP feed stream parameters are specified in Table 2.12-1 (24590-WTP-RPT-ENG-07-007, *Process Stream Properties* and 24590-PTF-3PS-MEVV-T0001, *Engineering Specification For Forced Circulation Vacuum Evaporator System*):

2.12.2.3 Precipitated Solids Management

Precipitation of solids may occur in the TLP system because of water removal during evaporation and temperature changes in the evaporator concentrate (24590-PTF-RPT-PET-08-001, *Solids Precipitation in the Treated LAW Evaporation Process: A Response to a Design Oversight Assessment*). The proposed mechanism to control solids precipitation is to develop a sampling plan that allows the evaporator to be operated in a way that would minimize evaporating the feeds beyond the point of saturation (see Section 2.12.4). Until a plan for sampling is in place, the evaporator logic is set to control the extent of evaporation to a maximum 8 M sodium.

Algorithms have been developed to predict solids precipitation and partitioning. Refer to the Model Design Document for the respective flowsheet for their use. These algorithms are applied in the TLP system at the locations and temperatures listed in Table 2.12-2.

2.12.2.4 Evaporator Operations

The treated LAW and the neutralized LAW SBS condensate enter the evaporator recirculation loop. The liquor is recirculated and discharges to the evaporator reboiler, which raises the temperature of the liquor. The pump and reboiler are located such that sufficient hydraulic head is provided by the liquid-level in the separator so that cavitation will not occur in the pump and boiling will not occur in the reboiler tubes. When the recirculating liquor enters the separator vessel, flash evaporation occurs due to the reduced pressure in the vessel. The vacuum in the separator vessel is maintained by the vacuum eductor system and by controlling the in-bleed of air to the suction side of the vacuum eductor. This reduced pressure lowers the boiling point of the liquor. The vapors exiting the evaporator separator must pass through a disengagement zone, three bubble-cap trays, and two de-entrainment pads (see Figure 2.12.2). Process condensate is delivered as a spray underneath the de-entrainment pad section to aid decontamination factor (DF) performance and de-entrainment. Antifoam is added to the disengaging zone below the bubble-cap trays.

Overheads from the evaporator are routed to the primary condenser, where most of the vapor is condensed at the saturation pressure. A two-stage steam eductor system maintains a vacuum in the evaporator. Vapor from the steam eductors is condensed in an intercondenser and aftercondenser. Non-condensable gases from the aftercondenser enter the PT Vessel Vent Process System (PVP).

The condensate from all three condensers is routed to the process condensate vessel, TLP-VSL-00002. Normally, condensate is then transferred to the Radioactive Liquid Waste Disposal System (RLD), where the solution is recycled for various uses in WTP processes, or excess condensate is transferred to Liquid

Effluent Retention Facility/Effluent Treatment Facility. Some of the TLP process condensate is filtered and routed to the de-entrainment section of the evaporator separator. If activity of the condensate is above specifications, the contaminated condensate is recycled to the LAW SBS condensate receipt vessels (TLP-VSL-00009A/B).

The evaporator must be capable of handling the range of treated LAW feeds and facility recycle streams at the required throughput rates. The evaporator has a boil-off capacity of 30 gal/min. The evaporator boil-off rate can be adjusted by adjusting the steam flow rate to the reboiler and adjusting the feed and take-off pumps.

The TCP system stores waste from the evaporator before sending the concentrated waste to the melter feed system. This waste is normally fed from the treated LAW evaporator (concentrate) and pumped to the LAW Facility feed receipt vessels. The concentrate vessel has high-pressure steam injection to maintain fluid temperatures above the point at which solids crystallize or precipitate.

During off-normal operation the concentrate storage vessel (TCP-VSL-00001) can also receive treated LAW, meeting LAW vitrification specifications, which has been stored in the waste feed receipt tanks (FRP-VSL-00002A/B/C/D), the ultrafiltration feed vessels (UFP-VSL-00002A/B), or the treated LAW storage vessels (CXP-VSL-00026A/B/C). The concentrate storage vessel during off-normal conditions can be used to route concentrate back to the feed receipt tanks (FRP-VSL-00002A/B/C/D) for lag storage, or can send the waste back to the treated LAW evaporation SBS condensate receipt vessels (TLP-VSL-00009A/B) in cases where additional concentration is needed.

2.12.3 Basis

2.12.3.1 Evaporator Type

A continuous, forced circulation, vacuum type evaporator was selected for the waste feed evaporators based on engineering assessment and the existing 242-A evaporator. The 242-A evaporator is a continuous, forced circulation, vacuum evaporator that concentrates Tank Farm waste to increase tank storage space (*242-A Evaporator-Crystallizer Facility Description Manual*). This evaporator also processes the same wastes that the WTP will process.

2.12.3.2 Evaporator Capacity

The evaporator is "capable of continuous operation; while achieving a feed evaporation rate ranging from 10 to 30 gal/min. The feed evaporation rate excludes all water and fluid additions to demister pads' spray, separation trays, and antifoam injection" (24590-PTF-3PS-MEVV-T0001). Operating flexibility exists to accommodate the varying load by turning down the evaporator.

2.12.3.3 Rates for Feed Delivery, Recirculation, Concentrate Removal, and Boil-Off

Treated LAW feed and SBS condensate feed is transferred to the evaporator at a continuous flow rate and composition determined to meet the requirements of the flowsheet run. The evaporator feed streams mix with the evaporator bottoms in the forced-circulation piping loop.

The forced-circulation pump recirculates the evaporator contents at approximately 11,000 gal/min (24590-QL-POA-MEVV-00001-08-01). The contents of the evaporator are turned over in less than a minute and the velocity through the reboiler tubes reduces scale build-up. The mixing and pumping of the feed and recirculated concentrate determine the composition and enthalpy of the material delivered to the reboiler.

Concentrate is removed from the evaporator at a continuous flow rate and composition that have been determined to meet the requirements of the flowsheet. Concentrate may also be removed on a semi-batch basis to achieve a periodic velocity in the transfer pipe necessary to keep solids from settling in the concentrate transfer line. This periodic velocity is determined by detailed design calculations and is approximately 4 ft/sec or higher. Feed to the evaporator may be delivered to achieve the concentrate flow velocity and minimize the frequency of the concentrate line post-transfer flush. Operation with dilute feed may require variation of the separator liquid level within control requirements to periodically achieve the concentrate flow velocity.

The Semi-Integrated Pilot Plant (SIPP) average boil-off rate for the TLP evaporator reported in SCT-M0SRLE60-00-208-00003 met or exceeded the plant boil-off rate. The tests also showed that additions of different recycle streams to the evaporator feed had no impact on average boil-off rate of the SIPP evaporator.

2.12.3.4 Recycle Streams to the Treated LAW Evaporation Process

The LAW offgas recycle streams (SBS purge and WESP condensate) are collected downstream of the TLP system. The volumes and compositions of these recycle streams are determined within the flowsheet material balance. The solutions are transferred to the LAW SBS condensate receipt vessels (TLP-VSL-00009A/B), and sampled and neutralized as necessary (24590-WTP-RPT-ENG-07-007). Out-of-specification TLP process condensate is included in the TLP evaporator energy balance evaluation in order to obtain the maximum boil-off rate and utility loads for operation of the evaporator.

2.12.3.5 Antifoam Addition

The antifoaming agent (AFA) DOW Q2-3183A is added to the evaporator to minimize foaming. The antifoam constituents and composition from the material safety data sheet (No. 01603183) are listed below:

40 - 70 wt %	Polypropylene glycol
40 - 70 wt %	Polydimethylsiloxane
3 - 7 wt %	Octylphenoxy polyethoxy ethanol
3 - 7 wt %	Treated silica (trade secret)
3 - 7 wt %	Polyether polyol
SpG @ 25 °C	= 1.0

The primary compounds of the AFA (CCN 182189, *Antifoam MW, WT% Carbon and Degradation Stoichiometry*) are:

- Polypropylene glycol (PPG) = $(C_3H_6O)_{60} * H_2O$
- Polydimethylsiloxane (PDMS) = $(H_3C)_3 * SiO[Si(CH_3)_2O]_{470}Si(CH_3)_3$
- Molecular weight of PPG = 3,503 g/mol
- Molecular weight of PDMS = 35,015 g/mol

Heating and irradiation will cause the PPG and PDMS to decompose at a rate of 20 wt% every 24 hours (SCT-M0SRLE60-00-99-00009, *Ultrafiltration Process (UFP) Caustic Leaching Antifoam Performance*). The AFA is delivered to the evaporator at the rate necessary to achieve and maintain a

concentration of 500 ppm in the concentrate (not including any dilution of the antifoam for delivery). Thus, the antifoam delivery rate to the evaporator varies with the concentrate flow rate, which depends on the operating methodology. For additional AFA information see Section 2.16.

2.12.3.6 Treated LAW Evaporator End Product Concentration

Processing experience from the 242-A evaporator indicates that solids will precipitate at a lower concentration for some liquids at Hanford (VanderCook and Ogren 1976). The waste processing for the TLP system differs from the 242-A evaporator in that the system in not intended to achieve dissolved solids saturation (24590-PTF-3YD-TLP-00001). The TLP evaporator's objective is to increase the treated LAW concentrations to less than the solids crystallization point (expected range: 8 to 10 M Na) such that the vitrification efficiency is maximized without solids build-up in the transfer lines or vessels. Some suspended solids are anticipated, however, in the LAW SBS recycle streams to the evaporator. Based on process calculations, it is anticipated that under normal operating conditions the suspended solids will not exceed 3.4 wt %. Dissolved solids, containing oxalate and phosphorous, may precipitate when TLP feeds solutions are blended, undergo solubility adjustments, or are evaporated. The evaporator product concentration is limited to the saturation regions associated with sodium compounds. This is addressed further in Sections 2.12.3.17.5 through 2.12.3.17.7. The concentrate vessel (TCP-VSL-00001) is equipped with high-pressure steam injection to maintain fluid temperatures above the point at which crystallization or precipitation of solids occurs.

2.12.3.7 Fate of Mercury in the Evaporators

Mercury is generally categorized as elemental, inorganic, or organic. Based on experience, small mercury concentrations, and the caustic nature of the Hanford Tank Farm waste, the mercury delivered to the WTP is predicted to be predominantly HgO. Mercury is predicted to be volatilized in the LAW and HLW melters and sent to the LAW and HLW offgas systems (24590-WTP-RPT-PR-01-011, *Mercury Pathway and Treatment Assessment for the WTP*).

The gaseous mercury is converted to soluble Hg^{+2} gas ($HgCl_2$) or remains as elemental mercury gas (Hg^{+0}) in the offgas systems. The fraction of mercury converted to $HgCl_2$ can be determined by the molar ratio of Hg:Cl in the melter offgas streams (24590-101-TSA-W000-0004-125-00004, *WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant*).

If the ratio of Hg:Cl ≤ 0.1, Hg = 100 % $HgCl_2$
= 0.1 to 0.5, Hg = mixture of $HgCl_2$ + Hg^{+0}
≥ 0.5, Hg = 100 % Hg^{+0}

When the ratio results in a mixture of mercury species, the following relationship can be applied to partitioning of the stream:

$$\% \, Hg^{+0} = \left[\frac{(\text{ratio} - 0.1)}{(0.5 - 0.1)} \right] * 100\%$$

2.12.3.7.1 Stream pH Impacts on Mercury Speciation

The LAW SBS streams identified in Section 2.12.3.4 are neutralized to pH = 12 with 5 M NaOH in TLP-VSL-00009A/B. An Environmental Simulation Program (ESP) model run predicts that all of the aqueous mercury will be converted to hydrated mercuric oxide $HgO{\bullet}H2O_{(s)}$ when the stream is neutralized (CCN 028630, *Mercury Speciation in Pretreatment*).

The expected reaction is (24590-WTP-RPT-PR-01-011):

$$Hg^{+2}_{(l)} + 2OH^{-}_{(l)} = HgO{\bullet}H2O_{(s)}$$

A study was performed that examined the fate of mercury in evaporator bench scale testing for solutions, excessively injected with $Hg(NO3)_2$, with a pH of 13 (24590-101-TSA-W000-0004-125-00004). These studies concluded that in experimental conditions, an evaporator DF = 22 (compared to CCN 022422, *Estimates of Evaporator Decontamination Factors – Corrected Definition* which estimates DF = 1010) was more applicable.

However, by injecting the stream with mercury nitrate, the composition of the stream was made to contain a higher concentration of nitrate/nitrite species than what is predicted to be in the feeds to the WTP. Based on the *White Paper for Evaluation of Mercury Impacts on Pretreatment Evaporators* (24590-WTP-RPT-PT-02-011), mercury species become more soluble in higher pH solutions. In the presence of high nitrites and high pH, mercury will be reduced to Hg^0.

It was determined (CCN 156324, *Mercury and Mercury Compounds*) that pH does impact the speciation of mercury in the presence of other compounds, but the overall chemistry (e.g. organic types/concentration, mercury species, and chloride concentration) of the high pH stream is the driving force for determining the reactions and end products of mercury in the evaporator (Hg^0, HgO, $HgCl_2$, or DMHg). All other studies have concluded that the split fraction from the evaporator to the offgas would be negligible (*Treated LAW Feed Evaporation: Physical Properties and Solubility Determination*, SCT-M0SRLE60-00-184-01). Therefore, at this time the DF for mercury in the evaporator will remain as 1010.

2.12.3.7.2 Dimethyl Mercury in the Evaporators

The two constituents necessary for the formation of dimethyl mercury (DMHg), mercury and organics (AFA), are present in the WTP evaporators. Formation of DMHg at the WTP is dependent on several conditions, including temperature, catalyst, time, the quantity and speciation of mercury, and amount of methylating agent present (CCN 074276, *Risk Response Report for Formation of Hazardous Mercury Compounds (Dimethyl Mercury) in Evaporator Overheads*). Testing at the Savannah River Site (SRS) showed no DMHg formation at the maximum operating temperature for the TLP evaporator of 50 °C (CCN 163052, *Studies of Mercury in High-Level Waste Systems*). This testing was conducted to simulate the SRS tank waste, which contains ~forty times more mercury than that found in the Hanford Tank Farms waste. Because of these two findings, DMHg formation is not modeled for the TLP evaporator at this time.). The calculation *Estimated Concentrations of Dimethyl Mercury in WTP Process Streams* (24590-WTP-M4C-V11T-00013) uses the soluble mercury to determine bounding conditions for the rate of formation of DMHg. Those bounding conditions were incorporated in *Assessment of Potential Environmental Risk Due to Dimethyl Mercury Emissions* (24590-WTP-RPT-ENV-10-002). Sampling evaporator feeds for mercury species and organic compositions, and monitoring dimethyl mercury may be necessary as part of normal WTP plant commissioning and operations.

2.12.3.8 Evaporator and Condenser DFs

The evaporation and condenser DFs are presented in Table 2.12-3 for radionuclides and Table 2.12-4 for chemical components. The DF is defined as the mass flow rate in the feed to be evaporated or condensed divided by the mass flow rate in the vapor discharged from the evaporator separator or condenser, as represented in the equations below.

Equation 2.12-1

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

The DFs are documented in *Waste Feed and Treated LAW Evaporator System DF Estimates* (24590-PTF-MEC-FEP-00004). The *242-A Evaporator-Crystallizer Safety Analysis Report* (Campbell 1999) provided the 242-A stream information to calculate the DFs. The exceptions to this are the DFs for Cs-134, Cs-137, and Cs+, which are documented in *Resolution of EFRT Issue P1 - Cesium Decontamination Factor in FEP and TLP Evaporators* (24590-WTP-RPT-PR-06-002). The iodine DFs are provided in *Iodine Decontamination Factors for WTP Evaporators* (CCN 023478). The 242-A de-entrainment section does not include bubble-cap trays, the de-entrainment mesh and thickness are different, and the de-entrainment spray is configured differently. The condenser DF values include the contribution of the condensate vessel to the vent system as defined in the 242-A SAR.

Assumption 2.12.1. Assumptions are made in the reference calculation that define some of the DF values for radionuclides and chemical components as having similar values to calculated values for which constituent information is available. Assumptions used to establish DF values are provided in the referenced calculation and briefly summarized in Table 2.12-3 and Table 2.12-4. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data.

2.12.3.9 Organic DF in Evaporators

Organic constituent behavior in the evaporators has been defined by the use of DFs, as previously defined in Section 2.12.3.8. For the emissions estimates used to support permitting, organic behavior is defined by the use of Henry's Law (see Section 7). Organic constituents have historically been considered in terms of total organic carbon (TOC) in the non-emissions flowsheets to reflect the form from which organic data was received from the Tank Farm Contractor. The DF values have previously been based solely on oxalate to define the TOC values in previous flowsheet versions. These DF values for TOC (oxalate) are 1000 for the evaporator DF and 17.2 for the condenser DF; based on literature reviews, the behavior of oxalate in feeds of high sodium concentration will more closely follow that of calcium in the evaporators. The evaporator and condenser DFs for organics are presented in Table 2.12-5.

Assumption 2.12.2. Assumptions are made in defining the DF values for organic components as having similar values to calculated values for formate, oxalate, and other test compounds as detailed in CCN 027646. Assumptions used to establish values in the calculation are briefly summarized in Table 2.12-5. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data.

2.12.3.10 Evaporator De-entrainment

The vapors and any entrainment generated in the evaporator bottoms of the evaporator separator must pass through a disengagement zone, three bubble-cap trays, and two de-entrainment pads before exiting the separator to the primary condenser (see Figure 2.12.2). The TLP system process condensate is filtered and delivered as a spray underneath the de-entrainment pad section. The spray is an aid to DF and de-

entrainment performance. The flow rate for this spray defined by the detail design is 3 gal/min (24590-QL-POA-MEVV-00001-08-01).

2.12.3.11 Evaporator and Condenser Operating Pressures

The evaporator is operated at a vacuum to reduce the boiling point of the solution. The two-stage vacuum eductor system will be designed to control the separator vessel pressure between 1.0 and 1.3 psia (24590-PTF-3PS-MEVV-T0001). Vacuum evaporation lowers the boiling temperature of the solution and reduces potential corrosion in the evaporator.

The actual boiling point of the solution is estimated to be a maximum of 122 °F and is determined by the operating vacuum of the separator and the boiling point elevation of the concentrate solution. However, the evaporator operating temperature could reach 126 °F (or 52 °C) for Envelope A waste to concentrate the solution to 8 M Na (SCT-M0SRLE60-00-191-01).

The operating vacuum for the evaporator and each condenser affects the vapor-liquid equilibrium that is calculated for the constituents and volatile components. A vacuum correction is also made in the Henry's Law coefficients for organics that are used in the emissions run (discussed in Section 7).

2.12.3.12 Evaporator Vacuum Eductor Steam Usage

The evaporator separator vessel pressure is maintained by a two-stage vacuum eductor system. The primary vacuum eductor maintains vacuum on the evaporator separator and primary condenser, and discharges to the intercondenser. The secondary vacuum eductor maintains vacuum on the intercondenser, and discharges to the aftercondenser.

- The high-pressure steam (HPS) supply conditions:
  - Minimum operating condition: 110 psig at 344 °F
  - Normal operating condition: 118 psig at 349 °F
  - Maximum operating condition: 135 psig at 358 °F
  - Design condition 163 psig at 372 °F

The high-pressure steam flows to the vacuum eductors will be updated by the vendor as part of the design analysis to ensure performance of the vacuum eductors (24590-PTF-3PS-MEVV-T0001).

2.12.3.13 Condenser Offgas Rates

The non-condensable offgas leaving the evaporator separator vessel passes through three condensers before exiting to the PVP system. The primary condenser is significantly larger than the intercondenser and aftercondenser. The condenser offgas system and vacuum eductors are sized for a nominal non-condensable air flow from the separator of 42.7 lb/hr.

- Air is added upstream of the primary vacuum eductor to maintain the nominal 1.0 to 1.3 psia operating pressure. The control air is varied to obtain a relatively constant non-condensable air flow to the vacuum eductor. An initial value of 7.6 lb/hr is set in the flowsheet and will be updated as part of detail design evaluation.
- Soluble gases and volatile components are released from the feed stream as it enters the separator due to the vacuum applied.

- Air in-leakage into the evaporator system is minimized by the low number of flanges present. No value is assigned in the flowsheet.
- The shell side of the reboiler (to reduce the temperature differential across the reboiler tube) and the steam condensate collection tank are also vented to the upstream side of the secondary vacuum eductor. No value is assigned in the flowsheet.

2.12.3.14 Cooling Water to the Condensers

The process cooling water delivered to the condensers is supplied at approximately 45 psig and 75 °F, with a peak summer maximum of 83 °F. The cooling duty required of each condenser is determined from the enthalpy change of the process stream.

2.12.3.15 Condenser Outlet Temperatures

The condenser outlet temperature is set at 30 °C (86 °F) for use in the flowsheet. This setpoint definition provides a maximum cooling load for the evaporator condensers. The vent streams leaving each condenser are set at this temperature and saturated with water vapor for use in the flowsheet. The condenser outlet stream temperatures will be updated by the vendor as part of the design analysis for the evaporator performance specification (24590-PTF-3PS-MEVV-T0001).

2.12.3.16 Steam to the Reboiler

HPS is delivered to the reboiler at approximately 135 psig (CCN 135608) and 358 °F (at PT Facility boundary) and routed first through a pressure reducing valve and then through a de-superheater. This results in a pressure of approximately 2.2 psig at a temperature of 219 °F (24590-QL-POA-MEVV-00001-04-04, *Calculation - 60% Design - Hanford Evaporation Project #1 - Evaporator Mass and Energy Balance*). The resulting temperature is based on the reboiler fouled tube condition.

2.12.3.17 Concentrate Physical Properties

Testing was conducted on simulants of the waste feed evaporator feed and post-evaporation blends and reported in *Treated LAW Feed Evaporation: Physical Properties and Solubility Determination* (SCT-M0SRLE60-00-184-01). Testing was conducted on blends of recycle with the treated LAW feed. The physical properties (density, vapor pressure, heat capacity, thermal conductivity, and viscosity) of the feed to the evaporator and the evaporator bottoms were measured as a function of temperature and sodium concentration.

2.12.3.17.1 Density

Correlations of specific gravity as a function of sodium molarity were developed for treated LAW feed and SBS condensate recycle in SCT-M0SRLE60-00-184-01. The increases in specific gravity per mole of sodium were 0.0386, 0.0402, and 0.0479 for Envelopes A, B, and C, respectively. This corresponds approximately to a density of 1.31 g/cc for Envelope A at 8 M Na and 25 °C, 1.20 g/cc for Envelope B at 5 M Na and 25 °C, and 1.38 g/cc for Envelope C at 8 M Na and 25 °C. (Additional information is found in the referenced report or in evaporation reports for specific waste feeds reported in the list of references.)

SIPP feed containing waste simulants with recycles was evaporated to a final density of 1.385 g/cc at 20 °C and 8.2 M Na (SCT-M0SRLE60-00-208-00003).

2.12.3.17.2 Vapor Pressure and Boiling Point Elevation

Increasing the sodium molarity decreases the vapor pressure (VP) and increasing temperature increases the VP parabolically. It is observed that there is a progressively larger spread in VP at higher temperatures as sodium molarity increases.

- Envelope A vapor pressure correlation vs. sodium molarity (Na M):
  VP (mm Hg) = 1 / (.0359 + .00249*Na M)
- Envelope B vapor pressure correlation vs. sodium molarity:
  VP (mm Hg) = 1 / (.0370 + .00244*Na M)
- Envelope C vapor pressure correlation vs. sodium molarity:
  VP (mm Hg) = 1 / (.0351 + .00284*Na M)

(Additional information is found in the referenced report, SCT-M0SRLE60-00-184-01, or in evaporation reports for specific waste feeds reported in the list of references.)

2.12.3.17.3 Heat Capacity

On average, all heat capacities for all three waste envelopes were lower than the heat capacity of water at 20 °C. Additionally, heat capacity was found to slowly decrease as sodium molarity increased. (Additional information is found in the referenced report or in evaporation reports for specific waste feeds reported in the list of references.)

2.12.3.17.4 Viscosity

Viscosity was found to decrease with temperature and increase with sodium concentration. At 25 °C and 8 M Na the viscosity ranged from 4 to 8 cP for Envelope A, 4 to 6 cP for Envelope B, and 8 to 11 cP for Envelope C. (Additional information is found in the referenced report or in evaporation reports for specific waste feeds reported in the list of references.)

2.12.3.17.5 Concentrate Solids

The formation of solids in the evaporator concentrate is dependent on many factors pertaining to how the WTP process is operated and the operating setpoint of the evaporator. Solids characterization was performed for the waste envelopes and recycles that were tested in the reference report SCT-M0SRLE60-00-184-01. The list of solids that may be present is not all-inclusive. Insoluble solids will also be present in the recycled streams of the LAW SBS condensate. (Additional information is found in the referenced report or in evaporation reports for specific waste feeds reported in the list of references.)

From the reference report SCT-M0SRLE60-00-184-01, a brief summary is provided of the solids that were analyzed to be present in most of the concentrated recycle streams for each waste envelope.

- Envelope A concentrate (at 8 M Na and mixtures held over 7 days):

  Na3FSO4, Na7F(PO4)2(H2O)19, NaNO2, SiO2, Na2CO3xH2O, NaNO3, (Al2Li[OH]6)2CO3xH2O, Na5Al3CSi3O15

- Envelope B concentrate (at 5.5 M Na and mixtures held over 7 days):

  Na3AlF6, Na3FSO4, NaNO2, Al(OH)3 (gibbsite, bayerite), SiO2, NaNO3, (Al2Li[OH]6)2CO3xH2O

- Envelope C concentrate (at 8 M Na and mixtures held over 7 days):

  Na3FSO4, Na7F(PO4)2(H2O)19, NaNO2, SiO2, NaNO3, Na2CO3xH2O, (Al2Li[OH]6)2CO3xH2O

2.12.3.17.6 NAS Solids Formation Potential

The formation of sodium aluminosilicate (NAS) was also evaluated in the reference report SCT-M0SRLE60-00-184-01.

- No NAS was found prior to 24 hr after mixing in the samples tested.
- NAS was found in Envelope A simulant at 24 hr after mixing and in many other mixtures it held for periods greater than 24 hr.
- For samples held for 7 days, X-ray diffraction (XRD) results revealed that cancrinite (Na6CaAL6Si6[CO3]O24.2H20), a sodium aluminosilicate, had formed in 6 and 7 M samples; however, no NAS was detected in the 8 and 8.5 M samples.
- NAS is not likely to form as crystals in the treated feed evaporator, but more likely to form later in the melter feed system. Furthermore, although the NAS solids were not found in mixtures prior to 24 hr, it is possible that NAS existed as a homogeneous gel. For samples tested at 7 or more days after mixing, NAS was found throughout Envelope A and C blends and even in waste feed simulants.
- Testing of the pilot-scale evaporator reported in SCT-M0SRLE60-00-54-00002 discusses the formation of NAS solids.
- In WSRC-TR-2002-00330 (Jantzen 2003), thermodynamic modeling is performed with high caustic aluminosilicate solubility data. The data for all solutions indicate that the NAS-gel persists along with the zeolite-A and sodalite. With increasing time, the mass percent of the NAS-gel decreases as the mass percent of the crystalline species increases. Based on the kinetic analysis, it is clear that the NAS-gel forms first, and that once formed (once a solution is supersaturated with respect to the NAS-gel), the NAS-gel phase can persist at the elevated temperatures in the evaporator along with the more thermodynamically stable sodalite and cancrinite crystalline phases. It is the function of the process control model (developed in the reference) to prevent the evaporator solutions from ever becoming supersaturated with respect to the NAS-gel, thus preventing the precipitation of the NAS-gel and all subsequent stable crystalline NAS phases.

2.12.3.17.7 Solubility

- For AN-105 (SCT-M0SRLE60-00-06-01, *Evaporation of Hanford Envelope a Simulant (AN-105)*) the final concentration endpoint for these experiments was determined to be ~7.5 M Na. "The endpoint was established using a criterion that limits bulk solubility of the evaporator bottoms to less than or equal to 80 % saturation at 25 °C. The RPP-WTP R&T team established this criterion to preclude the formation of solids during storage and transfer of evaporator products." The testing performed was for the TLP evaporator.
- For AN-102 (SCT-M0SRLE60-00-18-02, *Bench-Scale Evaporation of a Large Hanford Envelope C Sample (Tank 241-AN-102)*), The final boildown demonstrated a dramatic solubility endpoint at ~8.2 M Na, changing from 2 to 16 % insoluble solids in a few minutes. The major precipitant at the endpoint was identified by XRD as sodium carbonate hydrate." The testing performed was for the TLP evaporator.
- For AN-107 (SCT-M0SRLE60-00-15-01, *AN-107 (C) Simulant Bench-Scale LAW Evaporation with Organic Regulatory Analysis*), "A very sharp transition to saturation at approximately 10.1 M Na concentrate concentration was observed." "Insoluble solids increase only slightly during concentration from approximately 8.3 M Na." "Exhibiting a sharp transition, the evaporator

concentrate within a 1 to 2 min period went from a green semi-translucent liquid to very viscous greenish-white gel." The recommendation is made in the report to "evaporate the waste to 80 % of bulk solubility thereby preventing the formation of solids." The testing performed was for the TLP evaporator.

- For AW-101 (from SCT-M0SRLE60-00-191-01, *Evaporation of Pretreated Hanford Tank AW-101 Sample Mixed with Recycle*), "Precipitation began between 8.7 M and 10.4 M Na." "During these evaporation tests, no problematic or excessive solids were observed." The testing performed was for the TLP evaporator.
- AP-101, the LAW hot commissioning tank, is discussed in *Rheological and Physical Properties of AP-101 LAW Pretreated Waste and Melter Feed* (24590-101-TSA-W000-0004-104-05). "It was observed that the material at 4 M Na did not contain visible solids. However, solids did precipitate during the evaporation to 6 M Na concentration and beyond. These solids were identified to be primarily sodium nitrate and possibly potassium carbonate. The quantity of these phases precipitating increased with increasing sodium concentration." Nitrate-cancrinite increased in concentration with increasing sodium concentration. The solids at 6, 8, and 10 M Na appeared similar in chemistry with increasing weight percent solids at higher sodium concentrations. At 72 hr, the volume percent settled solids at 25 °C increased from 3.8 vol % at 6 M Na to 9.9 vol % at 8 M Na.
- For AZ-101 (Calloway 2000, *Evaporation of Hanford Envelope B Simulant (AZ-101) Preliminary Report*), "It was found from these studies that the as-prepared AZ-101 simulant was already 80 % saturated at 4.8 M sodium." This leads to a saturation limit of 6 M Na. The testing performed was for the TLP evaporator.
- A small-scale test with AN-104 mixed with 65 % simulated SBS recycle (from SCT-MOSRLE60-00-203-00001, *Evaporation, Rheology, and Vitrification of Pretreated Radioactive Hanford Tank 241-AN-104 Sample Mixed with Simulated LAW SBS Recycle*) found visible suspended solids at 4.74 M and 7.29 M Na; however, no NAS or potentially troublesome solids were formed.

2.12.4 Ongoing Work and Potential Changes

Potential changes to this section include updating the TLP sampling strategy to prevent precipitation of the bulk electrolytes by taking a sample upstream of the evaporator. This information would then be used to determine the appropriate density and condensate production criteria to use on a feed-by-feed basis. (24590-PTF-RPT-PET-08-001).

2.12.5 References

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24590-PTF-3YD-TLP-00001, Rev 1, *System Description for Treated LAW Evaporation Process (TCP).*

24590-PTF-M5-V17T-00005, Rev 2, *Process Flow Diagram; Treated LAW Evaporation, System TLP.*

24590-PTF-M5-V17T-00006, Rev 1, *Process Flow Diagram; Treated LAW Concentrate Storage, System TCP.*

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CCN 023478, *Iodine Decontamination Factors for WTP Evaporators.* 27 September 2001.

CCN 027646, *Organic Compound Decontamination Factors for WTP Evaporators.* 17 January 2002.

CCN 028630, *Mercury Speciation in Pretreatment.* 14 February 2002.

CCN 074276, *Risk Response Report for Formation of Hazardous Mercury Compounds (Dimethyl Mercury) in Evaporator Overheads.* 31 October 2003.

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SCT-M0SRLE60-00-99-00009, Rev 00A, *Ultrafiltration Process (UFP) Caustic Leaching Antifoam Performance*), March 2006.

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Table 2.12-1 TLP Evaporator Feed Properties

	TLP-VSL-00009A/B	CXP-VSL-00026A/B/C
Maximum Temperature	165 °F	113 °F
Maximum Specific Gravity	1.55	1.5
Maximum Viscosity	16 cP	10 cP
Maximum Vapor Pressure	5 psia	1.2 psia
Maximum Wt % Solids	5	0
Maximum Sodium Molarity	8	8
Maximum Pump Flow	38	34

Table 2.12-2 Solubility Application

Vessels	Temperature (°C)	Frequency
CXP-VSL-00026A/B/C	35	After filled
TLP-SEP-00001	50	Continuous
TCP-VSL-00001	31	After filled

Table 2.12-3 Evaporation and Condenser Radionuclide DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
3H(s)+	NA	Follows H2O	NA	Follows H2O
3H+	NA	Follows H2O	NA	Follows H2O
14C(s)+4	1.01E+03	242-A FSAR 3E, ^{14}C	6.50E+02	242-A FSAR 3E, ^{14}C
14C+4	1.01E+03	242-A FSAR 3E, ^{14}C	6.50E+02	242-A FSAR 3E, ^{14}C
60Co(s)+3	1.01E+03	242-A FSAR 3E, ^{60}Co	6.50E+02	242-A FSAR 3E, ^{60}Co
60Co+3	1.01E+03	242-A FSAR 3E, ^{60}Co	6.50E+02	242-A FSAR 3E, ^{60}Co
63Ni(s)+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
63Ni+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
90Sr(s)+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
90Sr+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
99Tc(s)+7	1.01E+03	242-A FSAR 3E, ^{99}Tc	6.50E+02	242-A FSAR 3E, ^{99}Tc
99Tc+7	1.01E+03	242-A FSAR 3E, ^{99}Tc	6.50E+02	242-A FSAR 3E, ^{99}Tc
125Sb(s)+3	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb
125Sb+3	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb

Table 2.12-3 Evaporation and Condenser Radionuclide DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
126Sn(s)+2	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb
126Sn+2	4.00E+03	SRTC Lab data for Pb	2.79E+04	242-A FSAR 3E, Pb
129I-	4.33E+02	CCN 023478	9.10E+02	242-A FSAR 3E, ^{129}I
129I(s)-	4.33E+02	CCN 023478	9.10E+02	242-A FSAR 3E, ^{129}I
134Cs(s)+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
134Cs+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
137Cs(s)+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
137Cs+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
151Sm(s)+3	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu
151Sm+3	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu
152Eu(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
152Eu+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
154Eu(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
154Eu+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
155Eu(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
155Eu+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
232Th(s)+4	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
232Th+4	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
233U(s)+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
233U+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
234U(s)+6	1.01E+03	242-A FSAR 3E, ^{234}U	6.50E+02	242-A FSAR 3E, ^{234}U
234U+6	1.01E+03	242-A FSAR 3E, ^{234}U	6.50E+02	242-A FSAR 3E, ^{234}U
235U(s)+6	1.01E+03	242-A FSAR 3E, ^{235}U	6.50E+02	242-A FSAR 3E, ^{235}U
235U+6	1.01E+03	242-A FSAR 3E, ^{235}U	6.50E+02	242-A FSAR 3E, ^{235}U
236U(s)+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
236U+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
237Np(s)+4	1.01E+03	242-A FSAR 3E, ^{237}Np	6.50E+02	242-A FSAR 3E, ^{237}Np
237Np+4	1.01E+03	242-A FSAR 3E, ^{237}Np	6.50E+02	242-A FSAR 3E, ^{237}Np
238Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu

Table 2.12-3 Evaporation and Condenser Radionuclide DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
238Pu+4	3.74E+06	242-A FSAR 3E, ^{238}Pu	3.12E+03	242-A FSAR 3E, ^{238}Pu
238U(s)+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
238U+6	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
239Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
239Pu+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
240Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
240Pu+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
241Am(s)+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
241Am+3	1.41E+06	242-A FSAR 3E, ^{241}Am	3.18E+03	242-A FSAR 3E, ^{241}Am
241Pu(s)+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
241Pu+4	3.74E+06	242-A FSAR 3E, ^{239}Pu	3.12E+03	242-A FSAR 3E, ^{239}Pu
243Cm(s)+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm
243Cm+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm
244Cm(s)+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm
244Cm+3	1.01E+03	242-A FSAR 3E, ^{244}Cm	6.50E+02	242-A FSAR 3E, ^{244}Cm

Source: 24590-PTF-MEC-FEP-00004.

Table 2.12-4 Evaporation and Condenser Chemical Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent (ACM)	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
Ag(s)+	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu
Ag+	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu
Al(s)+3	1.52E+03	242-A FSAR 3E, AlO_2^{-1}	6.50E+02	242-A FSAR 3E, AlO_2^{-1}
Al+3	1.52E+03	242-A FSAR 3E, AlO_2^{-1}	6.50E+02	242-A FSAR 3E, AlO_2^{-1}
As(s)+3	1.01E+03	242-A FSAR 3E, ^{79}Se	6.50E+02	242-A FSAR 3E, ^{79}Se
As+3	1.01E+03	242-A FSAR 3E, ^{79}Se	6.50E+02	242-A FSAR 3E, ^{79}Se
B(s)+3	1.01E+03	242-A FSAR 3E, B	5.65E+02	242-A FSAR 3E, B
B+3	1.01E+03	242-A FSAR 3E, B	5.65E+02	242-A FSAR 3E, B
Ba(s)+2	1.01E+03	242-A FSAR 3E, Ba	4.96E+02	242-A FSAR 3E, Ba
Ba+2	1.01E+03	242-A FSAR 3E, Ba	4.96E+02	242-A FSAR 3E, Ba
Bi(s)+3	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
Bi+3	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
C2O4(s)-2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
C2O4-2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Ca(s)+2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Ca+2	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
CCl4	1.00E+00	no new data	1.00E+00	no new data
Cd(s)+2	2.21E+04	SRTC Lab Data for Cd	6.50E+02	242-A FSAR 3E, Cd
Cd+2	2.21E+04	SRTC Lab Data for Cd	6.50E+02	242-A FSAR 3E, Cd
Ce(s)+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
Ce+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
Cl-	5.26E+02	242-A FSAR 3E, Cl^-	7.70E+03	242-A FSAR 3E, Cl^-
Cl(s)-	5.26E+02	242-A FSAR 3E, Cl^-	7.70E+03	242-A FSAR 3E, Cl^-
CO	1.00E+00	no new data	1.00E+00	no new data
CO2	1.00E+00	no new data	1.00E+00	no new data
CO3(s)-2	1.01E+03	242-A FSAR 3E, CO_3^{-2}	6.50E+02	242-A FSAR 3E, CO_3^{-2}

Table 2.12-4 Evaporation and Condenser Chemical Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent (ACM)	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
CO3-2	1.01E+03	242-A FSAR 3E, CO_3^{-2}	6.50E+02	242-A FSAR 3E, CO_3^{-2}
Cr(s)+3	3.54E+04	242-A FSAR 3E, Cr	5.32E+03	242-A FSAR 3E, Cr
Cr+3	3.54E+04	242-A FSAR 3E, Cr	5.32E+03	242-A FSAR 3E, Cr
Cs(s)+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
Cs+	2.8E+07	24590-WTP-RPT-PR-06-002, ^{137}Cs	2.34E+04	242-A FSAR 3E, ^{137}Cs
Cu(s)+2	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu
Cu+2	1.01E+03	242-A FSAR 3E, Cu	5.31E+02	242-A FSAR 3E, Cu
F-	2.43E+04	242-A FSAR 3E, F^-	1.89E+03	242-A FSAR 3E, F^-
F(s)-	2.43E+04	242-A FSAR 3E, F^-	1.89E+03	242-A FSAR 3E, F^-
Fe(s)+3	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
Fe+3	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
H+	1.00E+01	no new data	1.00E+02	no new data
H2O	N/A	Defined by concentration setpoint	N/A	Defined by concentration setpoint
HCl	1.00E+00	no new data	1.00E+00	no new data
HF	1.00E+00	no new data	1.00E+00	no new data
Hg(s)+2	1.01E+03	242-A FSAR 3E, Hg	6.49E+02	242-A FSAR 3E, Hg
Hg+2	1.01E+03	242-A FSAR 3E, Hg	6.49E+02	242-A FSAR 3E, Hg
HNO3	N/A	no new data	N/A	no new data
K(s)+	3.54E+03	242-A FSAR 3E, K	6.37E+02	242-A FSAR 3E, K
K+	3.54E+03	242-A FSAR 3E, K	6.37E+02	242-A FSAR 3E, K
La(s)+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
La+3	1.01E+03	242-A FSAR 3E, ^{238}U	6.49E+02	242-A FSAR 3E, ^{238}U
Li(s)+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
Li+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
Mg(s)+2	1.01E+03	242-A FSAR 3E, Mg	2.86E+01	242-A FSAR 3E, Mg

Table 2.12-4 Evaporation and Condenser Chemical Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent (ACM)	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
Mg+2	1.01E+03	242-A FSAR 3E, Mg	2.86E+01	242-A FSAR 3E, Mg
Mn(s)+3	1.01E+03	242-A FSAR 3E, Mn	6.09E+02	242-A FSAR 3E, Mn
Mn+3	1.01E+03	242-A FSAR 3E, Mn	6.09E+02	242-A FSAR 3E, Mn
MnO4-	1.01E+03	242-A FSAR 3E, Mn	6.09E+02	242-A FSAR 3E, Mn
N2	1.00E+00	no new data	1.00E+00	no new data
Na(s)+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
Na+	3.03E+04	242-A FSAR 3E, Na	6.26E+02	242-A FSAR 3E, Na
NH3	1.11E+00	242-A FSAR 3E, NH_4^+	1.24E+01	242-A FSAR 3E, NH_4^+
NH4+	1.11E+00	242-A FSAR 3E, NH_4^+	1.24E+01	242-A FSAR 3E, NH_4^+
Ni(s)+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
Ni+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
NO	1.00E+00	no new data	1.00E+00	no new data
NO2	1.00E+00	no new data	1.00E+00	no new data
NO2-	2.43E+03	242-A FSAR 3E, NO_2^-	1.04E+04	242-A FSAR 3E, NO_2^-
NO2(s)-	2.43E+03	242-A FSAR 3E, NO_2^-	1.04E+04	242-A FSAR 3E, NO_2^-
NO3-	5.77E+02	242-A FSAR 3E, NO_3^-	1.04E+04	242-A FSAR 3E, NO_3^-
NO3(s)-	5.77E+02	242-A FSAR 3E, NO_3^-	1.04E+04	242-A FSAR 3E, NO_3^-
O(s)--	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
O2	1.00E+00	no new data	1.00E+00	no new data
OH-	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
OH(b)-	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
OH(s)-	1.01E+03	242-A FSAR 3E, OH^-	6.50E+02	242-A FSAR 3E, OH^-
P(s)+5	1.01E+03	242-A FSAR 3E, Si	2.30E+02	242-A FSAR 3E, Si
Pb(s)+2	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
Pb+2	4.00E+03	SRTC Lab Data for Pb	2.79E+04	242-A FSAR 3E, Pb
Pd(s)+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni

Table 2.12-4 Evaporation and Condenser Chemical Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent (ACM)	Evaporator DF	Evaporator DF Assumption	Condenser DF	Condenser DF Assumption
Pd+2	2.95E+04	SRTC Lab Data for Ni	6.50E+02	242-A FSAR 3E, Ni
PO4(s)-3	1.01E+03	242-A FSAR 3E, PO_4^{-3}	6.50E+02	242-A FSAR 3E, PO_4^{-3}
PO4-3	1.01E+03	242-A FSAR 3E, PO_4^{-3}	6.50E+02	242-A FSAR 3E, PO_4^{-3}
S(s)+6	1.01E+03	242-A FSAR 3E, ^{79}Se	6.50E+02	242-A FSAR 3E, ^{79}Se
Si(s)+4	1.01E+03	242-A FSAR 3E, Si	2.30E+02	242-A FSAR 3E, Si
SiO4-4	1.01E+03	242-A FSAR 3E, Si	2.30E+02	242-A FSAR 3E, Si
SO4(s)-2	1.42E+03	242-A FSAR 3E, SO_4^{-2}	4.21E+03	242-A FSAR 3E, SO_4^{-2}
SO4-2	1.42E+03	242-A FSAR 3E, SO_4^{-2}	4.21E+03	242-A FSAR 3E, SO_4^{-2}
Sr(s)+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
Sr+2	2.32E+05	242-A FSAR 3E, ^{90}Sr	1.17E+04	242-A FSAR 3E, ^{90}Sr
Ti(s)+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
Ti+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
TOC	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Zn(s)+2	1.01E+03	242-A FSAR 3E, Zn	6.17E+02	242-A FSAR 3E, Zn
Zn+2	1.01E+03	242-A FSAR 3E, Zn	6.17E+02	242-A FSAR 3E, Zn
Zr(s)+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe
Zr+4	1.01E+03	242-A FSAR 3E, Fe	5.01E+02	242-A FSAR 3E, Fe

Source: 24590-PTF-MEC-FEP-00004.

Table 2.12-5 Evaporation and Condenser Organic Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent (ACM)	Chemical Formula	Molecular Weight	Separator DF	Separator Assumption	Condenser DF	Condenser Assumption
Oxalate	$C2O4^{-2}$	88.02	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Formate	$CHO2^{-1}$	45.02	10.7	CCN 027646	652,000	242-A FSAR 3E, TOC
Acetate	$C2H3O2^{-1}$	59.05	10.7	Same as formate	652,000	242-A FSAR 3E, TOC
Glycolate	$C2H3O3^{-1}$	75.05	10.7	Same as formate	652,000	242-A FSAR 3E, TOC
IDA	$C4H5NO4^{-2}$	131.10	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Citrate	$C6H5O7^{-3}$	189.11	10.7	Same as formate	652,000	242-A FSAR 3E, TOC
HEDTA	$C10H15N2O7^{-3}$	275.27	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
EDTA	$C10H12N2O8^{-4}$	288.24	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Toluene	C7H8	92.13	1.01	CCN 027646	1.01	CCN 027646
Phenol	C6H6O	94.11	1.01	Same as benzene	1.01	Same as benzene
Tributyl phosphate	C12H27O4P	266.30	1.00E+03	242-A FSAR 3E, Ca	1.72E+01	242-A FSAR 3E, Ca
Perchloro-ethylene	CCN 027646	165.84	1.19	Same as 1,2,3-Trichloro-propane from CCN 027646	1.07	Same as 1,2,3-Trichloro-propane from CCN 027646
Polychlorinated biphenyls (PCBs)	C12H4Cl6	326.43	2332	Same as pentachloro phenol, from CCN 027646	1.00	Same as pentachloro phenol, from CCN 027646
Ace-naphthylene	C12H8	152.18	1.02	Same as MIBK, from CCN 027646	1.02	Same as MIBK, from CCN 027646
Carbon Tetrachloride	CCl4	153.83	1.19	Based on 1,2,3-Trichloro-propane from CCN 027646	1.07	Based on 1,2,3-Trichloro-propane from CCN 027646
1,1-Dimethyl-hydrazine	C2H8N2	60.10	1.01	Similar to toluene from CCN 027646	1.01	Similar to toluene from CCN 027646

Table 2.12-5 Evaporation and Condenser Organic Component DF Values

$$DF_{evap} = \frac{\text{Mass Flowrate}_{\text{Evaporator Feed}}}{\text{Mass Flowrate}_{\text{Evaporator Overheads}}} \qquad DF_{cond} = \frac{\text{Mass Flowrate}_{\text{Evaporator Overheads}}}{\text{Mass Flowrate}_{\text{Condenser Offgas}}}$$

Constituent (ACM)	Chemical Formula	Molecular Weight	Separator DF	Separator Assumption	Condenser DF	Condenser Assumption
Tridecane	C13H28	184.35	1.9999	Assumed similar to sucrose. DFs from MRQ 04-0063	2.0	Assumed similar to sucrose. DFs from MRQ 04-0063
Benzene	C6H6	78.11	1.00	From CCN 027646	1.01	From CCN 027646
Acetonitrile	C2H3N	41.05	1.03	Similar to naphthalene from CCN 027646	1.21	Similar to naphthalene from CCN 027646
Trichloro-ethylene	C2HCl3	262.79	1.19	Based on 1,2,3-Trichlorop ropane from CCN 027646	1.07	Based on 1,2,3-Trichlorop ropane from CCN 027646
Antifoam-PPG/dPPG	H2O*(C3H6O)60	3503.00	1.0E+08	SCT-M0SRLE60-00-99-00009	N/A	N/A
Antifoam-PDMS/dPDMS	(CH3)3 SiO[Si(CH3)2O]470 (Si(CH3)3)	35,015.00	1.0E+08	SCT-M0SRLE60-00-99-00009	N/A	N/A
Naphthalene	C10H8	128.16	1.03	From CCN 027646	1.21	From CCN 027646
Acetophenone	C8H8O	120.14	1.03	Similar to naphthalene from CCN 027646	1.21	Similar to naphthalene from CCN 027646

Figure 2.12.1 Evaporator Separator Sketch for FEP and Treated LAW Evaporation Process Systems (TLP)

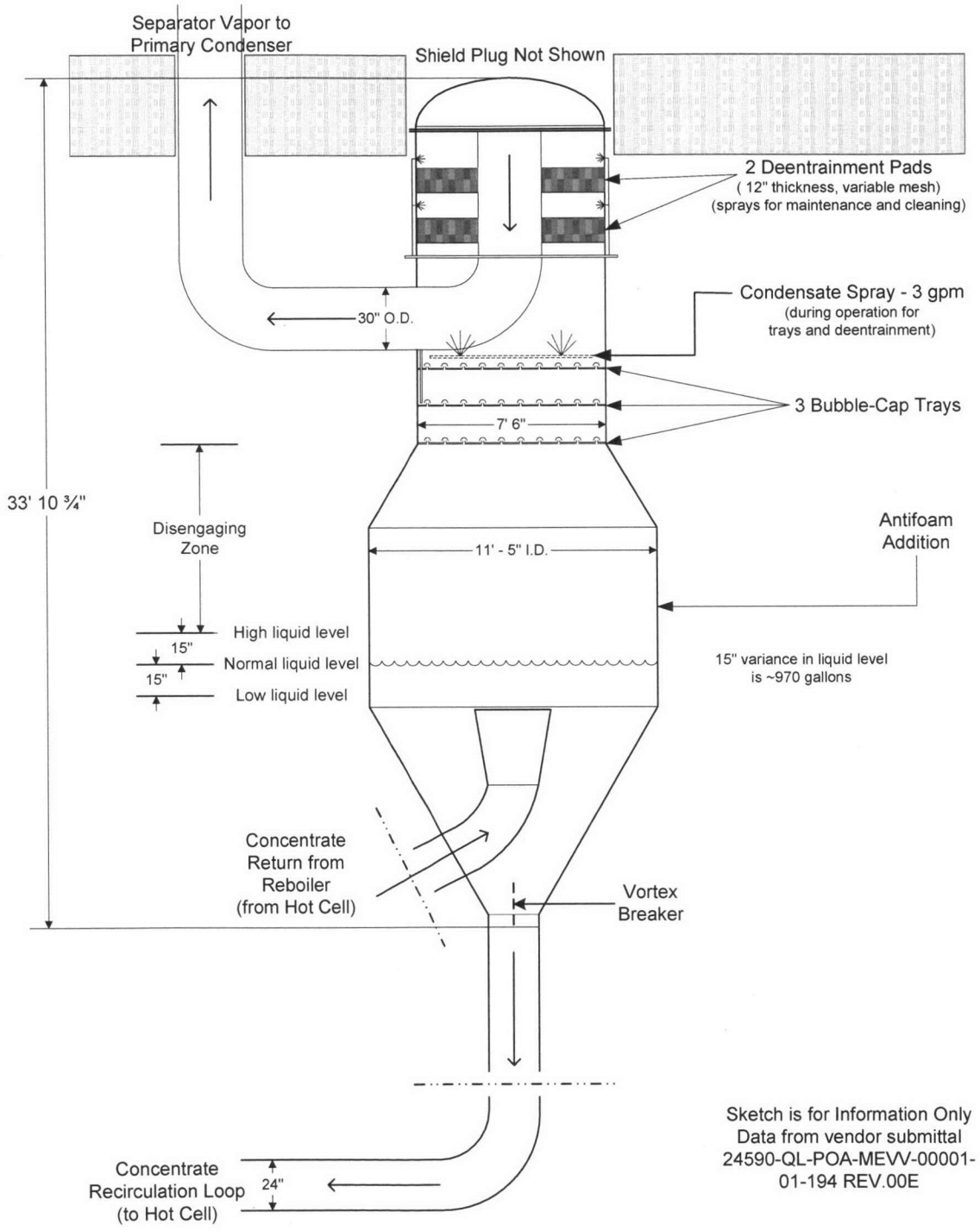
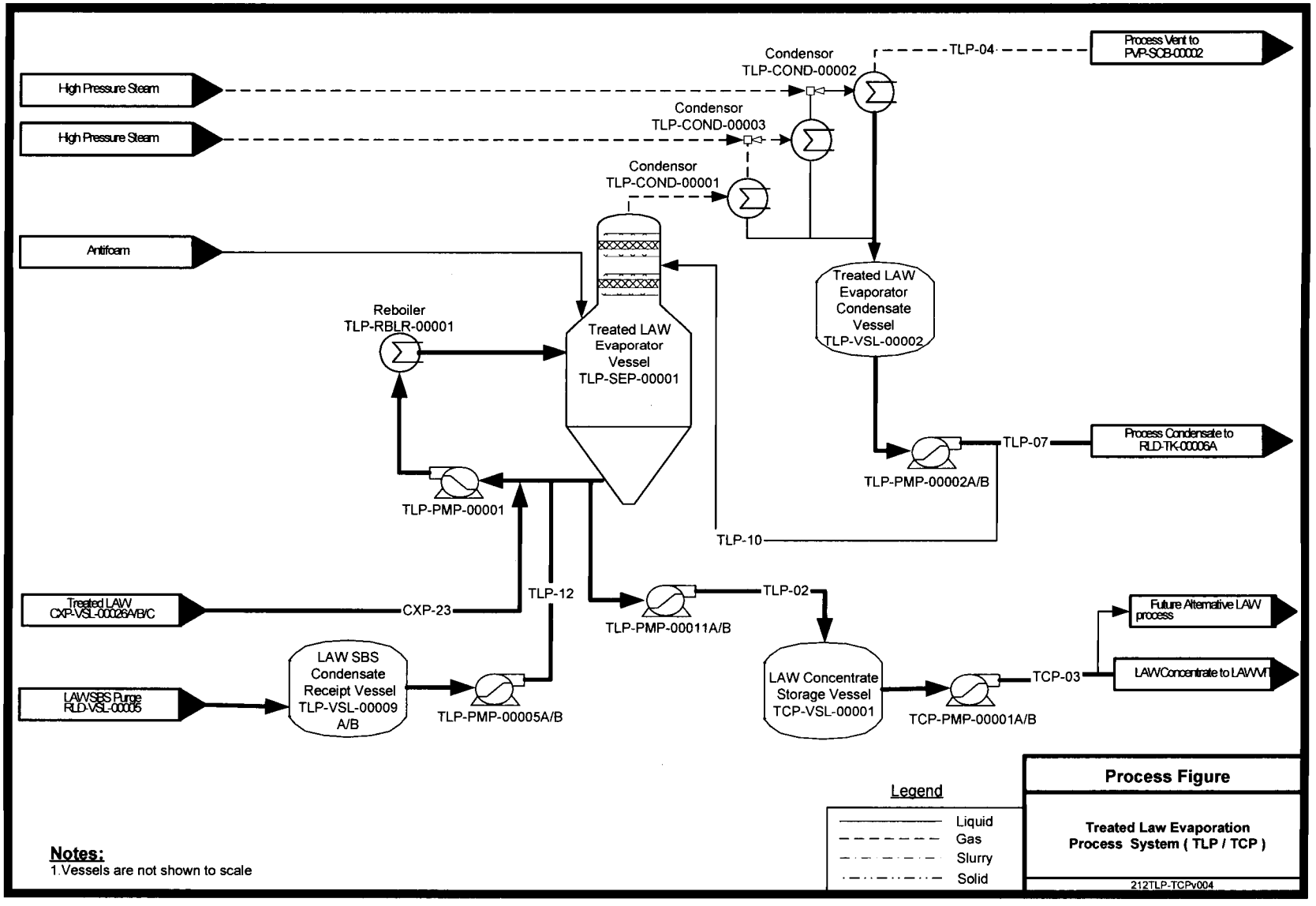


Figure 2.12.2 Treated LAW Evaporation and Concentrate Storage Process



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2.13 Systems PVP/PVV: Pretreatment Vessel Vent and Exhaust System

The primary functions of the pretreatment vessel vent process system (PVP) and process vessel vent exhaust system (PVV) are to:

- Provide forced and passive purge air supply for the important to safety (ITS) requirement for radiolytic hydrogen control for the pretreatment (PT) vessels.
- Collect the vent gases from the process vessels located in PT C5 cells, PT C3 cells, and two vessels located outside the PT Facility in a common header.
- Provide process treatment of the combined exhaust gases to absorb acid gases, remove liquid droplets, condensate, mists, and solid particulates.
- Separate entrained solids by high-efficiency particulate air (HEPA) filters
- Treat the gases by oxidation of volatile organic compounds (VOC) and absorption of other chemicals. The treated exhaust flows through the PVV exhaust fans and then vented to the atmosphere from an exhaust stack.

Other important functions of the PVP system in combination with other systems include:

- Maintain negative pressures in the process vessels.
- Safely exhaust flammable gases (hydrogen).

2.13.1 Function and Requirements

The primary functions of the PVP and PVV systems are to prevent flammable gas accumulation in process vessels in the PT Facility, collect offgases from PT process vessels, and abate radiological and environmental contaminants from vessel offgas streams before atmospheric release.

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7(a)(12) states that the WTP shall be designed to:

> *Comply with applicable Federal, State, and local requirements, including environmental permits and other regulatory approvals and authorizations. The WTP shall be designed and operated to ensure that exposure to the maximally exposed offsite individual (non-acute) is ALARA but not more than 1.5 mrem per year and hazardous organic emissions are ALARA but not more than 0.375 tons per year from components regulated under 40 CFR 265 subpart AA.*

In accordance with the Washington Administrative Code, the PVP/PVV systems must demonstrate the best available control technology (BACT) for criteria pollutants, radionuclides (BARCT), and toxic air pollutants (T-BACT) (24590-WTP-DB-ENG-01-001, *Basis of Design*).

2.13.2 Process Description

The vent streams from vessels located in the C5 area flow through a network of subheaders (piping) that tie into a common collection header. The vent gases from vessels located in the C3 area and the two vessels located outside the PT building also flow through subheaders that tie into the common collection header for further treatment.

The PVP system includes the forced and passive purge air supply into the process vessels, vent gas collection, and the treatment sections, which is composed of a caustic scrubber, high-efficiency mist eliminators (HEME), a VOC oxidation unit, and the carbon bed adsorbers. The PVP system interfaces with the PVV system, which includes a hot air in-bleed system, two stages of HEPA filters, exhaust fans, stack air stream monitoring and the exhaust stack. Control devices are provided to control the fan speed to maintain operating suction pressure of the vent gas stream to the vessel vent caustic scrubber.

The PT vessel vent systems (i.e., PVP/PVV) are separated from the reverse flow diverter (RFD) and pulse jet mixer (PJM) exhaust system (PJV) to allow better control of pressures and exhaust airflow rates, as well as to minimize the size of the components (VOC oxidation unit, carbon bed adsorbers, and caustic scrubber).

The equipment that comprises systems PVP and PVV is shown in Figure 2.13-1, taken from the process flow diagrams for the PT vessel vent system (24590-PTF-M5-V17T-00021001, 002, and 004), and includes the following:

- Caustic scrubber (PVP)
- One caustic scrubbing liquid cooler (PVP)
- Two 100 % capacity scrubber recirculation pumps: 1 operating and 1 standby (PVP)
- Three 50 % capacity HEMEs: 2 operating and 1 standby (PVP)
- One 800 gal batch HEME drain collection vessel (PVP)
- Two 100 % capacity HEME drain transfer pumps: 1 operating and 1 standby (PVP)
- Two parallel trains supplying heated air in-bleed consisting of a dust filter, heater, and HEPA filter: 1 operating and 1 standby (PVV)
- Two parallel trains of primary and secondary HEPA filters: 1 operating and 1 standby (PVV)
- Thermal oxidizer unit with regenerative heat exchanger, recirculation blower, and aftercooler (PVP)
- Two 100 % capacity carbon bed adsorbers with common dust filter: 1 operating and 1 standby (PVP)
- Two 100 % capacity exhaust fans: 1 operating and 1 standby (PVV)
- Medium efficiency filter (PVP)
- Exhaust stack (PVV)

The total flow of offgases entering the caustic scrubber includes the purge air (both forced and passive) supplied to the PT vessels plus aerosols and vapors transferred from the process liquid inside the vessel to the PVP offgas air stream. The caustic scrubber removes NO_x, other acid gases and particulates. As the vessel vent offgas stream flows upward through the packed bed tower of the scrubber, a caustic scrubbing solution flows downward to the scrubber sump. The caustic solution reacts with the acid gases in the vessel vent stream to form sodium salts (e.g., $NaNO_3$). Two centrifugal pumps, one operating and one standby, recirculate the scrubbing solution from the sump to both the top of the packed bed tower. Fresh demineralized water and 5 M NaOH are added to control the pH of the scrubbing solution and to maintain a minimum liquid level in the scrubber sump. The recirculation pumps also transfer a portion of the caustic scrubbing solution from the scrubber sump to the plant wash vessel, PWD-VSL-00044 as needed to prevent build up of dissolved and undissolved solids in the scrubbing solution. Chilled water circulates through the vessel vent scrubbing liquid cooler on the recirculation loop to remove heat generated from acid-base reactions and to control the temperature of the offgas stream. The caustic scrubber is in an R5/C5 cell, with its recirculation pumps outside the cell in a bulge area.

The vessel vent offgases exit the caustic scrubber and flow to the two operating HEMEs. Each HEME contains fiber filter elements that remove aerosols. The filter elements are stacked into "candles" and arranged inside the HEME in an annular shape. The HEMEs are operated wet, which allows aerosols that accumulate on the filter elements, on a liquid film, and then drain to the bottom of the HEME. A continuous atomizing spray of demineralized water keeps the offgas stream saturated upon entering the HEME. When a HEME is offline, the filter elements can be washed with demineralized water to remove accumulated solids, thus extending the operating life of the filter elements. The HEME liquid effluent discharges to a collection vessel. Two centrifugal pumps, one operating and one standby, recirculate the effluent to prevent solids from settling in the collection vessel. The pumps also transfer the effluent as needed to plant wash vessel, PWD-VSL-00044, for subsequent recycle to the waste feed evaporator. The HEMEs are in the common filter cave where the elements can be replaced remotely using the manipulator and filter cave operating crane. The HEME drain collection vessel is in an R5/C5 cell, with the recirculation pumps outside the cell in a bulge. Isolation valves for the HEMEs are in the bulge and filter cave areas. The vessel vent offgas stream cannot bypass the HEMEs.

Excessive moisture in the offgas can adversely affect the performance of the downstream HEPA filters. Two parallel hot air in-bleed trains, one operating and one standby, are provided to protect the downstream primary and secondary HEPA filters from condensation. Air from the R3/C3 area is heated and mixed with the vessel vent exhaust exiting the HEMEs to ensure that the relative humidity of the combined stream is below 70 %. Each hot air in-bleed train consists of a medium-efficiency air filter, an electric heater, and HEPA filter. The hot air in-bleed HEPA filter prevents cross-contamination from backflow of vessel vent exhaust into the R3/C3 ventilation area. The hot air in-bleed filters and heaters are in an R3/C3 area. The hot air in-bleed air is mixed with the vessel vent exhaust in the R5/C5 area, downstream of the HEMEs.

HEPA filtration is the primary means of removing radioactive particulates from the vessel vent offgas stream. HEPA banks are arranged in two parallel trains, each consisting of a primary and a secondary HEPA filter. The vessel vent offgases enter one of the HEPA trains. The primary HEPA filters are in the same filter cave as the HEMEs and are remotely changeable. Secondary HEPA filters are in an R3/C3 area, which permits hands-on filter removal and replacement. Filter changeout frequency for both primary and secondary HEPA filters is determined by monitoring the differential pressure across each filter. Isolation valves are provided at the inlet and outlet of each HEPA train: inlet isolation valves are upstream of the primary HEPAs in the filter cave, and outlet isolation valves are downstream of the secondary HEPAs, also in the filter cave. The vessel vent offgas stream cannot bypass both the primary and secondary HEPA banks at the same time.

Following HEPA filtration, the primary abatement equipment for VOC is the regenerative thermal oxidizer unit. Thermal destruction of VOCs takes place in three stages: preheat, reaction, and heat recovery. The vessel vent offgas stream exiting the HEPA filters is preheated to approximately 1450 °F. The offgas then enters a chamber sized to provide sufficient residence time to achieve the required VOC destruction efficiency. Electric heating elements in the chamber further increase the temperature to a minimum of 1600 °F. The combination of high temperature and available oxygen inside the chamber forces combustion reactions, which converts VOCs into primarily carbon dioxide and water. Heat is recovered from the reaction chamber exhaust gases to preheat the incoming vessel vent offgas stream. The preheat and heat recovery stages of the thermal destruction process use an alternating ceramic bed heat exchanger. Structured ceramic heat exchange media store and release heat as the incoming and exiting offgases pass through the exchanger beds. Flows alternate through each of the beds in such a way that the bed that had previously removed heat from the reaction chamber exhaust gases will then release this stored energy to preheat the incoming vessel vent offgases. Process cooling water flows through a finned tube aftercooler downstream of the thermal oxidizer unit to further cool the exhaust gases to

approximately 97 °F, which corresponds to a relative humidity of approximately 50 % (24590-PTF-MEC-PVP-00001). The thermal oxidizer unit and aftercooler have a bypass line. During startup, the vessel vent offgases are routed to the downstream carbon bed adsorbers while the oxidizer unit is brought up to operating temperature. Both the thermal oxidizer unit and the aftercooler are in an R2/C2 area.

Two carbon bed adsorbers provide secondary abatement of VOCs. Each bed is filled with activated carbon media. As the vessel vent gases flow through the bed, VOCs become trapped in the pores. A medium-efficiency filter downstream of the carbon bed adsorber removes any remaining particulate dust from the offgas stream. One carbon bed adsorber remains in standby while the other is operating. If the thermal oxidizer unit is shut down, the vessel vent offgases will be routed through a bypass line to the adsorption system. A separate VOC abatement bypass line allows the vessel vent offgases to circumvent the thermal oxidizer unit, aftercooler, carbon bed adsorbers, and dust filter. Any time the adsorption process is not operating, the thermal oxidizer unit must be shut down. During loss of offsite power, neither the thermal oxidizer unit nor the carbon bed adsorber will operate.

An exhaust fan downstream of the carbon bed adsorbers supplies the motive force to draw the purge air through the process vessels and the emission abatement equipment. The exhaust fan discharges to the PVV stack, which is continuously monitored by the Stack Discharge Monitoring System (SDJ). During normal operation of systems PVP and PVV, one exhaust fan operates while a second is in standby. The exhaust fans are connected to the emergency diesel generator for electrical power post-design basis event operation.

2.13.3 Basis

2.13.3.1 Vessel Vent Purge Air

Alternative configurations meeting the requirements for both hydrogen mitigation in process vessels and treatment of contaminants using BACT were evaluated for systems PVP and PVV (RPT-W375PT-PR00010). The recommended alternative for hydrogen control combines passive vessel inlets with an active extraction system. Further refinements to systems PVP and PVV added a forced purge air component which is supplied by the Plant Service Air System (PSA) via separate vessel inlets. Reliability of the forced purge air component is enhanced by redundant ITS air compressors.

Table 2.13-1 lists the collective passive purge air, forced purge air, and sparge air requirements for the PT process vessels. The forced purge air requirements are determined from the hydrogen generation rates of PT vessels, which can contain radioactive waste. These forced purge air requirements are then used to determine the passive purge air requirements. Minimum passive purge flows are set at 10 scfm for vessels having a forced purge requirement of less than or equal to 10 scfm. For vessels which require a forced purge flow in excess of 10 scfm, the passive purge rate will be equal to the forced purge flow (24590-PTF-M6C-PVP-00002, Rev E).

Assumption 2.13.1. The forced purge air and passive purge air flow rates listed in Table 2.13-1 are unverified assumptions for hydrogen mitigation. Additional calculations (e.g., hydrogen generation, passive purge inlet line sizing, forced purge inlet line sizing) are needed to verify these assumptions for hydrogen mitigation.

2.13.3.2 Vessel Vent Offgas

In addition to an increase in temperature and moisture content, the purge air also becomes contaminated as it passes through the vessel vapor space. Mixing, sparging, radiolytic hydrogen generation, process transfers, and evaporation contribute to the release of aerosols and particulates into the vessel offgas stream. A method used to estimate the hydrogen generation in process vessels is provided and outlined below.

The amount of hydrogen released depends on waste contents, its temperature, and the intensity of nuclear radiation. Pretreatment and vitrification of low-activity waste and high-level waste involve various process steps changing the composition of the waste at each step. The following equations are used to calculate hydrogen generation (24590-101-TSA-W000-0004-150-00003, Rev 00A; 24590-WTP-RPT-RT-04-0002, Rev 0). Hydrogen, along with other gases, is vented into the vessel ventilation system.

The expression to calculate hydrogen generation rate contains the following:

Galpha	G-value for water radiolysis by alpha radiation, H2 molecules/100 eV
Gbeta	G-value for water radiolysis by beta/gamma radiation, H2 molecules/100 eV
Gh2o	G-value for water radioysis by alpha and beta/gamma radiation, H2 molecules/100 eV
Gtoca	G-value for organic radiolysis by alpha radiation, H2 molecules/100 eV
Gtocbg	G-value for organic radiolysis by beta/gamma radiation, H2 molecules/100 eV
Gtoc	G- value for organic radiolysis by alpha and beta/gamma radiation, H2 molecules/100 eV
Gtot	G- value for water and organic radiolysis by alpha and beta/gamma radiation, H2 molecules/100 eV
HGRtherm	Hydrogeneration rate by thermolysis, mol H2/day/kg-waste
HGRad	Hydrogen generation rate by radiolysis, mol h2/day/kg-waste
HGR	Total hydrogen generation rate by mol H2/day/kg-waste
TOC	Weight percent of total organic carbon (TOC) in liquid waste
Alwt	Weight percent of aluminum in liquid waste
a0	Coefficient of radiolysis of organics, 2.49E+06
aT	Coefficient of thermolysis of organics, 2.76E+09
Qrad	Activation energy for radiolysis of organics, 44.30 KJ/mol
Qtherm	Activation energy for thermolysis of organics, 89.30 KJ/mol
R	Universal gas constant, 8.314J/mol-K
T	Waste temperature in Kelvin (K)
f	Tank dependent reactivity coefficient, f = 0.7 DST and f = 0.4 for SST and f = 1 for 241- AW-101
DecayHeatAlpha	Decay heat rate from alpha radiation, watt/kg waste
DecayHeatBetag	Decay heat rate from beta and gamma radiation, watt/kg waste

Use Equation 2.13-1 to calculate the weight percent of TOC.

Equation 2.13-1

[TOC] = 100* {24*Mass("oxylate")/(MWt("oxylate")*MassTotal)
+12*Mass("formate")/(Mwt("formate")*MassTotal)
+ 24*Mass("acetate")/(MWt("acetate")*MassTotal)
+24*Mass("glycolate")/(MWt("glycolate")*MassTotal)
+48*Mass("IDA")/(MWt("IDA")*MassTotal)
+72*Mass("citrate")/(MWt("citrate")*MassTotal)
+120*Mass(HEDTA")/(MWt("HEDTA")* MassTotal)
+120*Mass("EDTA")/(MWt("EDTA")*MassTotal.)}

Equation 2.13-2

Gh2o = Galpha + Gbetag

The G-value for organic radiolysis from alpha and beta/gamma radiation:

Equation 2.13-3

Gtoc = Gtoca + Gtocbg

Total G-value:

Equation 2.13-4

Gtot = Gh2o + Gtoc

The G-value for water radiolysis from alpha radiation is (24590-101-TSA-W000-0004-150-00003):

Equation 2.13-5

Galpha = 1.05/(1 + 2.4*[NO3] + 0.63*[NO2]) + 0.35/(1 + 3900*[NO3] + 1400*[NO2])

The G-value for water radiolysis from beta/gamma radiation is (24590-101-TSA-W000-0004-150-00003):

Equation 2.13-6

Gbetag = 0.34/(1 + 2.4*[NO3] + 0.62*[NO2]) + 0.11/(1 + 120*[NO3] + 43*[NO2])

The G-value for organic radiolysis from alpha radiation is (24590-101-TSA-W000-0004-150-00003):

Equation 2.13-7

Gtoca = 0.5*a0*(f*[TOC])*exp(-Qrad/RT)

The G-value for organic radiolysis from beta/gamma radiation is (24590-101-TSA-W000-0004-150-00003):

Equation 2.13-8

Gtocbg = a0*(f*[TOC])*exp(-Qrad/RT)

Use f=0.7 for DST and f=0.4 for SST, and Qrad = 44.30 KJ/mol.

Equation 2.13-9

[Alwt] = 100* (27*Mass ("AlOH3")/(MWc("AlOH3") * MassTotal))

[NO3-] = Nitrate ion concentration in liquid waste (gmoles/L)

[NO2-] = Nitrite ion concentration in liquid waste (gmoles/L)

Hydrogen generation by radiolysis (24590-WTP-RPT-RT-04-0002):

Equation 2.13-10

HGRrad = fl*F*(decayHeatalpha*(Galpha + Gtoca) + DecayHeatbetag*(Gbetag + Gtocbg))

Where fl is the weight fraction of liquid in waste, F is the conversion factor given by (24590-WTP-RPT-RT-04-0002) and the following expression:

Equation 2.13-11

F = (molecules of H2/100 eV)*(watt/kg waste)*6.241E+11 eV/erg*(1.0E+07 erg/J)*(mol of H2/6.022E+23 molecules of H2)*(86400 sec/day) = 0.00895

Hydrogen generation by organic thermolysis is calculated by (24590-WTP-RPT-RT-04-0002):

Equation 2.13-12

HGRtherm = aT*f*[TOC]*[Alwt]^ 0.4*fl* exp(-Qtherm/RT); Qtherm = 89.30KJ/mol

Total hydrogen generation rate mol H2/day/kg waste is:

Equation 2.13-13

HGR = HGRrad + HGRtherm

Moles of hydrogen generated per day is obtained by: HGR*mass of waste.

DecayHeatalpha is the rate of heat generation from all the alpha emitting radionuclides and DecayHeatbetag is the rate of heat generation from all the beta and gamma emitting radionuclides.

Specific activity and decay heat generation rates for selected alpha and beta/gamma emitting radionuclides (DOE/RW-0006):

Radionuclides	Ci/g	W/Ci
Co-60	1.13E+03	1.54E-02
Sr-90	1.36E+02	
Sr-90/Y-90	6.70E-03	

Radionuclides	Ci/g	W/Ci
Tc-99	1.69E-02	5.01E-04
Cs-137	8.67E+01	
Cs-137/Ba-137		4.95E-03
Eu-154	2.70E+02	9.08E-03
U-233	9.68E-03	2.86E-02
U-235	2.16E-06	2.71E-02
Pu-238	1.71E+01	3.26E-02
Pu-239	6.22E-02	3.02E-02
Pu-240	2.28E-01	3.06E-02
Am-241	3.43E+00	3.28E-02
Cm-244	8.09E+01	3.44E-02

A liquid entrainment factor has been calculated for several process vessels based on *PT Vessel Vent System Baseline Operating Conditions and Radioactive Aerosol Loading of Exhaust Air Stream* (RPT-W375PT-PR00021). These entrainment factors are listed in Table 2.13-2.

From the entrainment factor for inorganics and radionuclides, the quantity of a constituent in the vessel vent offgas stream can be determined by multiplying the quantity of the constituent entering the vessel in the liquid phase by the entrainment factor for that vessel. The quantity of organics in the offgas stream is determined through the application of Henry's Law, which estimates the equilibrium gas phase concentration of a compound from the known liquid phase concentration (RPT-24590-EN00001).

Based on the operating temperatures of the vessels that vent to system PVP, the maximum temperature of the vessel vent offgas streams exiting the process vessels is 138 °F (58.9 °C) and fully saturated (24590-PTF-MEC-PVP-00005, Rev B).

2.13.3.3 Selection of Air Emission Control Equipment

To select air emission control equipment, options were grouped together to create a set of alternatives (RPT-W375PT-PR00010). Using prescribed selection criteria, the alternatives were compared to each other, and the best components from each were chosen for the recommended alternative.

The final sequence of the selected emission control equipment in the figure in Section 2.13.2 was established through subsequent analysis of emissions modeling results and evaluations of impacts from the PT Facility reconfiguration study (CCN 019468). Each piece of emission control equipment has an associated removal efficiency dependent on the contaminant of concern. A decontamination factor (DF) is a function of removal efficiency and is the ratio of the amount of a constituent entering the equipment to the amount of that constituent exiting the equipment in the offgas stream. The DFs for the PVP/PVV equipment references are provided for the PVP/PVV equipment DFs within the appropriate table, Table 2.13-3 for radionuclides, Table 2.13-4 for inorganic constituents, and Table 2.13-5 for organic constituents.

2.13.3.4 Caustic Scrubber

The caustic scrubber removes acidic gases (primarily NO_x) and large particulates. Demineralized water and 5 M NaOH are added to the scrubber sump to maintain a 0.01 M NaOH scrubbing solution. Nitrogen oxide, present as NO_2 and carbon dioxide in the vessel vent offgas stream will react with the NaOH solution according to the following chemical equations:

Equation 2.13-14

$$2NaOH + 2NO_2 \rightarrow NaNO_2 + NaNO_3 + H_2O$$

and

Equation 2.13-15

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

The baseline DFs applied to the caustic scrubber are shown in Table 2.13-3 and are based on the mechanical data sheet for the PVP scrubber (24590-PTF-MKD-PVP-00002).

The conditions for the vessel vent offgases at the inlet and outlet of the caustic scrubber are 138 °F (58.9 °C) and 77 °F (25 °C) respectively at 100 % relative humidity (24590-PTF-MEC-PVP-00005, Rev B).

The concentration of NO_2 in the vessel vent offgas stream is negligible (24590-PTF-MVC-PVP-00012). Therefore, the chilled water load for the vessel vent scrubbing liquid cooler due to heat of reaction is also negligible.

A batch volume of approximately 2160 gal caustic scrubbing solution will be transferred to the plant wash vessel, PWD-VSL-00044, as often as necessary at 60 gpm (24590-PTF-MVC-PVP-00012).

2.13.3.5 High-Efficiency Mist Eliminators

Three HEMEs (PVP-HEME-00001A/B/C) remove sub-micron aerosols and particulates from the vessel vent offgas stream. Two HEMEs operate in parallel while the third is in standby. Because HEMEs are required to operate wet during normal ops, a continuous atomizing spray of demineralized water is provided at the inlet nozzle to each HEME. As a result, the offgas stream exiting the HEME will be saturated. The demineralized water will gravity drain to the HEME drain collection vessel, PVP-VSL-00001.

The baseline DFs applied to the HEMEs for particulates, acid gases, and vapors are 200, 1, and 1, respectively (24590-WTP-RPT-PO-03-008).

The summed flow rates of demineralized water entering the two operating HEMEs is 8 gal/hr (24590-PTF-MVC-PVP-00010). An 800 gal batch volume of HEME drain solution will be transferred to the plant wash vessel, PWD-VSL-00044, twice per week at 50 gpm (24590-PTF-MVC-PVP-00010 and 24590-PTF-M5-V17T-00021001).

2.13.3.6 C3 Heated Air In-Bleed Heater

The required relative humidity of the vessel vent offgas stream entering the HEPA filters is below 70 % (24590-PTF-3YD-PVP-00001). Hot air is bled into the vent air upstream of the HEPA filters to assist in lowering the relative humidity of the offgas stream. The air in-bleed will dilute the vent air stream with 400 scfm of air from the C3 area. The heater (PVV-HTR-00002A/B) in the air in-bleed assembly will heat the air to 225 °F (107 °C). The electrical load required by the heaters is determined from the difference in enthalpy between the entering and exiting C3 air.

2.13.3.7 C3 Heated Air In-Bleed Filters

Two 100 % duty parallel trains provide C3 air, which is passed through a medium efficiency filter (PVV-FLTH-00001A/B) to remove dust before air enters the heater in order to reduce fouling of the heater (PVV-HTR-00002A/B). Following the heater, the air is passed through a HEPA filter (PVV-HEPA-00004A/B) before being injected into the vessel ventilation stream. The baseline flowsheet does not account for particulates in the C3 air.

2.13.3.8 Primary and Secondary High-Efficiency Particulate Air Filters

The primary purpose of HEPA filtration is to remove radioactive particles to achieve compliance with both environmental and dose limits. The HEPA filters generally have a minimum removal efficiency of 99.97 % (DF of 3333) for 0.3 micron particles (24590-WTP-MKC-50-00002). The baseline DF applied to the HEPAs for particulates is 1,667,000, based on a first stage removal efficiency of 99.97 % (DF of 3333) and, for conservatism, a second stage removal efficiency of 99.8 % (DF of 500). The particulate DF applied to the HEPAs is defined differently for emissions estimates and is described in Section 7.

2.13.3.9 Vessel Vent VOC Oxidizer Unit

A combustion reaction that destroys VOCs takes place in the thermal oxidizer unit. Products of combustion include carbon dioxide and water vapor. The average baseline DF applied to the thermal oxidizer for organics is 10 (CCN 044540, *Organic DFs Across Abatement Equipment in the PVP System*).

Because a DF is applied to the thermal oxidizer to estimate the amount of VOCs destroyed, rather than a chemical reaction, no additional water vapor is produced in the thermal oxidizer unit. Therefore, the assumed mass of water vapor exiting the thermal oxidizer unit is equal to the mass of water vapor entering the thermal oxidizer unit.

Regenerative thermal oxidizer systems typically operate with thermal efficiencies in excess of 90 %, and as high as 95 % for clean gases (24590-PTF-3YD-PVP-00001). The thermal efficiency of the thermal oxidizer unit's ceramic bed heat exchangers is to be 95 % (24590-PTF-3PS-MBT0-T0001, Rev 0). This thermal efficiency determines the temperature of the vessel vent offgases exiting the thermal oxidizer unit. The electrical load required by the thermal oxidizer unit during normal operations is determined from the difference in enthalpy between the entering and exiting streams.

The plant service air usage and electrical load required to bring the thermal oxidizer unit up to operating temperatures from a cold start is not addressed in the baseline flowsheet.

2.13.3.10 Aftercooler

The required relative humidity of the vessel vent offgas stream entering the carbon bed adsorbers is approximately 50 % (24590-PTF-3YD-PVP-00001). Plant cooling water flowing through the aftercooler cools the offgases exiting the thermal oxidizer unit, thereby raising the relative humidity. The cooling water load required by the aftercooler is determined from the difference in enthalpy between the entering and exiting vessel vent offgas streams.

2.13.3.11 Vessel Vent Carbon Bed Adsorber

The carbon bed adsorbers remove residual organic vapors from the cooled offgas stream. The average baseline DF applied to the carbon bed adsorber for organics is 15.61 (24590-PTF-M0C-PVP-00003, Rev 00B).

2.13.3.12 Carbon Bed Adsorber Outlet Filter

A medium-efficiency dust filter is provided downstream of the carbon bed adsorbers to remove carbon media, which may become entrained as the vessel vent offgas stream flows through the beds. Because no additional particulates are expected to become entrained in the vessel vent offgas stream under normal conditions, this dust filter is not included in the current baseline flowsheet.

2.13.3.13 Dimethyl Mercury Formation in UFP Leach Vessels

Elemental mercury reacts at elevated temperatures (CCN 195033) with a number of organic species initially to form monomethyl mercury (MMHg), and subsequently, at a slower rate, dimethyl mercury (DMHg). Antifoam agents used in the WTP PT Facility are expected to promote DMHg formation by acting as methyl donors. For WTP, vessels having the highest DMHg formation rates are the ultrafiltration process system (UFP) during caustic leaching, when at 85 °C and in the presence of antifoam agents. Due to its volatility, a majority of the DMHg generated in the UFP system during caustic leaching enters the offgas system. The PVP/PVV do not have any components credited for controlling mercury, however, any mercury MMHg or DMHg may be retained in the PVP carbon bed adsorber. It was concluded in the reference cited above that the mercury converted to DMHg is low enough to preclude incorporation into the flowsheet. However, DMHg will likely be tracked for the next revision to the integrated emissions report.

2.13.4 Ongoing Work and Potential Changes

Research and Technology (R&T) testing has neither been performed nor is planned for the PVP system (24590-WTP-PL-RT-01-002 and 24590-WTP-RPT-PR-01-012). Systems PVP/PVV include typical, commercially available emission control technologies for handling vessel ventilation systems containing trace amounts of organic compounds. There are no anticipated significant technical uncertainties associated with these units that would require further R&T study.

Future calculations may define some organic DFs for the carbon bed adsorbers. Current values are based on the *Integrated Emissions Baseline Report for the Hanford Tank Waste Treatment and Immobilization Plant* (24590-WTP-RPT-PO-03-008, Rev 2). DFs for the thermal oxidizer are not likely to be calculated due to the very low organics content. Future performance specifications for the emission control equipment could affect other DFs used in the baseline flowsheet. Additionally, changes in process vessel sizing and refinements to hydrogen mitigation calculations could result in new passive and forced purge air requirements.

There is one EFRT major issue, inadequate mixing system design (M3), and another issue, hydrogen in piping and ancillary vessels (HPAV), that may impact the PVP/PVV system. These issues are currently being worked. It is possible, that a design change to the PVP will be required when these issues have been closed.

2.13.5 References

24590-101-TSA-W000-0004-150-00003, Rev 00A, *Gas Generation Testing and Support for the Hanford Waste Treatment and Immobilization Plant.*

24590-PTF-3PS-MBT0-T0001, Rev 0, Engineering Specification: *Electrically Heated Regenerative Thermal Oxidizer.*

24590-PTF-3YD-PVP-00001, Rev 1, *System Description for Pretreatment Vessel Vent Process System, PVP.*

24590-PTF-3YD-PVV-00001, Rev 0, *System Description for Pretreatment Vessel Vent Exhaust System (PVV).*

24590-PTF-DCN-PR-02-009, Rev 0, *PT Thermal Oxidizer Treated Gas Recirculation.*

24590-PTF-M0C-PVP-00003, Rev 00B, *Sizing of Pretreatment Vessel Vent Carbon Adsorbers (PVP-ADBR-00001A/B).*

24590-PTF-M5-V17T-00021001, Rev 2, *Process Flow Diagram Pretreatment Vessel Vents Process (PVP/PVV) System PVP/PVV/PJV.*

24590-PTF-M6C-PVP-00002, Rev 00E, *Vessel Vent System Line Calculations.*

24590-PTF-M6C-PVP-00012, Rev D, *PTF Scrubber Line Sizing and Pump Sizing for PVP Scrubber.*

24590-PTF-MEC-PVP-00001, Rev 00B, *Duty of Pretreatment Vessel Vent After Cooler (PVP-CLR-00001).*

24590-PTF-MEC-PVP-00005, Rev B, *Calculation of Cooling Duty of PVP Caustic Scrubber PVP-SCB-00002.*

24590-WTP-MKC-50-00002, Rev 1, *Process Equipment Decontamination Factor Curves.*

24590-PTF-MKD-PVP-00002, Rev 11, *Mechanical Data Sheet: PTF Vessel Vent Caustic Scrubber.*

24590-PTF-MVC-PVP-00010, Rev 0, *Process Data for the Vessel Vent HEME Drain Collection Vessel 24590-PTF-MV-PVP-VSL-00001.*

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Table 2.13-1 Total Purge and Sparge Air Entering PVV from Pretreatment Process Vessels

Process Vessel No.	Process Vessel Name	Total Air Requirement (scfm)[a,b,c]	Vessel Vent Stream No.
FRP-VSL-00002A	Waste Feed Receipt	15	FRP04
FRP-VSL-00002B	Waste Feed Receipt	15	FRP04
FRP-VSL-00002C	Waste Feed Receipt	15	FRP04
FRP-VSL-00002D	Waste Feed Receipt	15	FRP04
FEP-VSL-00017A	Waste Feed Evaporator Feed	15	FEP04
FEP-VSL-00017B	Waste Feed Evaporator Feed	15	FEP04
FEP-SEP-00001A[d]	Waste Feed Evaporator Separator	5	FEP09
FEP-SEP-00001B[d]	Waste Feed Evaporator Separator	5	FEP09
FEP-VSL-00005	Waste Feed Evaporator Condensate	10	FEP10
HLP-VSL-00022	HLW Feed Receipt	60	HLP07
HLP-VSL-00027A	HLW Lag Storage	Run 1349[e] Idle 72	HLP04
HLP-VSL-00027B	HLW Lag Storage	Run 1349[e] Idle 72	HLP04
HLP-BRKPT-00004/6	HLP Break Pot	0	HLP04
HLP-VSL-00028	HLW Lag Storage & Feed Blending	Run 1638[e] Idle 72	HLP04
UFP-VSL-00001A	Ultrafiltration Feed Preparation	30 144 - Sparging	UFP20
UFP-VSL-00001B	Ultrafiltration Feed Preparation	30 144 - Sparging	UFP20
UFP-VSL-00002A	Ultrafiltration Feed	Run 461[e] Idle 133	UFP11
UFP-VSL-00002B	Ultrafiltration Feed	Run 461[e] Idle 133	UFP11
UFP-VSL-00062A	Ultrafilter Permeate	15	UFP35
UFP-VSL-00062B	Ultrafilter Permeate	15	UFP35
UFP-VSL-00062C	Ultrafilter Permeate	15	UFP35
CXP-VSL-00001	Cs IX Feed	15	CXP02
CXP-VSL-00004	Cs IX Caustic Rinse Collection	10	CXP02

Table 2.13-1 Total Purge and Sparge Air Entering PVV from Pretreatment Process Vessels

Process Vessel No.	Process Vessel Name	Total Air Requirement (scfm)[a,b,c]	Vessel Vent Stream No.
CXP-VSL-00005	Cs IX Reagent	10	CXP02
CNP-EVAP-00001[d]	Cs Evaporator Separator	5	CNP09
CNP-BRKPT-00002 (CXP-IXC-0001/2/3/4 via CNP-VSL-00001)	Cs Eluate Breakpot	15	CNP16
CNP-VSL-00003	Cs Eluate Contingency Storage	30	CNP16
CNP-VSL-00004	Cs Evaporator Recovered Nitric Acid	10	CNP16
CXP-VSL-00026A	Treated LAW Collection	10	CXP23
CXP-VSL-00026B	Treated LAW Collection	10	CXP23
CXP-VSL-00026C	Treated LAW Collection	10	CXP23
RDP-VSL-00002A	Spent Resin Collection	15	RDP02
RDP-VSL-00002B	Spent Resin Collection	15	RDP02
RDP-VSL-00002C	Spent Resin Collection	15	RDP04
TLP-VSL-00009A	LAW SBS Condensate Receipt	10	TLP06
TLP-VSL-00009B	LAW SBS Condensate Receipt	10	TLP06
TLP-VSL-00002	Treated LAW Evaporator Condensate	10	TLP11
TCP-VSL-00001	Treated LAW Concentrate Storage	10	TCP01
PWD-VSL-00015	Acid/Alkaline Effluent	10	PWD03
PWD-VSL-00016	Acid/Alkaline Effluent	10	PWD03
PWD-VSL-00033	Ultimate Overflow	15	PWD09
PWD-VSL-00043	HLW Effluent Transfer	15	PWD11
PWD-VSL-00044	Plant Wash	15	PWD07
RLD-VSL-00017A	Alkaline Effluent	10	RLD12
RLD-VSL-00017B	Alkaline Effluent	10	RLD12
RLD-TK-00006A	Process Condensate	10	RLD02
RLD-TK-00006B	Process Condensate	10	RLD02

Table 2.13-1 Total Purge and Sparge Air Entering PVV from Pretreatment Process Vessels

Process Vessel No.	Process Vessel Name	Total Air Requirement (scfm)[a,b,c]	Vessel Vent Stream No.
CRP Siphon Break	CRP Header	60	RDP02
CXP Siphon Break	CXP Header	60	CXP29

a scfm is defined as 60 °F (15.6 °C) and 14.696 psia (1.013 bar).

b 24590-PTF-M6C-PVP-00002, Attachment A.

c The total air requirement is the sum of passive and forced purge air, sparging, and sump inbleed flow and bubbler flow. Any additional air needed to mitigate hydrogen generation in process vessels will be evaluated when hydrogen generation calculation is completed.

d Purge air is supplied to this vessel only during shut down; however, offgases generated during processing are vented by this vessel to the PVP/PVV systems.

e Air spargers are used in these vessels as supplemental mixing to the pulse jet mixers. Due to air restrictions, the spargers will be cycled between idle and run modes. Spargers in UFP-VSL-00002A and HLP-VSL-00027A will run for an hour with the spargers in UFP-VSL-00002B, HLP-VSL-00027B, and HLP-VSL-00028 in idle mode. For the next hour, spargers in UFP-VSL-00002B and HLP-VSL-00027B will run with the spargers in UFP-VSL-00027A, HLP-VSL-00027A, and HLP-VSL-00028 in idle mode. During the third hour, spargers in HLP-VSL-00028 will run with the spargers in UFP-VSL-00002A, UFP-VSL-00002B, HLP-VSL-00027A, and HLP-VSL-00027B in idle mode. This cycle will repeat.

Table 2.13-2 Process Vessel Vent Entrainment Factors

Vessel Vent Stream No.	Process Vessels	Total Offgas (scfm)	^{137}Cs Ci/day in Vessel Vent (RPT-W375PT -PR00021)	^{137}Cs Ci/day in Vessel Feed (RPT-W375PT -PR00021)	Vessel Split Liquid Fraction[a]
FRP04	FRP-VSL-00002A	15	1.29E-03	2.73E+04	4.73E-08
FRP04	FRP-VSL-00002B	15	1.29E-03	2.73E+04	4.73E-08
FRP04	FRP-VSL-00002C	15	1.29E-03	2.73E+04	4.73E-08
FRP04	FRP-VSL-00002D	15	1.29E-03	2.73E+04	4.73E-08
FRP04 Subtotal		**60**			
FEP04	FEP-VSL-00017A	15	2.63E-02	4.71E+04	5.58E-07
FEP04	FEP-VSL-00017B	15	2.63E-02	4.71E+04	5.58E-07
FEP04 Subtotal		**30**			
FEP09	FEP-SEP-00001A	5	N/A	N/A	See Section 2.2
FEP09	FEP-SEP-00001B	5	N/A	N/A	See Section 2.2
FEP09 Subtotal		**10**			
FEP10	FEP-VSL-00005	10	3.52E-11	5.12E-04	7.00E-08
FEP10 Subtotal		**10**			
HLP07	HLP-VSL-00022	60	1.37E-02	4.59E+04	3.00E-07
HLP07 Subtotal		**60**			
HLP04	HLP-VSL-00027A	Run 1349 Idle 72	4.52E-06	2.01E+02	2.25E-08
HLP04	HLP-VSL-00027B	Run 1349 Idle 72	4.52E-06	2.01E+02	2.25E-08
HLP04	HLP-VSL-00028	Run 1638 Idle 72	4.52E-06	2.01E+02	2.25E-08
HLP04 Subtotal		**1782/1493**			
UFP20	UFP-VSL-00001A	177	2.28E-02	5.08E+04	4.49E-07
UFP20	UFP-VSL-00001B	177	2.28E-02	5.08E+04	4.49E-07
UFP20 Subtotal		**354**			
UFP11	UFP-VSL-00002A	Run 461 Idle 133	2.26E-02	5.08E+04	4.45E-07
UFP11	UFP-VSL-00002B	Run 461 Idle133	2.26E-02	5.08E+04	4.45E-07
UFP11 Subtotal		**594/266**			
UFP35	UFP-VSL-00062A	15	2.41E-02	4.65E+04	5.18E-07
UFP35	UFP-VSL-00062B	15	2.41E-02	4.65E+04	5.18E-07
UFP35	UFP-VSL-00062C	15	2.41E-02	4.65E+04	5.18E-07[c]
UFP35 Subtotal		**45**			

Table 2.13-2 Process Vessel Vent Entrainment Factors

Vessel Vent Stream No.	Process Vessels	Total Offgas (scfm)	^{137}Cs Ci/day in Vessel Vent (RPT-W375P T -PR00021)	^{137}Cs Ci/day in Vessel Feed (RPT-W375P T -PR00021)	Vessel Split Liquid Fraction[a]
CXP02	CXP-VSL-00001	15	4.28E-03	4.65E+04	9.00E-08
CXP02	CXP-VSL-00004	10	0.00E+00	0.00E+00	**2.00E-06**[b]
CXP02	CXP-VSL-00005	10	TBD	TBD	**2.00E-06**[b]
CXP02 Subtotal		**35**			
CNP09	CNP-EVAP-00001	5	N/A	N/A	See Section 2.6
CNP09 Subtotal		**5**			
CNP16	CNP-BRKPT-00002	15	TBD	TBD	**2.00E-06**[b]
CNP16	CNP-VSL-00003	30	TBD	TBD	**2.00E-06**[b]
CNP16	CNP-VSL-00004	10	1.12E-08	4.14E-02	3.00E-07
CNP16 Subtotal		**55**			
CXP27	CXP-VSL-00026A	10	TBD	TBD	**2.00E-06**[b]
CXP27	CXP-VSL-00026B	10	TBD	TBD	**2.00E-06**[b]
CXP27	CXP-VSL-00026C	10	TBD	TBD	**2.00E-06**[b]
TXP22 Subtotal		**30**			
RDP02	RDP-VSL-00002A	15	TBD	TBD	**2.00E-06**[b]
RDP02	RDP-VSL-00002B	15	TBD	TBD	**2.00E-06**[b]
RDP02	RDP-VSL-00002C	15	TBD	TBD	**2.00E-06**[b]
RDP02 Subtotal		**45**			
TLP06	TLP-VSL-00009A	10	TBD	TBD	**2.00E-06**[b]
TLP06	TLP-VSL-00009B	10	TBD	TBD	**2.00E-06**[b]
TLP06 Subtotal		**20**			
TLP11	TLP-VSL-00002	10	TBD	TBD	**2.00E-06**[b]
TLP11 Subtotal		**10**			
TCP01	TCP-VSL-00001	10	TBD	TBD	**2.00E-06**[b]
TCP01 Subtotal		**10**			
PWD03	PWD-VSL-00015	10	5.26E-08	2.69E+00	1.96E-08
PWD03	PWD-VSL-00016	10	5.28E-08	2.69E+00	1.96E-08
PWD03 Subtotal		**20**			
PWD09	PWD-VSL-00033	15	TBD	TBD	**2.00E-06**[b]
PWD09 Subtotal		**15**			
PWD11	PWD-VSL-00043	15	2.57E-05	1.56E+03	1.65E-08
PWD11 Subtotal		**15**			
PWD07	PWD-VSL-00044	15	3.58E-05	2.73E+04	1.31E-09
PWD07 Subtotal		**15**			

Table 2.13-2 Process Vessel Vent Entrainment Factors

Vessel Vent Stream No.	Process Vessels	Total Offgas (scfm)	^{137}Cs Ci/day in Vessel Vent (RPT-W375PT -PR00021)	^{137}Cs Ci/day in Vessel Feed (RPT-W375PT -PR00021)	Vessel Split Liquid Fraction[a]
RLD12	RLD-VSL-00017A	10	TBD	TBD	**2.00E-06**[b]
RLD12	RLD-VSL-00017B	10	TBD	TBD	**2.00E-06**[b]
RLD12 Subtotal		**20**			
RLD02	RLD-TK-00006A	10	TBD	TBD	**2.00E-06**[b]
RLD02	RLD-TK-00006B	10	TBD	TBD	**2.00E-06**[b]
RLD02 Subtotal		**20**			

a Vessel split liquid fraction = $\frac{\text{137Cs Ci/day in Vessel Vent}}{\text{137Cs Ci/day in Vessel Feed}}$

b For vessels not included in the analysis (RPT-W375PT-PR00021), a default value of 2.00E-06 has been assumed (24590-PTF-Z0C-W14T-00036).

Table 2.13-3 Process Vessel Vent System Radionuclide Decontamination Factors

PVP/PVV Equipment	Caustic Scrubber[a,b]	HEME[a,b]	HEPA[b,c,d]	Thermal Oxidizer Unit[a,b]	Carbon Bed Adsorber[a,b]
Constituent					
^{241}Am	3.5	200	1,667,000	1	1
^{14}C	1	1	1	1	1
^{60}Co	3.5	200	1,667,000	1	1
^{243}Cm	3.5	200	1,667,000	1	1
^{244}Cm	3.5	200	1,667,000	1	1
^{137}Cs	3.5	200	1,667,000	1	1
^{152}Eu	3.5	200	1,667,000	1	1
^{154}Eu	3.5	200	1,667,000	1	1
^{155}Eu	3.5	200	1,667,000	1	1
^{3}H	1	1	1	1	1
^{129}I	3.5	1	1	1	1
^{63}Ni	3.5	200	1,667,000	1	1
^{237}Np	3.5	200	1,667,000	1	1
^{238}Pu	3.5	200	1,667,000	1	1
^{239}Pu	3.5	200	1,667,000	1	1
^{240}Pu	3.5	200	1,667,000	1	1
^{241}Pu	3.5	200	1,667,000	1	1
^{125}Sb	3.5	200	1,667,000	1	1
^{151}Sm	3.5	200	1,667,000	1	1
^{126}Sn	3.5	200	1,667,000	1	1
^{90}Sr	3.5	200	1,667,000	1	1
^{99}Tc	3.5	200	1,667,000	1	1
^{232}Th	3.5	200	1,667,000	1	1
^{233}U	3.5	200	1,667,000	1	1
^{234}U	3.5	200	1,667,000	1	1
^{235}U	3.5	200	1,667,000	1	1
^{236}U	3.5	200	1,667,000	1	1
^{238}U	3.5	200	1,667,000	1	1

a Reference 24590-PTF-MKD-PVP-00002, Rev 11, *Mechanical Data Sheet: PTF Vessel Vent Caustic Scrubber*

b $DF = \frac{\text{activity of constituent in incoming stream}}{\text{activity of constituent in exiting stream}}$

c Reference 24590-WTP-MKC-50-00002, Rev1, *Process Equipment Decontamination Factor Curves.*

d Reported DFs are for the combined primary and secondary HEPAs

Table 2.13-4 Process Vessel Vent System Inorganic Constituent Decontamination Factors

PVP/PVV Equipment	Caustic Scrubber[a,b]	HEME[a,b]	HEPA[b,c,d]	Thermal Oxidizer Unit[a,b]	Carbon Bed Adsorber[a,b]
Constituent					
CO	1	1	1	1	1
CO_2	1	1	1	1	1
H_2O	1	1	1	1	1
NO	1	1	1	1	1
NO_2	1.8	1	1	1	1
N_2	1	1	1	1	1
O_2	1	1	1	1	1
SO_2	3	1	1	1	1
NH_3	3	1	1	1	1
HNO_3	3	1	1	1	1
HCl	3	1	1	1	1
HF	3	1	1	1	1
Ag^{+}	3.5	200	1,667,000	1	1
Al^{+3}	3.5	200	1,667,000	1	1
As^{+3}	3.5	200	1,667,000	1	1
B^{+3}	3.5	200	1,667,000	1	1
Ba^{+2}	3.5	200	1,667,000	1	1
Bi^{+3}	3.5	200	1,667,000	1	1
Ca^{+2}	3.5	200	1,667,000	1	1
Cd^{+2}	3.5	200	1,667,000	1	1
Ce^{+3}	3.5	200	1,667,000	1	1
Cl^{-}	3.5	200	1,667,000	1	1
CO_3^{-2}	3	200	1,667,000	1	1
Cr^{+3}	3.5	200	1,667,000	1	1
Cu^{+2}	3.5	200	1,667,000	1	1
F^{-}	3.5	200	1,667,000	1	1
Fe^{+3}	3.5	200	1,667,000	1	1
H^{+}	---	---	---	---	---
H_2O	---	---	---	---	---
Hg^{+2}	1	1	1	1	1
K^{+}	3.5	200	1,667,000	1	1
La^{+3}	3.5	200	1,667,000	1	1
Li^{+}	3.5	200	1,667,000	1	1
Mg^{+2}	3.5	200	1,667,000	1	1

Table 2.13-4 Process Vessel Vent System Inorganic Constituent Decontamination Factors

PVP/PVV Equipment	Caustic Scrubber[a,b]	HEME[a,b]	HEPA[b,c,d]	Thermal Oxidizer Unit[a,b]	Carbon Bed Adsorber[a,b]
Mn^{+3}	3.5	200	1,667,000	1	1
Na^{+}	3.5	200	1,667,000	1	1
Ni^{+2}	3.5	200	1,667,000	1	1
NO_2^{-}	3.5	200	1,667,000	1	1
NO_3^{-}	3.5	200	1,667,000	1	1
O^{-2}	3.5	200	1,667,000	1	1
OH^{-}	3.5	200	1,667,000	1	1
P^{+5}	3.5	200	1,667,000	1	1
Pb^{+2}	3.5	200	1,667,000	1	1
Pd^{+2}	3.5	200	1,667,000	1	1
PO_4^{-3}	3.5	200	1,667,000	1	1
S^{+6}	3.5	200	1,667,000	1	1
Si^{+4}	3.5	200	1,667,000	1	1
SO_4^{-2}	3.5	200	1,667,000	1	1
Sr^{+2}	3.5	200	1,667,000	1	1
Ti^{+4}	3.5	200	1,667,000	1	1
Zn^{+2}	3.5	200	1,667,000	1	1
Zr^{+4}	3.5	200	1,667,000	1	1

a Reference 24590-WTP-RPT-PO-03-008, Rev 2, *Integrated Emissions Baseline Report for the Hanford Tank Waste Treatment and Immobilization Plant.*

b $DF = \frac{\text{mass of constituent in incoming stream}}{\text{mass of constituent in exiting stream}}$

c Reference 24590-WTP-MKC-50-00002, Rev1, *Process Equipment Decontamination Factor Curves*

d Reported DFs are for the combined primary and secondary HEPAs.

Table 2.13-5 Process Vessel Vent System Organic Constituent Decontamination Factors

PVP/PVV Equipment	Caustic Scrubber[b,c]	HEME[b,c]	HEPA[c,d,g]	Thermal Oxidizer Unit[c,e]	Carbon Bed Adsorber[c,f]
Constituent[a]					
Oxalate	3	200	1,667,000	10	15.61
Formate	3	200	1,667,000	10	15.61
Acetate	3	200	1,667,000	10	15.61
Glycolate	3	200	1,667,000	10	15.61
IDA	3	200	1,667,000	10	15.61
Citrate	3	200	1,667,000	10	15.61
HEDTA	3	200	1,667,000	10	15.61
EDTA	3	200	1,667,000	10	15.61

a The organic constituents listed in this table are applicable to the baseline flowsheet. Additional organics for the purpose of emissions estimates are listed in Section 7. DFs for organics are considered average values.

b Reference 24590-WTP-RPT-PO-03-008, Rev 2, *Integrated Emissions Baseline Report for the Hanford Tank Waste Treatment and Immobilization Plant*.

c $DF = \frac{\text{mass of constituent in incoming stream}}{\text{mass of constituent in exiting stream}}$

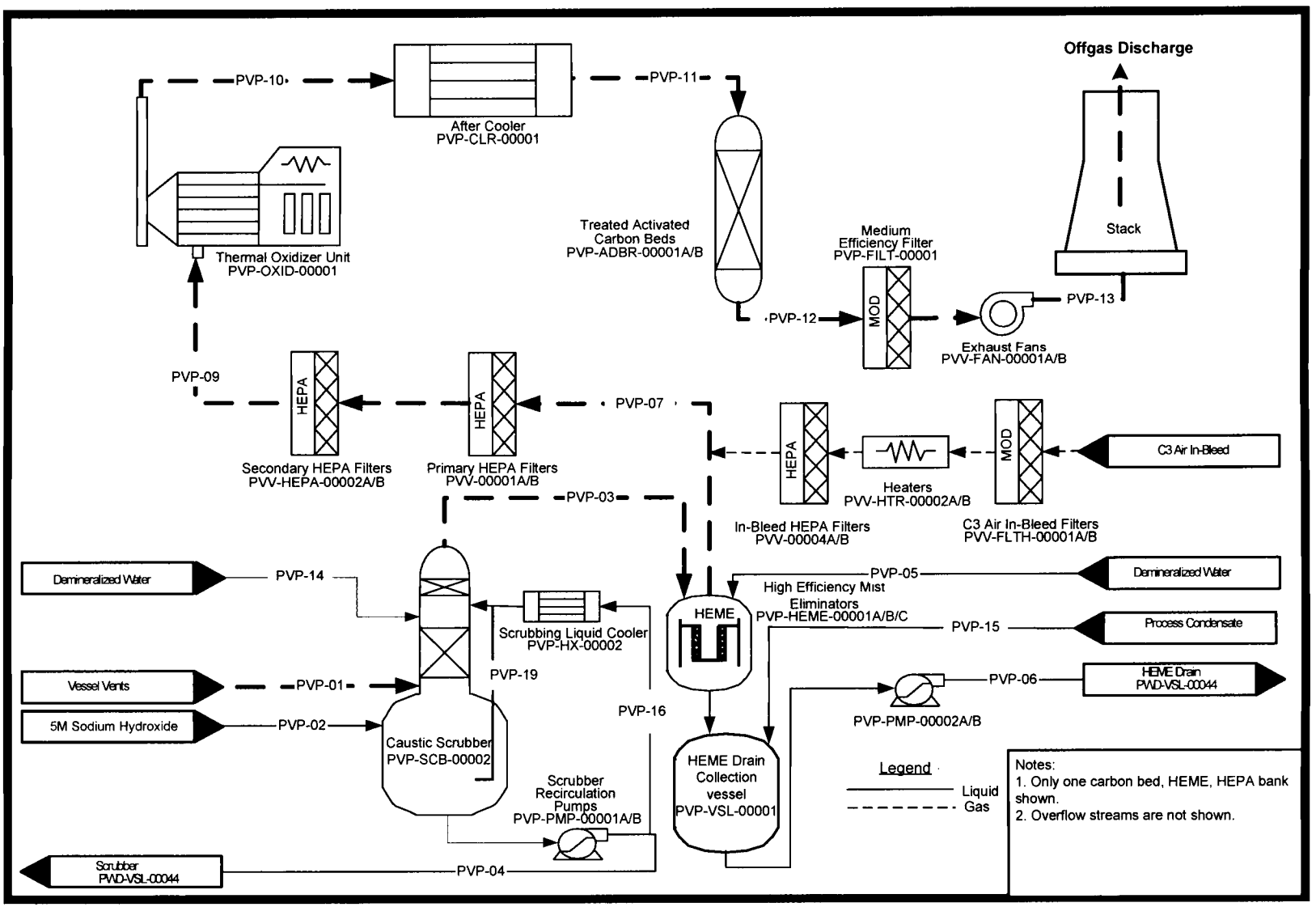
d Reference 24590-WTP-MKC-50-00002, Rev1, *Process Equipment Decontamination Factor Curves*.

e Reference CCN 044540, *Organic DFs Across Abatement Equipment in the PVP System*.

f Reference 24590-PTF-M0C-PVP-00003, Rev B, *Sizing of Pretreatment Vessel Vent Carbon Adsorbers (PVP-ADBR-00001A/B)*. This acronym was fixed via ECCN against the referenced calc.

g Reported DFs are for the combined primary and secondary HEPAs

Figure 2.13-1 Pretreatment Vessel Vent Process System



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2.14 System PJV: Pretreatment Pulse Jet Ventilation

2.14.1 Function and Requirements

The function of the Pretreatment (PT) Facility pulse jet ventilation system (PJV) is to collect the exhausts from reverse flow diverter (RFD) and pulse jet mixer (PJM) fluidic devices and provide abatement of contaminants from the exhaust streams before atmospheric release.

The WTP *Statement of Work* (DE-AC27-01RV14136), Facility Specification, Section C.7(a)(12) states that the WTP shall be designed to:

> *Comply with applicable Federal, State, and local requirements, including environmental permits and other regulatory approvals and authorizations. The WTP shall be designed and operated to ensure that exposure to the maximally exposed off site individual (non-acute) is ALARA but not more than 1.5 mrem per year and hazardous organic emissions are ALARA but not more than 0.375 tons per year from components regulated under 40 CFR 265 subpart AA.*

In accordance with Washington Administrative Code, the PJV system must demonstrate best available control technology (BACT), best available radionuclide control technology (BARCT), and best available control technology for toxic air pollutants (T-BACT) (24590-WTP-DB-ENG-01-001).

The PJV system is important to safety for confinement and containment of the exhausts up to the primary high-efficiency particulate air (HEPA) filters. The PJV system also has a credited safety function to treat RFD/PJM exhausts prior to release to the environment.

2.14.2 Process Description

The PJV system consists of the RFD and PJM exhaust collection headers and emission control equipment. PJMs are used throughout the PT Facility to resuspend solids in process vessels in order to facilitate sampling of the vessel contents and to disperse mixtures prior to sampling vessel contents. The number of PJMs inside a vessel varies with the size of the vessel and the amount of solids in the process liquid. RFDs are used for liquid transfers and for collecting samples of process liquids. RFDs and PJMs are both fluidic devices that use compressed air to draw process liquid into a charge vessel and then force the liquid back out to achieve the desired operation. The charge vessel is inside the process vessel and is connected to a pair of jet pumps: one for the suction phase and one for the drive phase. Compressed air flows through the jet pump pair and exhausts to the PJV system. Cycle times for the suction and drive phases can vary from less than 1 min to more than 10 min. At the end of the drive cycle, residual compressed air in the charge vessel flows through the jet pump pair and into the PJV system. Exhausts from the jet pump pair and the charge vessels are collected into subheaders and routed to the emission abatement equipment for removal of entrained aerosols and radiolytic particulates. The equipment that makes up the PJV system is shown schematically in Figure 2.14-1 (24590-PTF-M6-PJV-00001, -00002, -00004. and -00007 through -00012), and includes the following:

- Three 50 % capacity demisters: 2 operating and 1 standby.
- Two parallel trains of in-bleed air filters: 1 operating and 1 standby. Each train consists of a moderate-efficiency air filter, electric heater, and HEPA filter.
- Seven parallel primary stage HEPA filters: 5 operating and 2 standby.

- Six parallel secondary stage HEPA filters: 4 operating and 2 standby.
- Three 50 % capacity exhaust fans: 2 operating and one standby.

The RFD/PJM exhausts flow to two of the operating demisters. Each demister contains fiber elements to remove particles greater than 1 micron in diameter. As the exhaust stream flows through the demister elements, aerosols and particulates accumulate on the elements. When the differential pressure across a demister indicates the element needs servicing, the demister is taken offline and the elements are washed with demineralized water. The demister wash water flows by gravity to PWD-VSL-00033. After flushing with demineralized water, the demister is then put back in service. If the differential pressure remains elevated, the demister is taken offline and the filter elements replaced. The demisters are in the common filter cave, where the elements can be changed out remotely using the manipulator and filter cave operating crane. The RFD and PJM exhausts cannot bypass the demisters.

Two parallel hot air in-bleed trains, one operating and one standby, are provided to prevent condensation on the downstream primary and secondary HEPA filters. Air from the R3/C3 area is heated and mixed with the RFD/PJM exhaust exiting the demister to ensure that the relative humidity of the combined stream is below 70 %. Each hot air in-bleed train consists of a medium-efficiency air filter, an electric heater, and a HEPA filter. The hot air in-bleed HEPA filter prevents cross-contamination from backflow of RFD/PJM exhaust into the R3/C3 ventilation area. The hot air in-bleed filters and heaters are in an R3/C3 area. The hot air in-bleed air is mixed with the RFD/PJM exhaust in the R5/C5 area, downstream of the demisters.

HEPA filtration provides the primary means of removing radioactive particulates from the PJV system and is divided into primary and secondary stages. The primary stage consists of seven parallel HEPA filters: five operating and two standby. The secondary stage consists of six parallel HEPA filters: four operating and two standby. The primary HEPA filters are in the common filter cave with the demisters and are remotely changeable. Secondary HEPA filters are in an R3/C3 area, which permits hands-on filter removal and replacement. Filter changeout for the primary HEPA filters is determined by monitoring the common differential pressure across the entire primary HEPA filter system and comparing it with the flow rate through each individual primary HEPA filter. Determining the filter changeout for the secondary HEPA filters is performed in the same manner as the primary HEPA filters. Isolation valves are provided at the inlet and outlet of each primary and secondary stage. Inlet and outlet isolation valves for the primary HEPA filters are in the filter cave and are remotely operated by the manipulator. Isolation valves at the inlet and outlet of the secondary HEPA filters are in an R3/C3 area, which permits hands-on operation.

The motive force to draw the RFD/PJM exhaust and hot in-bleed air through the collection header and the emission abatement equipment is supplied by two exhaust fans downstream of the primary and secondary HEPA filters. The exhaust fans discharge to the PT Facility stack (PT-S4), which is continuously monitored by the stack discharge monitoring system (SDJ). Two exhaust fans operate during normal operation of the PJV system while a third fan is in standby. During loss of site power, none of the exhaust fans will operate.

2.14.3 Basis

2.14.3.1 Separation of RFD and PJM Vents from Vessel Vents

Alternative configurations meeting the requirements for both hydrogen mitigation in process vessels and treatment of contaminants using BACT were evaluated for the PT vessel ventilation system

(RPT-W375PT-PR00010). Each of the four initial alternatives under consideration combined vessel purge air offgases with exhausts from RFD and PJM fluidic devices. A fifth alternative was later developed, which separated the RFD and PJM exhausts from the purge air offgases. The primary advantages for separating the two offgas systems include the following:

- The RFD and PJM exhausts have very high flow rates and relatively low emissions compared to the vessel purge air offgases, which have much lower flow rates and higher concentrations of contaminants. Sizing of downstream emission abatement equipment can be significantly reduced when the volumetric flow rate of the purge air offgases is minimized, especially for items such as the caustic scrubber, thermal oxidizer, and carbon bed adsorbers.
- The RFD and PJM exhausts are pulsing streams, in contrast with the nearly constant flow rates of the vessel purge air stream. Separating the highly pulsating streams from the vessel vent system allows better pressure control and increased reliability at the passive purge air inlets.

2.14.3.2 RFD and PJM Exhaust

Both RFDs and PJMs use compressed air to raise and lower process fluid in a charge vessel located inside the process vessel. One end of the charge vessel is connected to a jet pump pair that provides the suction for drawing liquid up into the charge vessel and the drive for forcing the liquid back out of the charge vessel. At the end of the drive phase, residual compressed air in the charge vessel passes back up through the jet pump pair and into the PJV header. Significant quantities of compressed air are exhausted through the jet pump pair during the suction and vent phases. Cycle times can vary from less than 1 min to more than 10 min. Liquid aerosols and radiolytic particulates will become entrained in the exhausts from the jet pump pair and the charge vessel. The vaporization of organics will be negligible, considering the small volume of the charge vessels and short cycle time. The evaporation of organics contributed by an RFD has been estimated in a study, *Rates of Emission of Dissolved Constituents from Waste Liquid Operability and Safety Evaluation, Tasks 3 and 4* (24590-SC-HXYG-0055-01A, FAI/01-28), to be less than 0.1 % of that contributed by the vessel vent system for the vessel containing the RFD.

An aerosol entrainment factor is used to calculate the amount of process liquid in the charge vessel that is transferred to the exhaust stream. The aerosol entrainment factor is derived from the British Nuclear Fuels Limited (BNFL) release fraction (RF) of 1×10^{-10} for exhausts from RFDs (BNFL, Inc. 1996). The RF is defined as the ratio of activity or mass per unit volume in the exhaust to the activity or mass per unit volume in the process liquid. The total aerosol release (mass flow rate) is equal to the RF multiplied by the ratio of the volumetric flow rate of the RFD/PJM exhaust to the volumetric flow rate of the process liquid multiplied by the mass flow rate of the process liquid.

Equation 2.14-1

$$RF = \frac{\text{activity or mass / volume in air}}{\text{activity or mass / volume in liquid}}$$

$$RF = \frac{\text{lbs(i) / ft}^3 \text{ vent}}{\text{lbs(i) / ft}^3 \text{ liquid}}$$

where:

(i) is constituent of interest

For RF in terms of flow rate:

Equation 2.14-2

$$RF = \frac{\text{lbs(i) / min in vent}}{\text{lbs(i) / min in liquid}} \times \frac{\text{ft}^3\text{ / min liquid}}{\text{ft}^3\text{ / min vent}}$$

where:

RF is 1×10^{-10} for RFD exhaust
lb(i)/min in liquid is known
ft^3/min liquid is known
ft^3/min vent is known (fixed value of RFD/PJM exhaust)

$$\therefore \text{ lb(i) / min in vent is RF} \times \text{lb(i) / min in liquid} \times \frac{\text{ft}^3\text{ / min vent}}{\text{ft}^3\text{ / min liquid}}$$

The following operating logic is assumed in the flowsheet for the RFDs and PJMs (24590-PTF-M6C-PJV-00001):

- When mixing is required, all PJMs in each process vessel operate simultaneously.
- For HLP-VSL-00027A, HLP-VSL-00027B, and HLP-VSL-00028, 100 % of the PJMs will run if the volume in the vessel is above the heel volume. If the vessel is at heel volume, one-third of the PJMs will run.
- Table 2.14-1 contains the average flowrate of air for a PJM or RFD cycle from *Line Sizing Calculation for Pulse Jet Ventilation System Exhaust Lines* (24590-PTF-M6C-PJV-00001).
- For vessels with sample hold points, mixing starts when the vessel is full, prior to sample analysis. Upon the completion of sample analysis, the PJMs will continue to mix until the vessel reaches heel volume.
- For vessels without sample hold points, mixing will start when the vessel reaches discharge level and the PJMs will continue to mix until the vessel reaches heel volume.
- For HLP-VSL-00022, the PJMs will run 100 % of the time as long as the volume in the vessel is above heel volume.
- Only one RFD per process vessel operates at any one time.
- The RFDs operate during the transfer of waste from one vessel to another.

2.14.3.3 Selection of Air Emission Control Equipment

The air emission control equipment alternative recommendation for the PJV system consists of high-efficiency mist eliminators (HEME) and HEPA filters to remove liquid aerosols and radiolytic particulates (RPT-W375PT-PR00010). Additional equipment for the removal of volatile organic compounds could not be justified for the small quantities of organics expected in the exhaust stream. The arrangement of the emission control equipment is depicted in Figure 2.14-1. The demisters and HEPAs each have decontamination factors (DF) for contaminants of concern. The DF is a measure of removal

efficiency and is the ratio of the amount of a constituent entering the equipment to the amount of the constituent exiting the equipment. DFs for the demisters and HEPA filters are presented by constituent in Table 2.14-2 for radionuclides, Table 2.14-3 for inorganic constituents, and Table 2.14-4 for organic constituents.

2.14.3.4 Demister

The demister removes aerosols and particulates greater than 1 micron from the RFD/PJM exhaust stream. The baseline DFs applied to the demister for particulates and vapors are 5 and 1, respectively (24590-WTP-RPT-PO-03-008, Table 13).

2.14.3.5 High-Efficiency Particulate Air Filters

The primary purpose of HEPA filtration is to remove radioactive particles to achieve compliance with environmental and dose limits. HEPA filters generally have a minimum removal efficiency of 99.97 % (DF of 3333) for 0.3 micron particles (RPT-W375PT-PR00010). The baseline DFs applied to the HEPAs for particulates are 1,667,000 based on a first stage removal efficiency of 99.97 % (DF of 3333) and, for conservatism, a second stage removal efficiency of 99.8 % (DF of 500).

2.14.3.6 C3 Hot Air In-Bleed Heaters

The required relative humidity of the RFD/PJM exhaust entering the HEPA filters is below 70 % (24590-PTF-3YD-PJV-00001). Hot air is bled into the vent air upstream of the HEPA filters to aid in lowering the relative humidity of the offgas stream. The air in-bleed will dilute the vent air stream with a maximum of 4000 scfm of air from the C3 area. The heater in the air in-bleed assembly will heat the air to 225 °F (107 °C). The electrical load required by the heaters is determined from the difference in enthalpy between the entering and exiting C3 air.

2.14.3.7 C3 Hot Air In-Bleed Filters

The C3 air is passed through a medium efficiency filter before entering the heater to remove dust to reduce fouling of the heater. Following the heater, the air is passed through a HEPA filter before being injected into the pulse jet ventilation stream.

2.14.4 References

24590-PTF-3YD-PJV-00001, Rev 0, *System Description for the PTF Pulse Jet Ventilation System (PJV).*

24590-PTF-M6-PJV-00001, Rev 3, *P&ID Pulse Jet Ventilation System Air Racks to Demisters.*

24590-PTF-M6-PJV-00002, Rev 3, *P&ID - PTF Pulse Jet Ventilation System Inlet Header to Demister Outlet.*

24590-PTF-M6-PJV-00004, Rev 3, *P&ID-PTF Pulse Jet Ventilation System Utility Services Plant Wash Rack.*

24590-PTF-M6-PJV-00007, Rev 1, *P&ID - PTF Pulse Jet Ventilation System Primary HEPA Exhaust Filters Elevation 56 FT-0 IN.*

24590-PTF-M6-PJV-00008, Rev 1, *P&ID - PTF Pulse Jet Ventilation System Primary HEPA Exhaust Filters Elevation 56FT-0IN.*

24590-PTF-M6-PJV-00009, Rev 1, *P&ID - PTF Pulse Jet Ventilation System Secondary HEPA Exhaust Filters Elevation 77FT-0IN.*

24590-PTF-M6-PJV-00010, Rev 1, *P&ID - PTF Pulse Jet Ventilation System Secondary HEPA Exhaust Filters Elevation 77FT-0IN.*

24590-PTF-M6-PJV-00011, Rev 1, *P&ID - PTF Pulse Jet Ventilation System In-Bleed Hot Air Injection System Elevation 56FT-0IN.*

24590-PTF-M6-PJV-00012, Rev 1, *P&ID - PTF Pulse Jet Ventilation System Exhaust Fans.*

24590-PTF-M6C-PJV-00001, Rev J, *Line Sizing Calculation for Pulse Jet Ventilation System Exhaust Lines.*

24590-PTF-M6C-PSA-00001, Rev 00H, *PTF Plant Service Air Line Sizing.*

24590-SC-HXYG-0055-01A, *Rates of Emissions of Dissolved Constituents from Waste Liquid Operability and Safety Evaluation, Tasks 3 and 4.* Fauske and Associates, Inc., Burr Ridge, IL.

24590-WTP-3YD-50-00003, Rev 00B, *System Description for Pulse Jet Mixer and Sparger Mixing Subsystems.*

24590-WTP-3YD-PSA-00001, Rev 1, *System Description for Waste Treatment Plant Service Air (PSA), Not Important to Safety.*

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

24590-WTP-MKC-50-00002, Rev 1, *Process Equipment Decontamination Factor Curves.*

24590-WTP-RPT-PO-03-008, Rev 2, *Integrated Emissions Baseline Report for the Hanford Tank Waste Treatment and Immobilization Plant.*

BNFL, Inc. 1996. *Release Fraction Databook*, Datasheet 1.4, Rev 1.2, Issue Number 96. May 1996.

CCN 025674, *Replacement of RFD/PJM Header HEMEs with Lower Efficiency Mist Eliminators.* 28 November 2001.

CCN 050737, *Resolve Input Assumptions of Pretreatment PJV Header Sizing.* 15 January 2003.

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

SCT-M0SRLE60-00-145-00020, Rev 00B, *Report - Transport of Waste Simulants in PJM Vent Lines.*

Table 2.14-1 RFD and PJM Exhaust Flow Rates

Process Vessel No.	Process Vessel Name	RFD Exhaust Flow Rate (scfm)[a,b,c]	Average PJM Exhaust Flow Rate (scfm)[a,b]	RFD/PJM Exhaust Stream No.
FRP-VSL-00002A	Waste Feed Receipt	0	2964	FRP05
FRP-VSL-00002B	Waste Feed Receipt	0	2964	FRP05
FRP-VSL-00002C	Waste Feed Receipt	0	2964	FRP05
FRP-VSL-00002D	Waste Feed Receipt	0	2964	FRP05
FEP-VSL-00017A	Waste Feed Evaporator Feed	0	1784	FEP05
FEP-VSL-00017B	Waste Feed Evaporator Feed	0	1784	FEP05
HLP-VSL-00022	HLW Feed Receipt	0	4428	HLP08
HLP-VSL-00027A	HLW Lag Storage	0	1304	HLP05
HLP-VSL-00027B	HLW Lag Storage	0	1304	HLP05
HLP-VSL-00028	HLW Lag Storage & Feed Blending	0	1296	HLP05
UFP-VSL-00001A	Ultrafiltration Feed Preparation	0	2940	UFP21
UFP-VSL-00001B	Ultrafiltration Feed Preparation	0	2940	UFP21
UFP-VSL-00002A	Ultrafiltration Feed	0	948	UFP12
UFP-VSL-00002B	Ultrafiltration Feed	0	948	UFP12
UFP-VSL-00062A	Ultrafilter Permeate	248	606	UFP36
UFP-VSL-00062B	Ultrafilter Permeate	249	606	UFP36
UFP-VSL-00062C	Ultrafilter Permeate	252	606	UFP36
CXP-VSL-00004	Cs IX Caustic Rinse Collection	78	129	CXP16
CNP-VSL-00003	Cs Eluate Contingency Storage	18	436	CNP18
CNP-VSL-00004	Cs Evaporator Recovered Nitric Acid	9	496	CNP18
CXP-VSL-00026A	Treated LAW Collection	0	594	CXP25
CXP-VSL-00026B	Treated LAW Collection	0	594	CXP25
CXP-VSL-00026C	Treated LAW Collection	0	594	CXP25
RDP-VSL-00002A	Spent Resin Slurry	0	552	RDP02
RDP-VSL-00002B	Spent Resin Slurry	0	552	RDP02
RDP-VSL-00002C	Spent Resin Slurry	0	552	RDP02
TLP-VSL-00009A	LAW SBS Condensate Receipt	0	704	TLP09
TLP-VSL-00009B	LAW SBS Condensate Receipt	0	704	TLP09
TCP-VSL-00001	Treated LAW Concentrate Storage	0	952	TCP02
PWD-VSL-00015	Acid/Alkaline Effluent	211	952	PWD04
PWD-VSL-00016	Acid/Alkaline Effluent	186	952	PWD04
PWD-VSL-00033	Ultimate Overflow	371	1104	PWD08
PWD-VSL-00043	HLW Effluent Transfer	388	1104	PWD10
PWD-VSL-00044	Plant Wash	169	1856	PWD06

a Reference temperature and pressure for standard conditions are 60 °F and 1 atm.

b PJM and RFD exhaust flow rate is from 24590-PTF-M6C-PJV-00001, Rev J.

c Vessels may have multiple RFDs. Only the RFD with the maximum flow rate is shown.

Table 2.14-2 Pulse Jet Ventilation System Radionuclide Decontamination Factors

PJV Equipment	Demister[a,c]	HEPA[b,c,d]
Constituent		
^{241}Am	5	1,667,000
^{14}C	1	1
^{60}Co	5	1,667,000
^{243}Cm	5	1,667,000
^{244}Cm	5	1,667,000
^{137}Cs	5	1,667,000
^{152}Eu	5	1,667,000
^{154}Eu	5	1,667,000
^{155}Eu	5	1,667,000
^{3}H	1	1
^{129}I	1	1
^{63}Ni	5	1,667,000
^{237}Np	5	1,667,000
^{238}Pu	5	1,667,000
^{239}Pu	5	1,667,000
^{240}Pu	5	1,667,000
^{241}Pu	5	1,667,000
^{125}Sb	5	1,667,000
^{151}Sm	5	1,667,000
^{126}Sn	5	1,667,000
^{90}Sr	5	1,667,000
^{99}Tc	5	1,667,000
^{232}Th	5	1,667,000
^{233}U	5	1,667,000
^{234}U	5	1,667,000
^{235}U	5	1,667,000
^{236}U	5	1,667,000
^{238}U	5	1,667,000

a Reference CCN 025674, *Replacement of RFD/PJM Header HEMEs with Lower Efficiency Mist Eliminators.*

b Reference 24590-WTP-MKC-50-00002, Rev 1, *Process Equipment Decontamination Factor Curves.*

c $DF = \frac{\text{activity of constituent in incoming stream}}{\text{activity of constituent in exiting stream}}$

d Reported DFs are for the combined primary and secondary HEPAs

Table 2.14-3 Pulse Jet Ventilation System Inorganic Constituent Decontamination Factors

PJV Equipment	Demister[a,c]	HEPA[b,c,d]
Constituent		
CO	1	1
CO_2	1	1
H_2O	1	1
NO	1	1
NO_2	1	1
N_2	1	1
O_2	1	1
SO_2	1	1
NH_3	1	1
HNO_3	1	1
HCl	1	1
HF	1	1
Ag^{+}	5	1,667,000
Al^{+3}	5	1,667,000
As^{+3}	5	1,667,000
B^{+3}	5	1,667,000
Ba^{+2}	5	1,667,000
Bi^{+3}	5	1,667,000
$C_2O_4^{-2}$	5	1,667,000
Ca^{+2}	5	1,667,000
Cd^{+2}	5	1,667,000
Ce^{+3}	5	1,667,000
Cl^{-}	5	1,667,000
CO_3^{-2}	5	1,667,000
Cr^{+3}	5	1,667,000
Cu^{+2}	5	1,667,000
F^{-}	5	1,667,000
Fe^{+3}	5	1,667,000
H^{+}	---	---
H_2O	---	---
Hg^{+2}	1	1
K^{+}	5	1,667,000

Table 2.14-3 Pulse Jet Ventilation System Inorganic Constituent Decontamination Factors

PJV Equipment	Demister[a,c]	HEPA[b,c,d]
Constituent		
La^{+3}	5	1,667,000
Li^{+}	5	1,667,000
Mg^{+2}	5	1,667,000
Mn^{+3}	5	1,667,000
Na^{+}	5	1,667,000
Ni^{+2}	5	1,667,000
NO_2^{-}	5	1,667,000
NO_3^{-}	5	1,667,000
O^{-2}	5	1,667,000
OH^{-}	5	1,667,000
P^{+5}	5	1,667,000
Pb^{+2}	5	1,667,000
Pd^{+2}	5	1,667,000
PO_4^{-3}	5	1,667,000
S^{+6}	5	1,667,000
Si^{+4}	5	1,667,000
SO_4^{-2}	5	1,667,000
Sr^{+2}	5	1,667,000
Ti^{+4}	5	1,667,000
Zn^{+2}	5	1,667,000
Zr^{+4}	5	1,667,000

a Reference CCN 025674, *Replacement of RFD/PJM Header HEMEs with Lower Efficiency Mist Eliminators.*

b Reference 24590-WTP-MKC-50-00002, Rev 1, *Process Equipment Decontamination Factor Curves.*

c $DF = \frac{\text{mass of constituent in incoming stream}}{\text{mass of constituent in exiting stream}}$

d Reported DFs are for the combined primary and secondary HEPAs

Table 2.14-4 Pulse Jet Ventilation System Organic Constituent Decontamination Factors

PJV Equipment	Demister[b,d]	HEPA[c,d,g]
Constituent[a]		
Oxalate	5	1,667,000
Formate	5	1,667,000
Acetate	5	1,667,000
Glycolate	5	1,667,000
IDA	5	1,667,000
Citrate	5	1,667,000
HEDTA	5	1,667,000
EDTA	5	1,667,000
PPG[e]	5	1,667,000
PDMS[f]	5	1,667,000

a The organic constituents listed in this table are applicable to the baseline flowsheet. Additional organics for the purpose of emissions estimates are listed in Section 7. DFs for organics are considered average values.

b Reference CCN 025674, *Replacement of RFD/PJM Header HEMEs with Lower Efficiency Mist Eliminators.*

c Reference 24590-WTP-MKC-50-00002, Rev 1, *Process Equipment Decontamination Factor Curves.*

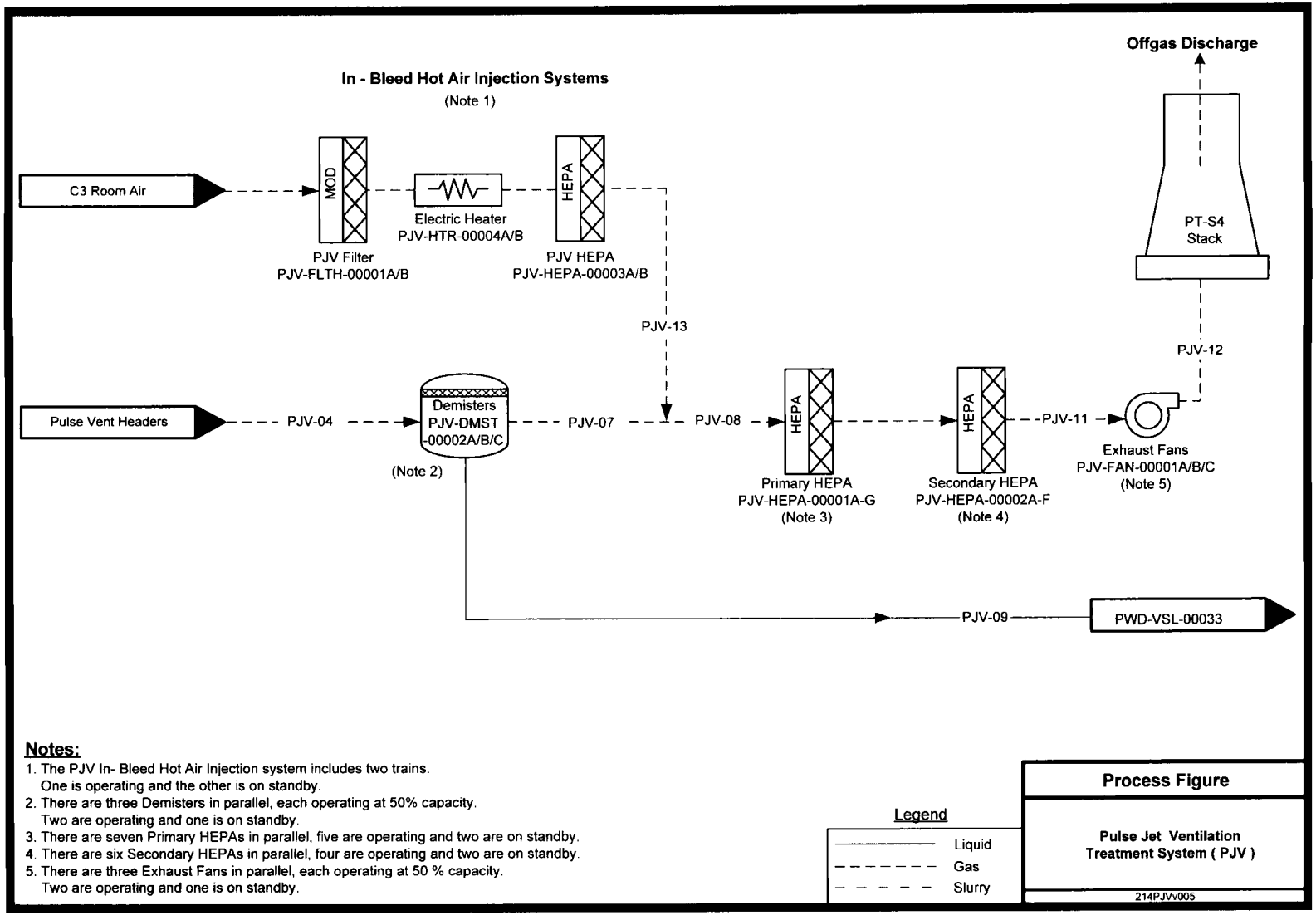
d $DF = \frac{\text{mass of constituent in incoming stream}}{\text{mass of constituent in exiting stream}}$

e Polypropylene glycol (antifoam constituent).

f Polydimethylsiloxane (antifoam constituent).

g Reported DFs are for the combined primary and secondary HEPAs

Figure 2.14-1 Pretreatment Pulse Jet Ventilation Flow Diagram



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2.15 System PWD: Plant Wash and Disposal System

2.15.1 Function and Requirements

The primary function of the plant wash and disposal system (PWD) is to collect process recycle streams and wash solutions for storage, neutralization, and transfer to evaporation systems. The effluent includes plant wash from Pretreatment (PT) Facility vessels and sumps, acidic and alkaline effluent generated during pretreatment operations, wash permeate from ultrafiltration, and line flushes from transfers. The PWD system also receives plant wash from the High-Level Waste (HLW) and Low-Activity Waste (LAW) Facilities and HLW submerged bed scrubber (SBS) condensate, as well as wastes from the Analytical Laboratory (Lab) (24590-PTF-3YD-PWD-00001). Certain vessels with the PWD designator are discussed further in Section 2.17, Pretreatment Liquid Waste Disposal Systems.

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), specifies the following requirements which are applicable to the PWD system:

> *C.7(a)(5) - Functional Design Requirements: Disposition all secondary wastes in accordance with ICD requirements; secondary wastes are identified in Section C.9, Interface Control Documents and Standard 6, Product Qualification, Characterization and Certification.*
>
> *C.7(d)(1)(vi) - Liquid Effluent Treatment: This operation collects the WTP effluent and provides for the discharge to the Hanford Site 200 East Area Effluent Treatment Facility (ETF) or allows for the re-use of liquid effluent as process water with the WTP. Treated effluent will be transferred to Hanford Site ETF as required.*

2.15.2 Process Description

The PWD system (as discussed in this section) is composed of five vessels with dedicated influent lines. These five vessels are PWD-VSL-00015, PWD-VSL-00016, PWD-VSL-00033, PWD-VSL-00043, and PWD-VSL-00044. The primary purpose of the PWD system vessels is to collect solutions that will be recycled to the waste feed evaporation process system (FEP). Vessels PWD-VSL-00044, PWD-VSL-00015, and PWD-VSL-00016 are able to add sodium hydroxide (19 M NaOH) to adjust the pH. Once the proper pH is achieved, the waste will be sent to FEP-VSL-00017A/B for concentration and separation of excess water.

The major sources of plant wash, acidic effluent, and alkaline effluent are HLW offgas condensate and purge solution, ultrafilter wash solution, ultrafilter cleaning solution, ion exchange displacement effluents, cesium nitric acid recovery process system (CNP) evaporator condensate, PT offgas condensate and purge solutions, vessel wash solutions, and transfer line flushes. Solids (e.g., $Al[OH]_3$, $Na_2C_2O_4$) may precipitate after the above solutions are blended. A brief description of each vessel in the system along with its normal mode of operation follows.

Further details of the PWD system are included in the process flow diagrams (24590-PTF-M5-V17T-00022001 and-00022002), the system description (24590-PTF-3YD-PWD-00001), and the piping and instrumentation diagrams (24590-PTF-M6-PWD-00002001, -00002002, -00003, -00057, and -00058) for these systems.

2.15.2.1 PWD-VSL-00015 and PWD-VSL-00016 Acidic/Alkaline Effluent Vessel

The primary functions of the acidic/alkaline effluent vessels (PWD-VSL-00015 and PWD-VSL-00016) are to receive miscellaneous acidic and alkaline effluent from various sources in the PT Facility, adjust pH to 12 or above using 19 M NaOH, provide buffer storage for these waste streams until they can be processed in the FEP system, and transfer pH adjusted effluent to the FEP system. Pulse jet mixers (PJM) are used for mixing, while both reverse flow diverters (RFD) and steam jets are used to transfer fluid from the vessels.

PWD-VSL-00015 and PWD-VSL-00016 are designed to be interchangeable; however, according to the process data for vessel design (24590-PTF-MVC-PWD-00031), each of these vessels will be used for a specific function. PWD-VSL-00016 will be used to receive nitric acid from ultrafiltration cleaning and also to receive the ultrafilter permeate from the washing step, which will use the hydroxyl concentration in the permeate for neutralization. PWD-VSL-00015 will serve as a support vessel and will receive other effluents while its counterpart is sampling and discharging to FEP-VSL-00017A/B. Vessel overflows are routed to the ultimate overflow vessel (PWD-VSL-00033).

2.15.2.2 Vessel Feeds to PWD-VSL-00015

During normal operations, vessel PWD-VSL-00015 receives acidic/alkaline effluent from UFP-VSL-00002A/B, caustic rinse from CXP-IXC-00001/2/3/4, process condensate from cesium evaporator condensers, and ultrafiltration solids wash from the ultrafiltration loops. During non-routine operations it receives emergency CXP eluate.

2.15.2.2.1 Vessel Feeds to PWD-VSL-00016

During normal operations vessel PWD-VSL-00016 receives acid cleaning effluent from UFP-VSL-00002A/B, ultrafiltration solids wash from the ultrafiltration loops, and flush fluid/washings from the CRP-BULGE-00001. During non-routine operations it receives caustic rinse from CXP-IXC-00001/2/3/4 and plant washing from PWD-VSL-00044.

2.15.2.2.2 Normal Operating Mode and Design Parameters for PWD-VSL-00015 / 00016

The acidic alkaline effluent vessels receive multiple effluents from the PT systems. The streams are pH-adjusted if necessary and sent to FEP-VSL-00017A/B. The normal operating range of this vessel will be 77 ° to 133 °F, while the minimum temperature is 59 °F and the maximum is assumed to be a boiling vessel, set at 230 °F. The maximum specific gravity of a stream entering the vessel is 1.5 (19 M NaOH). However, the nominal specific gravity of the vessel contents is expected to range between 1.0 and 1.1. A maximum limit of 1.3 is set for transfers from the plant wash vessel reaching a 5 M Na concentration and 5 wt % solids. The maximum viscosity is 3 cP and may be as low as 1 cP (24590-WTP-RPT-ENG-07-007).

2.15.2.3 PWD-VSL-00033 Ultimate Overflow Vessel

The ultimate overflow vessel, PWD-VSL-00033, collects, holds, and transfers effluent to the plant wash vessel, PWD-VSL-00044. The main source of input to PWD-VSL-00033 is collection of drain back from the ultrafiltration loop. Under normal operations the ultrafiltration loop will be flushed back to UFP-VSL-00002A/B prior to draining contents to PWD-VSL-00033. The vessel is required to maintain a heel sufficient to dilute non-Newtonian waste to make it Newtonian, and the vessel shall be continuously mixed whenever a transfer of non-Newtonian waste is taking place.

The other use for PWD-VSL-00033 is to collect overflows. Various vessels in the PT Facility are designed to overflow to this vessel, if necessary. The ultimate overflow vessel will receive any overflows and have the capability to transfer them to PWD-VSL-00044 when permitted to do so. This design fulfills WAC 173-303, *Dangerous Wastes Regulations*, by providing containment between an overflowing vessel and the cell floor (24590-PTF-MVC-PWD-00029), where the cell floor shall be considered the last overflow.

The primary functions of the ultimate overflow vessel, PWD-VSL-00033, are to collect gravity drains and line flushes, collect overflows and meet the requirements of the WAC 173-303, store effluent until plant wash vessel PWD-VSL-00044 is ready to receive transfers, and transfer effluent to plant wash vessel PWD-VSL-00044 (24590-WTP-RPT-ENG-07-007).

2.15.2.3.1 Vessel Feeds to PWD-VSL-00033

Vessel PWD-VSL-00033 will not receive any material during normal operations except for drains and flushes from the ultrafilter loops. The remaining vessel feeds are non-routine feeds consisting primarily of C3 and C5 area overflow and drain headers. These non-routine transfers are not included in the vessel batch sizing. An illustration of the collection system/vessel feeds to PWD-VSL-00033 is provided on 24590-PTF-M6-PWD-00002002.

2.15.2.3.2 Normal Operating Mode and Design Parameters for PWD-VSL-00033

The ultimate overflow vessel can receive overflows from any vessel in the facility, but will maintain a dilution heel to ensure undissolved solids concentrations cannot exceed 5 wt %. The maximum specific gravity of the vessel contents will be set at a solution of 5 wt % solids in a 5 M Na solution. The specific gravity for this solution is set at a maximum of 1.3 and will range between 1.0 and 1.3. The vessel contents temperature will be a nominal 59 to 140 °F, the normal operating temperature of the facility. The maximum temperature of the vessel is conservatively set at 230 °F, the boiling point temperature of the vessel contents. The viscosity of the vessel contents will range from 1 to 5 cP (24590-WTP-RPT-ENG-07-007).

2.15.2.4 PWD-VSL-00043 HLW Effluent Transfer Vessel

The HLW effluent transfer vessel, PWD-VSL-00043, is located at the lowest level of the PT Facility and shares a common overflow with PWD-VSL-00033. PWD-VSL-00043 accommodates gravity drains from the HLW Facility. These gravity drains primarily include drain back from waste transfer lines, HLW plant wash effluent transfer, and transfer of HLW SBS purge.

Waste Transfer Line Drain Back - A 3-in. line is used to transfer waste feed from the Hanford Tank Farms to the WTP waste feed receipt vessels. Each time this line is used, it will be flushed forward to the feed receipt vessels. When flushing has been completed, the remaining flush water is drained out of the line to vessel PWD-VSL-00043.

HLW/PT Facility Interface - Transfer line drains and flushes are received into PWD-VSL-00043 after every transfer from PT to the HLW Facility. The transfer line is flushed and then drained to PWD-VSL-00043. This combination will result in three line volumes being received in PWD-VSL-00043 after every transfer.

HLW Bed Scrubber Purge - HLW SBS purge and plant wash effluent are routinely transferred to PWD-VSL-00043 through RLD-BRKPT-00007/9.

The primary functions of the HLW effluent transfer vessel, PWD-VSL-00043, are to receive HLW SBS purge and plant wash effluent from the HLW Facility via gravity drain and underground piping, receive line drains from the HLW/PT interface and from the Hanford Tank Farms/PT interface, hold effluent until plant wash vessel PWD-VSL-00044 is ready to receive transfer, and transfer effluent to plant wash vessel PWD-VSL-00044.

2.15.2.4.1 Vessel Feeds to PWD-VSL-00043

During normal operations, vessel PWD-VSL-00043 receives material from the following: HLW effluent, transfer line drain following a transfer from PT to HLW, and transfer line drain from the Hanford Tank Farms/PT interface. During non-routine operations, vessel PWD-VSL-00043 receives material from overflow from PWD-VSL-00033, transfers from PWD-SUMP-00040, and drains from C5/R5 cells.

An illustration of the collection system/vessel feeds to PWD-VSL-00043 is provided on 24590-PTF-M6-PWD-00002002.

2.15.2.4.2 Normal Operating Mode and Design Parameters for PWD-VSL-00043

The HLW effluent transfer vessel receives effluents from the HLW Facility, required to have a pH of 8 and a maximum undissolved solids content of 5 wt %. The normal operating temperature of this vessel will range from 59 to 167 °F, with 230 °F conservatively set as the maximum temperature the vessel may reach in the event that contents boil. The maximum specific gravity of the vessel contents is set at 1.3, based on a 5 M Na feed with 5 wt % solids, and will nominally be 1.1 to 1.3 with a minimum of 1.0. The viscosity of the vessel contents will range from 1 to 3 cP.

2.15.2.5 PWD-VSL-00044 Plant Wash Vessel

The primary functions of the plant wash vessel, PWD-VSL-00044, are to receive effluent from various sources in the PT Facility, adjust pH to 12 or above using 19 M NaOH, transfer the pH adjusted effluent to the FEP system, and to provide safe and interim storage of the waste streams. Overflows are routed to the ultimate overflow vessel, PWD-VSL-00033. The vessel has PJMs for mixing and uses RFDs to transfer wastes from the vessel. A steam ejector can transfer the vessel heel. The PJMs provide a uniform mixture during neutralization and ensure hydrogen is not retained in the waste (24590-PTF-MVC-PWD-00028).

2.15.2.5.1 Vessel Feeds to PWD-VSL-00044

During normal operations, PWD-VSL-00044 receives recycle material and acidic waste from PWD-VSL-00043, material from PWD-VSL-00033 high-efficiency mist eliminator drains via vessel PVP-VSL-00001, and spent scrubber solution from PVP-SCB-00002.

During non-routine operations, PWD-VSL-00044 receives plant wash from the following: interior surfaces of PT vessels via vessel-emptying ejectors discharging to plant wash, PT cell walls, equipment exterior surfaces, and cell cladding via sump-emptying ejectors. Vessel PWD-VSL-00044 also receives plant waste from contaminated effluent from RLD-VSL-00003 (LAW Facility) and laboratory wastes.

During off-normal operations, PWD-VSL-00044 receives high-activity condensate from the high- and low-pressure condensate headers and off-specification waste from RLD-VSL-00017A/B.

2.15.2.5.2 Normal Operating Mode and Design Parameters for PWD-VSL-00044

Since PWD-VSL-00044 is larger than PWD-VSL-00033 and PWD-VSL-00043, the contents can be further diluted prior to transfer, if required. Therefore, the fluid range is set between 0 and 2 M sodium molarity and between 0 and 2 wt % solids. After neutralization, the target pH is ~12, prior to transfer to the FEP system for processing. Therefore, the fluid range after neutralization is set between 0.01 and 3 M sodium molarity and between 0 and 2 wt % solids (ignoring dilution effect on solids concentration). Based on these targets, the specific gravity of the vessel contents will range from 1.0 to 1.3 and the viscosity will range between 1 and 3 cP. The temperature range of this vessel will be 59 to 163 °F (based on receipt of ejector transfers) and the maximum temperature the vessel may achieve is 230 °F, the boiling temperature of the vessel contents (24590-WTP-RPT-ENG-07-007).

2.15.2.5.3 PWD-VSL-00044 Neutralization

To prevent adding more caustic than needed, it was determined that the waste can be transferred to the PWD vessels from HLW vitrification as partially neutralized. After the normal operating level of the vessel is reached, the pH will be measured and adjusted, if necessary. To avoid forming aluminosilicate solids, the pH in vessel PWD-VSL-00044 is increased to a minimum of 12 before transfers are made to the feed evaporator (CCN 018446C).

2.15.3 Transfer Line Flushes and Flush Volumes

The transfer line flush volumes and frequencies used in the flowsheet are found in Appendix F. The bases for the hydrogen in piping and ancillary vessels and line plugging flush volumes are documented in *Transmittal of Flush Requirements Following Transfers* (CCN 141492) and *Changes to Flush Requirements-Transfers from UFP to HLP* (CCN 142760). The flushes being transferred directly to PWD-VSL-00033 and PWD-VSL-00043 (24590-WTP-RPT-PO-07-001) are as follows:

Sequential Transfer Route Number	Destination of Flush	Volume per Flush (gallons)
HLP-22	PWD-VSL-00033	30.71
HLP-26	PWD-VSL-00033	30.71
HLP-13	PWD-VSL-00043	923.91
HLP-15	PWD-VSL-00043	905.64
UFP-13	PWD-VSL-00043	2507.49
UFP-18	PWD-VSL-00043	2630.84
HLW-51	PWD-VSL-00043	119.09

Four vessels, not included in the flowsheets, were added to the PWD system to provide additional flexibility to address line plugging and restrictions. These vessels, PWD-VSL-00148, PWD-VSL-00149, PWD-VSL-00150, and PWD-VSL-00151, are capable of delivering 2 M NaOH, 2M HNO_3, and demineralized water to the PT wash racks if needed (24590-PTF-M5-V17T-00026).

2.15.4 Vessel Sizes

The vessel volumes used in the flowsheet are found in Appendix B. Vessel volumes are based on the following vessel sizing calculations:

Vessel	Calculation
PWD-VSL-00015/16	24590-PTF-MVC-PWD-00018
PWD-VSL-00033	24590-PTF-MVC-PWD-00021
PWD-VSL-00043	24590-PTF-MVC-PWD-00022
PWD-VSL-00044	24590-PTF-MVC-PWD-00020
PWD-VSL-00148 through 00150	24590-PTF-MVC-PWD-00065

2.15.5 Ongoing Work and Potential Changes

No further ongoing work or potential changes have been identified for the PWD system discussed in this section.

2.15.6 References

24590-PTF-3YD-PWD-00001, Rev 2, *System Description for Plant Wash and Disposal System (PWD) and Radioactive Liquid Waste Disposal System (RLD).*

24590-PTF-M5-V17T-00022001, Rev 2, *Process Flow Diagram Pretreatment Effluent Plant Wash & Disposal System (PWD).*

24590-PTF-M5-V17T-00022002, Rev 2, *Process Flow Diagram Pretreatment Effluent Plant Wash & Disposal System (PWD).*

24590-PTF-M5-V17T-00026, Rev 0, *Process Flow Diagram Pretreatment Process Reagents PWD Flush System.*

24590-PTF-M6-PWD-00002001, Rev 0, *P&ID - PTF Plant Wash & Disposal System Effluent Collection PWD-VSL-00044.*

24590-PTF-M6-PWD-00002002, Rev 0, *P&ID - PTF Plant Wash & Disposal System Effluent Collection PWD-VSL-00043.*

24590-PTF-M6-PWD-00003, Rev 4, *P&ID PTF Plant Wash & Disposal System Effluent Collection PWD-VSL-00015 and 00016 (Q).*

24590-PTF-M6-PWD-00057, Rev 4, *P&ID PTF Plant Wash & Disposal System Underground Transfer Lines.*

24590-PTF-M6-PWD-00058, Rev 4, *P&ID PTF Plant Wash & Disposal System Underground Transfer Lines.*

24590-PTF-MVC-PWD-00028, Rev 00A, *Process Data for Plant Wash Vessel 24590-PTF-MV-PWD-VSL-00044.*

24590-PTF-MVC-PWD-00029, Rev 00A, *Process Data for Ultimate Overflow Vessel 24590-PTF-MV-PWD-VSL-00033 and HLW Effluent Transfer Vessel 24590-PTF-MV-PWD-VSL-00043.*

24590-PTF-MVC-PWD-00065, Rev A, *Vessel Sizing for PWD-VSL-00148 Through 151.*

24590-WTP-RPT-ENG-07-007, Rev 0, *Process Stream Properties.*

24590-WTP-RPT-PO-07-001, Rev 0, *External Flowsheet Review Team Issue P2 Dynamic Flowsheet Modeling Results.*

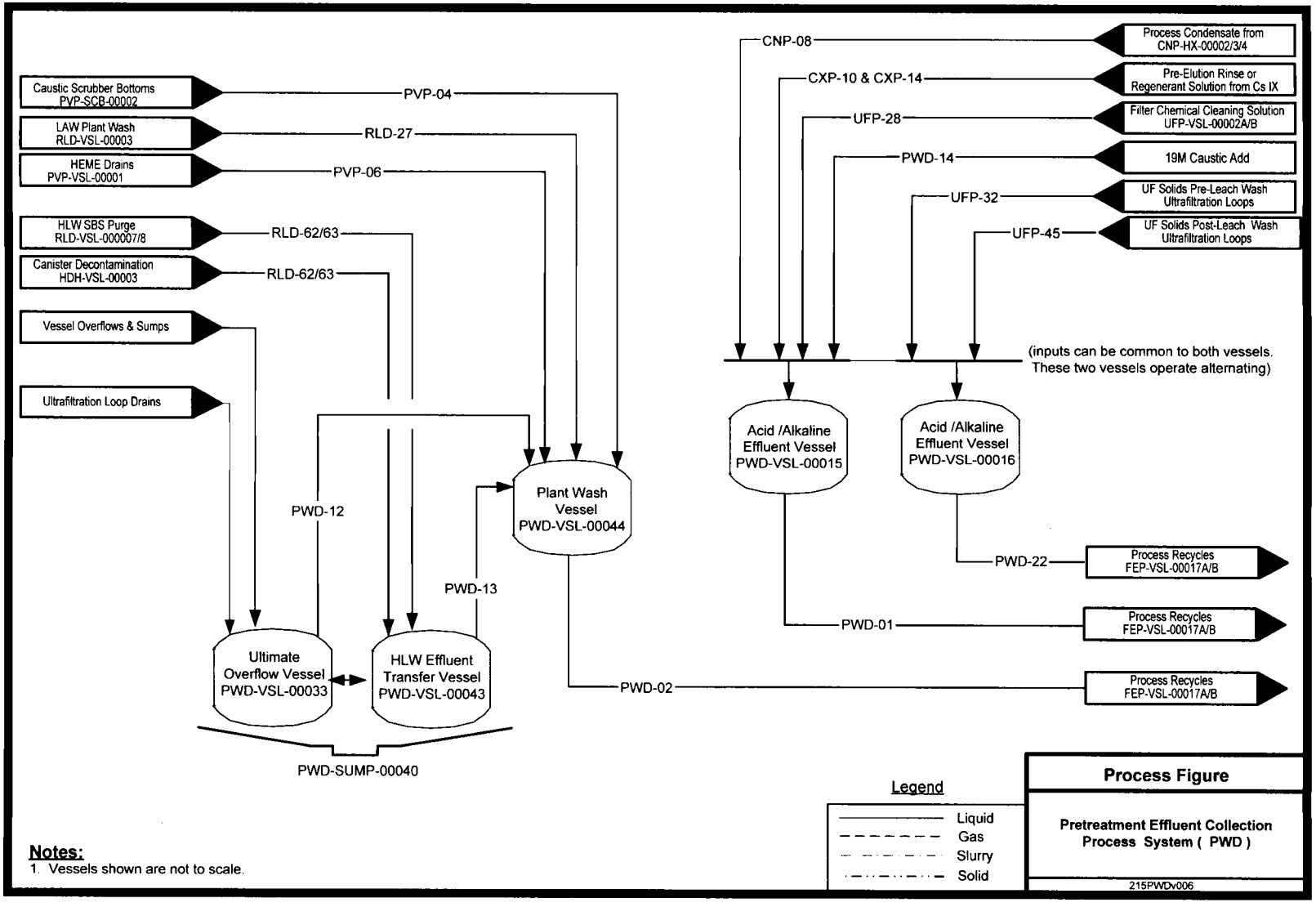
CCN 018446C, *Discuss Neutralization of Vitrification Effluents Recycled to Pretreatment.* 13 February 2001.

CCN 141492, *Transmittal of Flush Requirements Following Transfers.* 1 August 2006.

CCN 142760, *Changes to Flush Requirements - Transfers from UFP TO HLP.* 26 September 2006.

DOE. 2000. *DOE Statement of Work,* DE-AC27-01RV14136, US Department of Energy, Office of River Protection, Richland, WA, as amended (Modification No. A143).

Figure 2.15-1 Major Vessels in the PWD System



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2.16 Pretreatment Interfaces with WTP Reagents and Demineralized Water (NAR, STR, SPR, SHR, AFR, and DIW)

2.16.1 Introduction

The WTP reagent system receives, stores, and distributes chemical reagents for use within the WTP. The pretreatment system of reagents obtains these reagents from the Balance of Facilities (BOF) wet chemical storage facility (WCSF). The BOF distributes nitric acid (HNO_3, designated as NAR), sodium hydroxide (NaOH, designated as SHR) sodium permanganate ($NaMnO_4$, designated as SPR), and strontium nitrate ($Sr(NO_3)_2$, designated as STR) to the Pretreatment (PT) Facility at various concentrations (24590-WTP-3YD-SHR-00001). Antifoaming agent (designated as AFR) is also delivered to the PT Facility. Some of the reagents are distributed through bulges to the receiving vessels; others are piped through pressurized headers to the receiving vessels. Control valves and flow totalizers are used to ensure that the proper quantity of reagent is delivered to the receiving vessel. The demineralized water system (DIW) is a separate system from the WTP reagents. The feed water for the DIW system is supplied by the process service water system (PSW) (24590-WTP-3YD-DIW-00001). The DIW system receives, stores, and distributes reverse osmosis quality of water for use within the WTP. The DIW is primarily used for process operations, line flushes, vessel washes, and make-up water for reagent dilutions (24590-WTP-3YD-DIW-00001).

2.16.2 Process Description

The interfaces between the BOF and the PT Facility system are shown on the process flow diagrams *Process Flow Diagram Pretreatment Process Reagents System NAR* (24590-PTF-M5-V17T-00023001), *Process Flow Diagram Pretreatment Process Reagents System SHR* (24590-PTF-M5-V17T-00023002), and *Process Flow Diagram Pretreatment Process Reagents System AFR / STR / SPR* (24590-PTF-M5-V17T-00023004). The interfaces between the DIW system and PT are shown on *Process Flow Diagram Pretreatment Process Reagents System DIW* (24590-PTF-M5-V17T-00023003). The *System Description for the WTP Reagents (SHR, NAR, AFR, SPR, and STR)* (24590-WTP-3YD-SHR-00001) provides additional details and specific process descriptions for each of the chemical reagents.

The following subsections describe the chemical reagents used in the PT Facility and the destination points.

2.16.2.1 Nitric Acid Reagent (NAR)

Nitric acid from the BOF wet chemical storage facility is supplied as 0.5 M, 2 M, and variable 5-8 M solutions for distribution to the PT Facility end users.

A portion of the 0.5 M solutions of nitric acid is stored in the 0.5 M nitric acid head vessel (NAR-VSL-00007) will be used by the cesium ion exchange process system (CXP) in the event of emergency elution. This vessel should be filled to a minimum volume of 12,500 gal, which is equivalent to two column elutions. The 0.5 M solutions of nitric acid are also transferred from BOF in batches to cesium ion exchange reagent vessel (CXP-VSL-00005) as necessary.

The 2 M nitric acid solution is transferred through the pretreatment ultrafiltration process system (UFP) bulge or direct distribution as follows:

- UFP feed vessels (UFP-VSL-00002A/B)
- As a cleaning agent for the UFP pulse pots (UFP-PP-00001A/2A/3A and UFP-PP-00001B/2B/3B)
- Utility stations (PWD-VSL-00148/00149/00150/00151) and plant wash racks

Variable 5-8 M nitric acid is pumped from BOF to the nitric acid evaporator feed breakpot, CNP-BRKPT-00002. This is used as the initial charge acid for CNP-EVAP-00001.

2.16.2.2 Strontium Nitrate Reagent (STR)

The 1 M of STR is only required for processing Envelope C waste, and is batched by direct distribution to the ultrafiltration feed preparation vessels (UFP-VSL-00001A/B) from BOF.

2.16.2.3 Sodium Permanganate Reagent (SPR)

The 1 M of SPR is used for processing Envelope C waste and for oxidative leaching of chromium, and is batched by direct distribution to the UFP vessels (UFP-VSL-00001A/B and UFP-VSL-00002A/B).

2.16.2.4 Sodium Hydroxide Reagent (SHR)

NaOH from the BOF wet chemical storage facility is supplied as 19 M, 5 M, 2 M, 0.5 M, and 0.1 M solutions for distribution to the PTF end users.

The 19 M NaOH is transferred from BOF to the following vessels in the PT Facility:

- Ultrafiltration feed preparation vessels (UFP-VSL-00001A/B)
- Ultrafiltration feed vessels (UFP-VSL-00002A/B)
- Plant wash vessel (PWD-VSL-00044)
- Alkaline/Acidic effluent vessels (PWD-VSL-00015/16)
- Ultrafiltration permeate vessels (UFP-VSL-00062A/B/C)
- Waste feed evaporator feed vessel (FEP-VSL-00017A/B)
- HLW lag storage vessel (HLP-VSL-00027B)
- HLW feed blend vessel (HLP-VSL-00028)

The 5 M NaOH is transferred from BOF to:

- LAW submerged bed scrubber condensate receipt vessels (TLP-VSL-00009A/B)
- Vessel vent caustic scrubber (PVP-SCB-00002)

The 2 M NaOH is transferred from BOF to:

- Ultrafiltration feed vessels (UFP-VSL-00002A/B)
- Ultrafiltration pulse pots (UFP-PP-00001A/B and UFP-PP-00002A/B and UFP-PP-00003A/B)
- Cesium resin addition vessel (CRP-VSL-00001)
- Utility stations (PWD-VSL-00148/00149/00150/00151) and plant wash racks
- Ion Exchange Column regeneration via CRP-BULGE-00001

The 0.5 M sodium hydroxide transfers are made from BOF to the following locations in PT:

- CXP reagent vessel (CXP-VSL-00005)

The 0.1 M NaOH vessel (SHR-VSL-00001) stores the 0.1 M NaOH solution for Ion Exchange Column emergency elution. SHR-VSL-00001 has a batch volume of 2400 gal for emergency elution of the CXP columns.

The 0.1 M NaOH is transferred from BOF directly to the following locations in PT:

- CXP reagent vessel (CXP-VSL-00005)
- UFP power flush via SHR-VSL-00002/3

2.16.2.5 Antifoam Reagent (AFR)

Drums of concentrated antifoaming agent (AFA) are delivered directly to the antifoam reagent vessel (AFR-TK-00001) in the PT Facility. The reagent is diluted with demineralized water to a 3:1 water-to-antifoam ratio, agitated for homogeneity, and then transferred in batches to the vessels containing non-Newtonian fluids to reduce foaming caused by sparging. Antifoam is also transferred to the ultrafiltration feed preparation (UFP) vessels as needed to reduce foaming. The target concentration of antifoam in the waste feed evaporation process (FEP) and treated LAW evaporation process is 500 ppm. The target concentration for non-Newtonian vessels and UFP vessels is 350 ppm (SCT-M0SRLE60-00-99-00009). The antifoam and caustic delivery systems to non-Newtonian vessels provide the means for controlling waste characteristics within the range for acceptable pulse jet mixer (PJM) and sparger performance. Therefore, AFR and SHR delivery systems are to be continually operable in order to provide AFA as needed to the applicable vessels. Antifoam is made available to the following PT vessels:

- FEP-SEP-00001A/B
- TLP-SEP-00001
- UFP-VSL-00001A/B
- UFP-VSL-00002A/B
- HLP-VSL-00027A/B
- HLP-VSL-00028

2.16.2.6 Demineralized Water

The DIW is transferred in batches from the demineralized water head vessel (DIW-VSL-00001) through a reagent bulge or through direct distribution to the following vessels in the PT Facility (24590-PTF-M5-V17T-00023003):

- CRP-VSL-00001
- CXP-IXC-00001/2/3/4
- PVP-SCB-00002
- PVP-HEME-00001A/B/C
- PJV-DMST-00002A/B/C

- PCW-VSL-00001
- CHW-VSL-00023
- RDP-PMP-00008A/B
- CXP-VSL-00005
- RDP-VSL-00002A/B/C
- CRP-VSL-00001
- Spent resin dewatering container
- PWD-VSL-00148/149/150/151
- CNP-VSL-00004
- AFR-TK-00001
- Plant wash racks
- Autosamplers
- Reverse flow diverter/pulse jet mixer air racks

DIW can only be transferred to one location at a time, excluding all high-efficiency mist eliminators (HEME), since flow to HEMEs is continuous. If multiple requests are made, the operator will prioritize the transfers. An emergency elution of the IX columns takes precedence over other transfers.

2.16.3 Ongoing Work and Potential Changes

All system descriptions have had a full update.

2.16.4 References

24590-PTF-M5-V17T-00023001, Rev 2, *Process Flow Diagram Pretreatment Process Reagents System NAR.*

24590-PTF-M5-V17T-00023002, Rev 2, *Process Flow Diagram Pretreatment Process Reagents System SHR.*

24590-PTF-M5-V17T-00023003, Rev 2, *Process Flow Diagram Pretreatment Process Reagents System DIW.*

24590-PTF-M5-V17T-00023004, Rev 2, *Process Flow Diagram Pretreatment Process Reagents System AFR / STR / SPR.*

24590-WTP-3YD-DIW-00001, Rev 1, *System Description for the Waste Treatment Plant Demineralized Water System (DIW).*

24590-WTP-3YD-SHR-00001, Rev 2, *System Description for the WTP Reagents (SHR, NAR, AFR, SPR, and STR).*

SCT-M0SRLE60-00-99-00009, Rev 00A, *Ultrafiltration Process (UFP) Caustic Leaching Antifoam Performance.*

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2.17 System RLD: Pretreatment Radioactive Liquid Waste Disposal Systems

2.17.1 Function and Requirements

The primary functions of the Radioactive Liquid Waste Disposal System (RLD) and the Nonradioactive Liquid Waste Disposal System (NLD) are to collect and store liquid effluents, which receives transfers from the Pretreatment (PT) Facility (Plant Wash and Disposal System [PWD]) for disposal offsite. The RLD system collects process condensates for use as process wash and dilution streams and collects low active and potentially hazardous waste from the WTP for disposal to the Liquid Effluent Retention Facility/Effluent Treatment Facility (LERF/ETF). The NLD system collects uncontaminated, nondangerous waste for transfer to the Balance of Facilities (BOF) (NLD-TK-00001) and ultimately to the Treated Effluent Disposal Facility (TEDF).

Requirements for effluent collection are in the WTP *Statement of Work* (DE-AC27-01RV14136), Facility Specification, Section C.7.

> *C.7 (a) Functional Design Requirements (5):*
>
> *Disposition all secondary wastes in accordance with ICD requirements; secondary wastes are identified in Section C.9, Interface Control Documents and Standard 6, Product Qualification, Characterization and Certification.*
>
> *C.7 (d)(1)(vi) Liquid Effluent Treatment:*
>
> *This operation collects the WTP effluent and provides for the discharge to the Hanford Site 200 East Area Effluent Treatment Facility (ETF) or allows for the re-use of liquid effluent as process water with the WTP. Treated effluent will be transferred to the Hanford Site ETF as required.*

24590-WTP-ICD-MG-01-005, *ICD 05 - Interface Control Document for Nonradioactive, Nondangerous Liquid Effluents*, was developed to govern nonradioactive, nondangerous liquid effluent systems and operations, including transfer to the Tank Farm Contractor. ICD-05 calls for nonradioactive, nondangerous liquid effluents to be directed to TEDF. Discharges must meet TEDF requirements. Discharges to TEDF have a maximum instantaneous discharge rate of 500 gpm, a maximum temperature of 100 °F, and a maximum pressure of 100 psig.

24590-WTP-ICD-MG-01-006, *ICD 06 - Interface Control Document for Radioactive, Dangerous Liquid Effluents*, was developed to govern radioactive, dangerous liquid effluent systems and operations. ICD-06 calls for radioactive, dangerous liquid discharges from the PT Facility to be directed to LERF/ETF. Discharges to LERF/ETF shall be consistent with the treatability envelope (WMH-9758688). Discharges to LERF/ETF have a maximum instantaneous discharge rate of 170 gpm, a maximum temperature of 49°C (120 °F), and a maximum discharge pressure of 100 psig.

2.17.2 Process Description

The PWD system consists of two vessels (PWD-VSL-00045/46), and the system RLD-10 is composed of four vessels with dedicated influent lines.

The process flow diagrams for the RLD system are 24590-PTF-M5-V17T-00022003 and -00022004, referenced in Appendix A. The piping and instrumentation diagrams for C2 (PWD-VSL-00045) and C3

(PWD-VSL-00046) floor drain collection vessels are in 24590-PTF-M6-PWD-00040 through -00044 and 24590-PTF-M6-PWD-00060001, -00062, and -00063001. Vessel PWD-VSL-00046 transfers to RLD-VSL-00017A/B.

The vessels connected to the NLD system are primarily concerned with the collection of C2 drains that may be discharged to TEDF. The RLD vessels/tanks are primarily concerned with the collection of solutions that may be discharged to LERF/ETF. Most of the wastes received into the RLD system are process condensates from evaporators, caustic waste from the low-activity waste (LAW) caustic scrubber, spent reagents from the resin addition process, and C3 drains. A brief description of each vessel/tank in the system along with its normal mode of operation follows.

2.17.2.1 PWD-VSL-00045 C2 Drain Vessel

This vessel receives floor drains from all C2 areas in the PT Facility. When the maximum waste level is reached, the pumps begin recirculation and sampling mode. If no radioactive contamination is found, the waste is sent to NLD-TK-00001 in the BOF (see 24590-PTF-M6-PWD-00042, Note #15). Otherwise, the waste is transferred to RLD-VSL-00017A/B. Waste transferred to NLD-TK-00001 must meet the TEDF requirement.

The TEDF discharge limits are noted in Table 2.17-1.

2.17.2.2 PWD-VSL-00046 C3 Drain Vessel

This vessel receives floor drains from all C3 areas and C2 areas where the vessel in the room contains a Dangerous Waste Permit liquid that can overflow to the floor in the PT Facility. When the maximum waste level is reached, pumping begins recirculation and initiates its sampling mode. After sampling, the waste is transferred to RLD-VSL-00017A/B.

2.17.2.3 RLD-VSL-00017A/B Alkaline Effluent Vessels

The main influents to these vessels are LAW caustic scrubber waste and spent reagents from the Cesium Resin Addition Process System (CRP). The wastewater influent is expected to have low levels of contamination. The vessels can be operated so that one vessel can be online receiving waste while the other is isolated waiting for sample results. Based on sampling results, the wastewater can be transferred to RLD-TK-00006B with RLD-TK-00006A as its backup, or to TLP-VSL-00009A/B.

The alkaline effluent vessels may also receive the effluent process reagent sumps and C3 drains. These are off-normal flows and are not included in the flowsheet.

2.17.2.4 RLD-TK-00006A/B Process Condensate Tanks

Although these tanks are functionally identical, they operate differently. RLD-TK-00006A receives wastes that are monitored online. These wastes include process condensate from FEP-VSL-00005 and TLP-VSL-00002 (the feed and LAW evaporators). After the wastes are sampled, the low-activity effluent waste is discharged as process condensate for recycle, with the excess sent to RLD-TK-00006B. RLD-TK-00006B also receives batches of discharge from RLD-VSL-00017A/B. The waste accumulated in RLD-TK-00006B is transferred to LERF/ETF if it meets the LERF/ETF treatability envelope. The LERF/ETF radiological acceptance criteria are included in Table 2.17-2.

The tanks may receive process water. This water is used to fill the tank to a level so that there is sufficient fluid to provide recycle effluents when needed. This is used during startup and off-normal conditions.

2.17.3 Basis

The basis for operation of the RLD system is to provide a collection point for radioactive liquid wastes to be transferred from the WTP to LERF/ETF. RLD needs to provide enough space to be able to receive process condensate from the Waste Feed Evaporation Process System (FEP) and Treated LAW Evaporation Process System (TLP) evaporators and alkaline, radioactive effluents from the PT and LAW Facilities. There also needs to be enough liquid stored in the RLD system to be recycled back to the Ultrafiltration Process System (UFP) for use in dilution or solids washing.

2.17.3.1 Alkaline Effluent Vessels

The alkaline effluent vessels (RLD-VSL-00017A/B) receive the LAW caustic scrubber blowdown and the spent reagents from the CRP. These vessels operate on a fill/empty cycle. One vessel will be filling while the other is being sampled, emptied, or in standby mode. The vessel in fill mode will receive all transfers until it has received the full batch volume of 20,000 gal. The vessel is then held for 8.4 hr for sampling to ensure the LERF/ETF treatability envelope requirements are met (see CCN 254099, *Laboratory Sample Turnaround Times*). If the effluent does not meet the treatability envelope requirements, then the waste will be transferred to TLP-VSL-00009A/B to be evaporated. If the effluent meets the treatability envelope, then the sampled waste will be transferred through RLD-PMP-00005A/B to RLD-TK-00006B. During transfers 270 gpm (max.) is recirculated through a jet mixer to provide mixing of the vessel and 130 gpm (max.) is transferred; maximum flow rate for RLD-PMP-00005A/B is 400 gpm (24590-PTF-MVC-RLD-00014). The vessel volumes used in the flowsheet may be found in Appendix B and are based on the vessel sizing calculation (24590-PTF-MVC-RLD-00005).

2.17.3.2 Process Condensate Tank (RLD-TK-00006A)

The process condensate tanks are functionally identical but are operated differently under normal operation. RLD-TK-00006A is normally used to collect process condensate from the waste feed evaporator and the treated LAW evaporator. The condensate is recycled back through the process condensate header for use in the pretreatment process with the excess being transferred to RLD-TK-00006B.

Condensate is received into RLD-TK-00006A from the evaporator condensate collection vessels (FEP-VSL-00005 and TLP-VSL-00002). RLD-TK-00006A should always be able to receive process condensate so that the evaporator process does not back up.

Process condensate is recycled for use in the process (e.g., ultrafiltration dilution and solids washing). The process condensate header is charged with effluent from RLD-TK-00006A through RLD-PMP-00014A/B. The header is designed to supply up to 250 gpm (max.) of process condensate (24590-PTF-MVC-RLD-00014). The primary user of process condensate recycles is the ultrafiltration process. RLD-TK-00006A needs to maintain a sufficient volume of condensate to supply ultrafiltration's demand.

Both mixing of RLD-TK-00006A and transfers to RLD-TK-00006B are accomplished by pumps RLD-PMP-00012A/B. These pumps have suction lines from both process condensate tanks and discharge lines through jet mixers at the bottom of each tank. Each pump is rated for a flowrate of 1000 gpm (max.) (24590-PTF-MVC-RLD-00014).

The tank volumes used in the flowsheet may be found in Appendix B and are based on the tank sizing calculation (24590-PTF-MTC-RLD-00001).

2.17.3.3 Process Condensate Tank (RLD-TK-00006B)

The process condensate tanks are functionally identical but are operated differently under normal operation. RLD-TK-00006B receives excess process condensate (condensate left after recycle demands are met) from RLD-TK-00006A and low-active effluents from RLD-VSL-00017A/B. The tank fills until a full batch (265,000 gal) has been received (24590-PTF-M5-V17T-00022004).

The tank contents are held for sampling (when necessary) as identified in the *Integrated Sampling and Analysis Requirements Document* (ISARD) (24590-WTP-PL-PR-04-0001). In accordance with ICD-06, the first 5 to 10 batches of waste sent to LERF/ETF will be sampled. If the waste complies with the treatability envelope, then the frequency of sampling may be reduced to once every 10th batch. Hence, the samples from the first 5 to 10 batches are hold point samples. In addition, the lines to LERF/ETF are equipped with monitors for pressure, radioactivity, conductivity, temperature, and pH to ensure LERF/ETF compliance. Waste that does not meet the LERF/ETF treatability envelope is transferred, at 170 gpm (24590-PTF-3YD-PWD-00001), back to the LAW SBS condensate receipt vessel (TLP-VSL-00009A/B) for reprocessing. Waste that meets the LERF/ETF treatability envelope is transferred through pump RLD-PMP-00011A/B, which has a maximum rating of 190 gpm (24590-PTF-MVC-RLD-00014). Transfer is complete once the full batch volume has been transferred.

The tank volumes used in the flowsheet may be found in Appendix B and are based on the tank sizing calculation (24590-PTF-MTC-RLD-00001).

2.17.4 Ongoing Work and Potential Changes

There is ongoing work to add the HPS Secondary Loop, which will add condensate to RLD-TK-00006A/B. CCN 225792 calculates a continuous blowdown load of about 8 gpm and an intermittent blowdown load of about 333 gallons per day. This will be finalized when the selected vendor provides the design to the Project. The blowdown load from this system is not currently modeled.

2.17.5 References

24590-PTF-3YD-PWD-00001, Rev 2, *System Description for Plant Wash and Disposal System (PWD) and Radioactive Liquid Waste Disposal System (RLD).*

24590-PTF-M5-V17T-00022003, Rev 2, *Process Flow Diagram Pretreatment Radioactive Liquid Disposal System RLD, Sheet 3 of 4.*

24590-PTF-M5-V17T-00022004, Rev 2, *Process Flow Diagram Pretreatment Radioactive Liquid Disposal/Recycle System RLD, Sheet 4 of 4.*

24590-PTF-M6-PWD-00040, Rev 3, *P&ID-PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-PTF-M6-PWD-00041, Rev 3, *P&ID-PTF Plant Wash & Disposal System C2 Area Floor Drains Collection Vessel.*

24590-PTF-M6-PWD-00042, Rev 3, *P&ID-PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-PTF-M6-PWD-00043, Rev 3, *P&ID-PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-PTF-M6-PWD-00044, Rev 3, *P&ID-PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-PTF-M6-PWD-00060001, Rev 0, *P&ID-PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 77-0 Thru 109-0).*

24590-PTF-M6-PWD-00061001, Rev 0, *P&ID-PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 77-0 Thru EL 98-0).*

24590-PTF-M6-PWD-00062, Rev 1, *P&ID-PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 77-0).*

24590-PTF-M6-PWD-00063001, Rev 0, *P&ID-PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 77-0 Thru EL 98-0).*

24590-PTF-M6-RLD-00001, Rev 2, *P&ID - PTF Radioactive Liquid Waste Disposal System Process Condensate RLD-TK-00006A/B.*

24590-PTF-M6-RLD-00003001, Rev 0, *P&ID - PTF Radioactive Liquid Waste Disposal System Effluent Collection RLD-VSL-00017A.*

24590-PTF-M6-RLD-00003002, Rev 0, *P&ID - PTF Radioactive Liquid Waste Disposal System Effluent Collection RLD-VSL-00017B.*

24590-PTF-MTC-RLD-00001, Rev C, *Tank Sizing Calculation-Process Condensate Tanks - RLD-TK-00006A and RLD-TK-00006B.*

24590-PTF-MVC-RLD-00005, Rev E, *Vessel Sizing Calculation for Alkaline Effluent Vessels (RLD-VSL-00017A/B).*

24590-PTF-MVC-RLD-00014, Rev A, *Key Design Parameters for the RLD.*

24590-WTP-ICD-MG-01-005, Rev 4, *ICD 05-Interface Control Document for Nonradioactive, Nondangerous Liquid Effluents.*

24590-WTP-ICD-MG-01-006, Rev 4, *ICD 06-Interface Control Document for Radioactive, Dangerous Liquid Effluents.*

24590-WTP-PL-PR-04-0001, Rev 2, *Integrated Sampling and Analysis Requirements Document (ISARD).*

24590-WTP-PL-RT-03-003, Rev 3, Table 4-3, *Secondary Wastes Compliance Plan.*

CCN 094448, *Liquid Effluent Retention Facility/Effluent Treatment Facility Treatability Envelope* (WMH-9758688). 29 September 1997.

CCN 225792, *HPS Secondary Loop Blowdown Condensate Flow to RLD.* 11 March 2011.

CCN 254099, *Laboratory Sample Turnaround Times (WTP OR Model V7.0)*, 15 April 2013

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136, US Department of Energy, Office of River Protection, Richland, WA, as amended.

Ecology. 2000a. *State Waste Discharge Permit Number ST 4502*, issued April 18, 2000, State of Washington, Department of Ecology, Kennewick, WA.

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Table 2.17-1 TEDF Discharge Limits

Constituent	TEDF Limit
Average flow rate	Not specified
Chloride	58,000 µg/L
Cyanide	50 µg/L
Nitrate	620 µg/L
Sulfate	No target limits
Ammonia	No target limits
Arsenic	15 µg/L
Cadmium	5 µg/L
Chromium	20 µg/L
Iron	300 µg/L
Lead	10 µg/L
Manganese	50 µg/L
Mercury	2 µg/L
Total dissolved solids	250,000 µg/L
Conductivity	No target limits
PH	6.5 to 8.5
Gross alpha	15 pCi/L
Gross beta	50 pCi/L
Radium total	5 pCi/L
Radium-226	No target limits
Bis (2-ethylhexyl phthalate)	10 µg/L
Oil and grease	No target limits
Phenol	10 µg/L
Carbon tetrachloride	5 µg/L
Methyl chloride	5 µg/L
1,1,1-Trichloroethane	5 µg/L
Trihalomethanes (total)	20 µg/L
Chloroform	7 µg/L

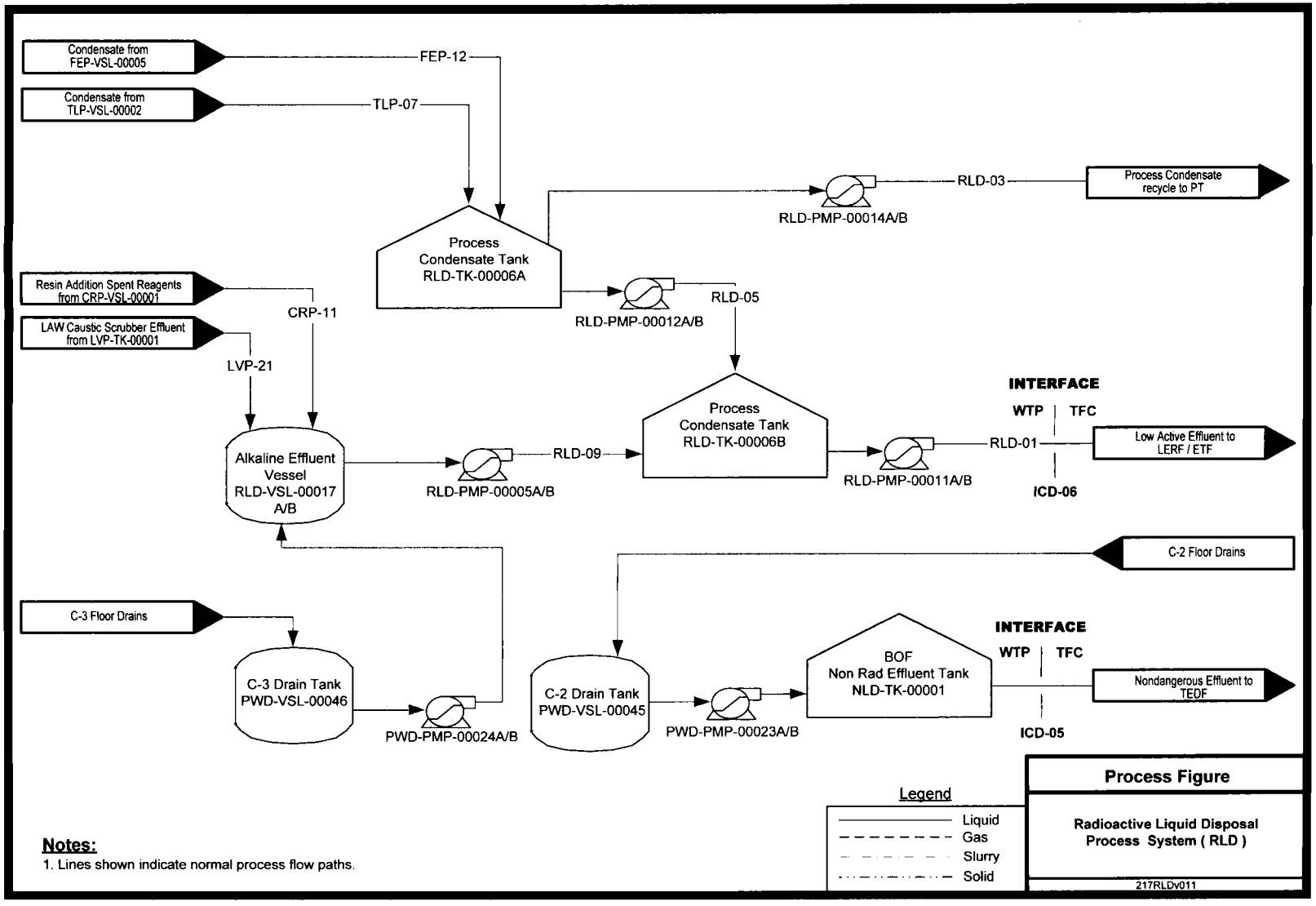
Sources: Ecology 2000a, *State Waste Discharge Permit Number ST 4502*, issued April 18, 2000, and Ecology 2000b, *Fact Sheet for State Waste Discharge Permit Number ST 4502*, issued April 18, 2000.

Table 2.17-2 LERF/ETF Radiological Acceptance Criteria

Radionuclide	LERF/ETF Acceptance Criteria (Curies/liter)
Tritium	2.4 E-04
Carbon-14	1.6 E-06
Cobalt-60	2.4 E-06
Selenium-79	1.5 E-07
Strontium-90	4.2 E-05
Niobium-94	2.6 E-07
Technetium-99	1.8 E-05
Ruthenium-106	6.5 E-07
Iodine-129	1.8 E-06
Cesium-134	4.1 E-07
Cesium-137	1.0 E-05
Cerium-144	2.0 E-05
Europium-154	9.8 E-06
Europium-155	6.3 E-05
Radium-226	6.4 E-08
Uranium (gross as Uranium-234)	2.1 E-10
Neptunium-237	2.1 E-09
Plutonium-238	2.8 E-09
Plutonium-239/240	1.8 E-08
Plutonium-241	2.6 E-08
Americium-241	1.4 E-09
Curium-244	2.5 E-08

Source: HNF-3172, *Liquid Waste Processing Facilities Waste Acceptance Criteria*, Table D-1.

Figure 2.17.1 Pretreatment Liquid Effluent Disposal System



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2.18 Pretreatment In-Cell Handling System (PIH)

2.18.1 Function and Requirements

Within the Pretreatment (PT) Facility, a significant amount of process equipment (i.e., pumps, filters, instruments) comes in contact with radioactive liquid waste during treatment. A hot cell in the PT Facility is used to locate all process equipment that needs to be remotely maintained. The primary function of the PT In-Cell Handling System (PIH) is to transport items between the process and the maintenance areas (24590-PTF-3YD-PIH-00001).

The purpose of the PIH system is to remotely service the process equipment in the PT hot cell. In serving this purpose, the PIH system provides the PT Facility with the following primary functions:

- Inspect process equipment:
  - Position cameras within the hot cell to allow visual inspections of process equipment.
- Handle process equipment:
  - View, disengage, lift, position, engage, and transport equipment, jumpers, and electrical equipment in the hot cell.
  - Remotely replace electrical cables and mount process equipment to the floor.
- Prepare equipment to leave the cell:
  - Size-reduce and package all failed equipment.
  - Transport handling equipment during maintenance activities to hands-on repair areas.
  - Decontaminate equipment to acceptable limits as needed in preparation for its export as waste or for hands-on maintenance.
- Remotely repair process equipment:
  - Position and mount process equipment. Manipulate or operate remote tooling using jib cranes, master slave manipulators, and the 30-ton in-cell bridge crane, when necessary.

2.18.2 Process Description

The PT 30-ton in-cell bridge crane (PIH-CRN-00004) is the primary crane used in the PIH system for maintenance and replacement of process equipment, and is the only component in the PIH system that is included in the Operations Research Flowsheet. In the flowsheet, crane PIH-CRN-00004 is used to assist with repair or replacement activities of valves, actuators, instruments, pumps, and equipment such as ion exchange columns, heat exchangers, evaporator reboilers, and ultrafilters. Crane PIH-CRN-00004 is also used to perform repair and maintenance of the Radioactive Solid Waste Handling System (RWH) crane and for size reduction of disposable equipment.

Activities involved in the equipment mean time to repair values include engaging, lifting, positioning, and transporting jumpers and electrical equipment in the hot cell and movements required between the equipment and laydown area. The crane resides in the cave when it is not busy. The layout of the hot cell and cave area is shown in the *Pretreatment General Arrangement Plan* (24590-PTF-P1-P01T-00003). If the crane is busy or failed, then pumps, equipment, valves, and actuators needing the crane must wait for it to become available. Equipment, pump, valve, and actuator failures requiring assistance from the crane will be queued, and after completing one repair the crane will move to the next repair in the queue. If there are no repairs in the queue, the crane will return to the cave.

After returning to the cave, the crane will begin size reduction activities. Repair work takes precedence over size reduction activities. Therefore, if there is any repair work to be done, the PIH crane would discontinue the size reduction activities, and perform the repair work. The crane would resume the size reduction effort when there is no longer a repair demand. If the crane itself has failed, then repair or size reduction activities will resume after the crane is repaired. Daily, monthly, quarterly, and annual maintenance is performed on the crane, as documented in CCN 206957.

2.18.3 PIH Crane Reliability, Availability, and Maintainability Data Basis

The PIH crane reliability, availability, and maintainability (RAM) data were incorporated into the Operations Research Flowsheet to determine whether or not the crane is overworked. PT Facility RAM data were developed and recorded in overall equipment efficiency data sheets. The basis for these RAM data are documented in CCNs 052245, 052246, 052249, 058345, and 110712.

Based on the input RAM data, the Operations Research Flowsheet provides crane PIH-CRN-00004 utilization statistics to support equipment repairs in the hot cell, waste handling, and size reduction activities. Past model results revealed that a high volume use of the PIH crane, along with a large number of repair backlogs, adversely affected PT Facility availability. Recent detailed studies show that, although the crane is key to maintaining plant availability above 70 %, the crane is not over-utilized and is capable of adequately supporting the PT maintenance activities (24590-WTP-RPT-PET-10-024). Modeling assumptions regarding crane utilization were changed, which also helped with availability. Previously, if a repair required crane use, the crane was assumed to be utilized during the entire repair. Now the crane is only utilized during the part(s) of the repair that actually requires it.

2.18.4 Crane Utilization and Ongoing Work

Since the use of the PIH crane is directly related to equipment repair time estimates, the PIH crane statistics will be monitored with any major PT equipment RAM data updates or changes in PT plant operations philosophy.

2.18.5 References

24590-PTF-3YD-PIH-00001, Rev 1, *System Description for Pretreatment In-Cell Handling System.*

24590-PTF-P1-P01T-00003, Rev 4, *Pretreatment Facility General Arrangement Plan at EL. 56'-0".*

24590-WTP-RPT-PET-10-024, Rev 0, *2010 WTP Operations Research Assessment.*

CCN 052245, *OEE Forms for Pretreatment-CNP, CRP, CXP, TEP, TRP, TXP, and RDP System(s).* 10 April 2003.

CCN 052246, *OEE Forms for Pretreatment-HLP, PVP, PJV, and UFP System(s).* 10 April 2003.

CCN 052249, *Revision 1 OEE Forms for Pretreatment-FEP, FRP, HLP, TCP, TLP, PWD, and UFP System(s).* 21 April 2003.

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CCN 110712, *Operations Research - Equipment Modeling Recommendations / Evaluations for Issue M-15, Task 1.* 1 August 2006.

CCN 206957, *Availability of Hot Cell Crane (PIH-CRN-00004).* 26 February 2010.

3 Low-Activity Waste Vitrification

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3.1 Systems LCP, GFR, and LFP: LAW Melter Feed Process

3.1.1 Function and Requirements

The purpose of the low-activity waste (LAW) concentrate receipt process (LCP) and melter feed preparation process (LFP) is to store and sample the LAW concentrate, mix it with glass formers, and feed it into the melter to make immobilized low-activity waste (ILAW) glass. The LAW melter feed process consists of:

- Concentrate receipt vessels: LCP
- Glass former mixers: Glass Formers Reagent System (GFR)
- Melter feed preparation vessels and melter feed vessels: LFP

The following is stated in the WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7(b)(2):

> *The LAW Vitrification Facility shall be designed to support a facility design capacity of 30 MTG/day. The LAW Vitrification Facility shall be capable of vitrifying treated LAW Envelopes A, B, and C in compliance with the waste loading specifications identified in Specification 2.2.2.2., Waste Loading.*

The WTP SOW, Operational Specification, Section C.8, Specification 2.2.2.2

> *Waste Loading: The loading of waste sodium from Envelope A in the ILAW glass shall be greater than 14 weight percent based on Na_2O. The loading of waste sodium from Envelope B in the ILAW glass shall be greater than 3.0 weight percent based on Na_2O. The loading of waste sodium from Envelope C in the ILAW glass shall be greater than 10 weight percent based on Na_2O.*

The LAW concentrate receipt vessels must be able to receive LAW concentrate from the Pretreatment (PT) Facility. A system for collection of a representative sample is required for glass formulation to ensure that the glass complies with the *ILAW Product Compliance Plan* (24590-WTP-PL-RT-03-001).

The glass former feed hoppers must be able to receive blended glass former batches from the glass former facility, re-blend the batches, and gravity feed the glass former batches to the melter feed preparation vessels (MFPV) (24590-LAW-3YD-LFP-00001). The glass former chemicals must be wetted prior to delivery to the MFPV in order to prevent dusting in the MFPV.

The LAW MFPVs must be able to receive LAW concentrate from the concentrate receipt vessels and mix the waste with glass formers from the glass former feed hopper. This mixture must be transferred to the melter feed vessels (MFV). Enough waste must be mixed with the glass formers to achieve the minimum waste loading of Na_2O as specified in the WTP SOW.

3.1.2 Process Description

Feed to the LAW melters consists of LAW concentrate mixed with glass formers and sucrose. The LAW feed system receives LAW concentrate from the PT Facility and mixes the waste with glass formers and sucrose. The mixed melter feed is transferred to the MFV where it is pumped to the LAW melters.

Process flow diagrams represent the interrelationships of process components (24590-LAW-M5-V17T-00001/2). The simplified LAW melter feed process system is depicted in Figure 3.1-1, at the end of this section.

The LAW concentrate receipt vessels (CRV), LCP-VSL-00001/2, receive LAW concentrate from the PT Facility. Each vessel has two pumps (LCP-PMP-00001A/B and LCP-PMP-00002A/B) to transfer waste to the LAW MFPVs, LFP-VSL-00001/3. The process control samples are collected from the LAW CRVs and analyzed to determine glass formulation. These samples are taken by running one of the pumps in recirculation mode and routing a portion of the stream to the sample cabinet. This sample is considered a process hold point to demonstrate waste compliance. Feed can move forward from the CRV to the MFPV, but glass forming chemicals cannot be added to the MFPV until the results are obtained from the Analytical Laboratory and the glass formulation is established.

The glass former mixers, GFR-TK-00022/23, receive glass formers by pneumatic conveyance from the LAW transporters, GFR-VSL-00007/8, located at the Balance of Facilities' (BOF) glass former handling facility. Each mixer holds the blended glass formers required for a batch of melter feed. Each mixer uses counter-rotating agitators to re-blend the glass former feed. In addition to blending the glass formers, the mixers will add demineralized water to mitigate dusting during mixing and transfer. After blending, the glass formers are fed with a screw conveyor into the MFPVs. This is consistent with CCN 077705, which directs the use of the design values.

The LAW MFPVs mix the glass formers from the glass former mixers with the LAW concentrate received from the LAW CRVs. The vessels have vertical pumps (LFP-PMP-00001A/B and LFP-PMP-00003A/B) to transfer waste between the MFPVs and to the MFVs, LFP-VSL-00002/4.

The LAW MFVs receive blended melter feed from the MFPVs and pump it to the melters. The MFVs are equipped with mechanical agitators, to keep the melter feed well mixed, and turbine pumps (LFP-PMP-00002/4), to return the feed to the MFPVs in case of a melter shutdown. Waste and glass formers are pumped to the melters via six air displacement slurry (ADS) pumps (LFP-PMP-00007 to -00018).

3.1.3 Basis

The basis for operation of the LAW melter feed system is to ensure adequate feed is provided at all times for all LAW melters (LMP-MLTR-00001/2) in operation at any one time. Continuous feed dictates the initiation of all unit operations in the LFP system and the LCP system. The feed system contains standardized equipment, with all four vessels (LFP-VSL-00001 through 00004) sized to hold the same batch capacity under similar process conditions. For the purpose of the energy balance, there is neither heating nor cooling in these systems and no utility loads are included in the flowsheet; this is due to the nature of the material and the process systems.

3.1.3.1 LAW Concentrate Receipt Vessel

The LAW CRVs (LCP-VSL-00001/2) receive pretreated melter feed concentrate from the PT vessel, TCP-VSL-00001. The LCP system is configured to receive, sample, and transfer concentrate to the MFPVs, LFP-VSL-00001/3 (24590-LAW-3YD-LCP-00001). The vessels can operate independently of each other for receiving sampling and transferring. The CRV feed sample is a hold point to determine the glass formulation; however, this is not a hold point for radionuclide reporting (24590-WTP-PL-PR-04-0001). The total hold-up time for determining the glass formulation is 10.5 hr, (see CCN 254099, *Laboratory Sample Turnaround Times*). The vessel providing concentrate to the MFPVs provides a

prescribed volume of concentrate to the selected vessel based on sample results and waste loading. Each LAW CRV has a batch volume of 9115 gal (24590-LAW-3YD-LCP-00001). The target sodium molarity of the LAW concentrate is set by the melter feed evaporator (Section 2.12) at 8 to 10 M for Envelopes A and C, and 5 M for Envelope B, in accordance with the *Basis of Design* (24590-WTP-DB-ENG-01-001).

3.1.3.1.1 Design Data - LAW Concentrate Receipt Vessel

LCP-VSL-00001 and LCP-VSL-00002 (24590-LAW-M6C-LCP-00001, and 24590-LAW-MFD-LCP-00004)

- Overflow volume: 14,876 gal
- Filled volume: 12,854 gal
- Batch volume: 9115 gal
- Heel volume: 3740 gal
- Influent rate (from PT): 88 gpm
- Effluent rate (to MFPV): 88 gpm
- Agitator: 40 hp

3.1.3.1.2 Operating Logic - LAW Concentrate Receipt Vessel

LCP-VSL-00001/2 (24590-LAW-3YD-LCP-00001)

- The LAW CRVs receive feed via one of two transfer pipelines at 88 gpm; the basis for this flow rate is the pump design (24590-LAW-MVC-LCP-00002)
- Initial fill at cold startup requires transfer of the filled volume of 12,854 gal
- Continuous operation batch transfers are the batch volume (9115 gal), with a fill time of approximately 105 min
- After filling to 12,854 gal, the tank is agitated for 20 to 30 min, then the solution is sampled through a recirculation pump line
- Holdup time for sample collection, transport, and analysis is 10.5 hr
- A specified volume of concentrate is transferred to one of two feed preparation vessels that is determined based on calculations described in Section 3.1.3.5
- The concentrate is batch fed at 88 gpm; flow rate is based on pump design. Pump hp is 20 (24590-LAW-MPD-LCP-00001)
- Feed is transferred to the MFPV when that vessel has completed transfer of feed to the MFV; for flowsheet analysis purposes, the setpoint to enable refill is 4255 gal
- The inter-facility transfer line is flushed with 642.6 to 664 gal of demineralized water to the CRV (see Appendix F)
- The line to the MFPV is flushed with one line volume of demineralized water to the MFPV following transfer with a total of 39.0 gal per transfer (24590-LAW-M0C-20-00006)

3.1.3.1.3 Energy Contributions - LAW Concentrate Receipt Vessel

These vessels are not heated or cooled (24590-LAW-MVC-LCP-00002).

3.1.3.1.4 Services - LAW Concentrate Receipt Vessel

Demineralized water: Used for line flushes following transfer and periodic vessel washes, the CRV receives flush water from the LCP-BULGE-00001 to the CRV (24590-LAW-M4C-20-00002). A total volume flush of 495 gal (24590-LAW-M0C-20-00006) is used to flush the line between the LCP-BULGE-00001 and pretreatment, with the flush water being sent to the ultimate overflow vessel (PWD-VSL-00033).

The line between the LCP and MFPV vessels (stream LCP01) is flushed with one line volume of demineralized water per transfer (24590-LAW-M4C-20-00002).

3.1.3.2 Glass Former Mixers

The glass former mixers (GFR-TK-00022/23) receive blended glass formers from the LAW transporters (GFR-VSL-00007/8). For additional information on the operation of the glass former facility, see Section 6.1. These pneumatically operated transporters convey glass formers and sucrose from the LAW blending silos. Amounts of constituents for each batch recipe received by the glass former mixers are determined by glass formulation recipe calculations made with LAW CRV assay information (Section 3.1.3.5.2). The glass formers are fed with a screw conveyor into the associated MFPV. These are also wetted with water in the mixer to mitigate dusting during mixing and delivery to the vessel.

3.1.3.2.1 Design Data - Glass Former Mixers

GFR-TK-00022 and GFR-TK-00023 (24590-LAW-M4C-GFR-00002)

- Maximum filled volume (no agitation): 470 ft^3
- Maximum batch volume: 470 ft^3
- (Batch capacity including contingency is 790 ft^3 with blending headspace)
- Heel volume: 0
- Influent rate (from blending silo): 470 ft^3/hr (24590-CM-POA-MH00-00001-07-00001)
- Effluent rate (to MFPV): 392 ft^3/hr (24590-CM-POA-MH00-00001-08-00380/381)

3.1.3.2.2 Operating Logic - Glass Former Mixers

GFR-TK-00022/23 (24590-BOF-3YD-GFR-00001)

- The glass former mixers receive a calculated volume of blended glass formers from the blending silos via GFR-VSL-00007/8; Section 3.1.3.5.2 provides equations and definitions of glass former constituents
- Batch volumes will vary, depending on required quantities of recipe constituents as determined by sample values received from LCP-VSL-00001/2 (inclusive of all envelopes)
- After a verified quantity of LAW concentrate has been added to the MFPV, the glass formers are gravity-fed to the MFPV

- During mixing, the glass former chemicals are wetted with water to prevent dusting that could overload the vessel vent and offgas system. Amount of water added is 3 % by weight of the total batch (CCN 077705)
- A knife gate valve, located beneath the hopper in an isolated space, serves as a contamination barrier between systems LFP and GFR

3.1.3.2.3 Energy Contributions - Glass Former Mixers

- These vessels are not heated or cooled (24590-LAW-M4C-GFR-00002)
- Glass formers enter the feed system at ambient temperatures (25 °C)

Assumption 3.1.5. The amount of water added for dusting control is 3 wt % for all LAW glass former batches (CCN 077705).

3.1.3.3 LAW Melter Feed Preparation Vessel

The LAW MFPVs (LFP-VSL-00001/3) receive batches of LAW concentrate from CRVs per results from sample analysis of the LAW concentrate. These batch volumes are in proportion to the recipe of glass formers received from glass former mixers (Section 3.1.3.5.4). The glass former solids volume and the concentrate slurry combine for a melter feed batch volume of about 3400 gal (24590-LAW-M4C-20-00002). A water mass concentration of 36 wt % is targeted for this vessel in order to meet melter feed rheological requirements (24590-WTP-RPT-PO-03-007). These are predetermined before transferring waste to the MFPV. When the concentrate volume is verified, wetted glass formers are added at a regulated rate through the rotary valve to ensure adequate dispersion of solids into the liquid concentrate. The mechanical agitator runs as long as the tank volume is above the agitator blades. The agitator should run during all normal operations. Vessel vents are sized to prevent pressure from exceeding maximum design limits during transfer of melter feed from the vessel. The vessel vent also releases interstitial air contained in the glass formers fed to MFPVs. An example of the solids volume of glass formers, which makes up the batch volume of 3400 gal, can be found in 24590-LAW-M4C-20-00002. For the purpose of flowsheet analysis, transfer of slurry to MFVs begins when the volume of that vessel reaches the instrumentation level uncertainty of 142 gal (24590-LAW-M6C-LFP-00002) above the heel volume. MFPVs can transfer to the other feed preparation vessel and its associated MFVs (Figure 3.1-1). MFPV cycle time is equivalent to the total feed time per batch as a function of melter feed rates. These melter feed rates are variable and serve as a function of waste/glass former requirements (Section 3.1.3.5.4). A sample is taken from this vessel, but it is not a hold point (24590-WTP-PL-PR-04-0001). The vessel is held for a 0.3 hr sampling time after glass formers are added. If the water mass concentration of the feed is below 36 %, dilution water will be added to raise the water mass above this value (24590-WTP-RPT-PO-03-007).

3.1.3.3.1 Design Data - LAW Melter Feed Preparation Vessel

LFP-VSL-00001 and LFP-VSL-00003 (24590-LAW-M6C-LFP-00001, 24590-LAW-MVC-LFP-00001)

- Overflow volume: 7489 gal
- Filled volume: 5132 gal
- Batch volume: 3400 gal
- Heel volume: 1732 gal

- Influent rate (from CRV): 88 gpm
- Effluent rate (to MFV): 50 gpm

3.1.3.3.2 Operating Logic - LAW Melter Feed Preparation Vessel

LFP-VSL-00001 and LFP-VSL-00003 (24590-LAW-3YD-LFP-00001)

- Initial vessel fill entails calculating waste and glass former volumes for 5132 gal of feed slurry (filled volume based on engineering calculations for vessel sizing)
- The MFPVs receive a calculated volume of LAW concentrate as determined by waste constituent sample values from CRVs, which varies with the waste loading and envelope type as a function of the melter feed recipe (see Section 3.1.3.5.2)
- Wetted glass formers are gravity-fed via a screw conveyer located above MFPV in an isolated space which serves as a contamination barrier between systems
- Interstitial air is vented to the vessel vent system
- Batch volume is 3400 gal for a filled volume of 5132 gal
- Melter feed slurry is agitated as long as a batch volume is present
- Slurry is fed at 50 gpm (LFP-PMP-00001A/B and -00003A/B) to the MFV when that vessel's volume is at 142 gal above the heel volume; flow rate is based on pump design (24590-LAW-MVC-LFP-00001)
- Setpoint for refill is equivalent to the heel volume
- The line to the MFV is flushed with 21.4 gal of demineralized water following each transfer via the transfer bulge (24590-LAW-M4C-20-00002)

3.1.3.3.3 Energy Contributions - LAW Melter Feed Preparation Vessel

- Adding glass former additive boric acid to basic LAW concentrate produces a heat of reaction; the estimated heat contribution is -4.71 kcal/gmole of boric acid. This heat of reaction is derived from the heats of formation of the reactants and products, which are -261.55 kcal/gmol for H_3BO_3, -321.23 kcal/gmol for $B(OH)_4^-$ and -54.970 kcal/gmol for OH- (Lide 1990).
- These vessels are not actively heated or cooled (24590-LAW-3YD-LFP-00001).

3.1.3.3.4 Services - LAW Melter Feed Preparation Vessel

Demineralized water: Used for line flushes following transfer and periodic vessel washes

3.1.3.3.5 Chemistry - LAW Melter Feed Preparation Vessel

Boric acid reaction is:

$$H_3BO_3 + NaOH \rightarrow Na^+ + B(OH)_4^- \text{ at pH} > 10$$

Note: (Skoog and others 1992. See Acid Dissociation Constant Table.)

3.1.3.4 LAW Melter Feed Vessel

The LAW MFVs (LFP-VSL-00002 and LFP-VSL-00004) provide continuous feed of LAW slurry to the melter as required to produce 15 metric tons of glass (MTG)/day/melter. Batch volume is 3330 gal (24590-LAW-3YD-LFP-00001). Feed rate, and therefore cycle time, vary depending on the waste loading of the glass and waste concentration in the feed (Section 3.1.3.5.4). Each vessel pumps via six air-displacement slurry pumps (LFP-PMP-00007 to 18) to its corresponding melter. When the vessel volume is approximately 142 gal above the heel, a new batch of melter feed is transferred from the MFPV. Two vertical pumps (LFP-PMP-00002/4) enable the vessel to pump to the corresponding MFPV (in the event of melter shutdown), to the plant wash vessel, or to recirculate for sampling. Vessel vents are sized to prevent pressure from exceeding maximum vacuum design during transfer of melter feed from the vessel. For flowsheet analysis purposes, a continuous feed from the LAW MFVs to the melter as one stream is appropriate.

3.1.3.4.1 Design Data: LAW Melter Feed Vessel

LFP-VSL-00002 and LFP-VSL-00004 (24590-LAW-M6C-LFP-00002, 24590-LAW-MVC-LFP-00001)

- Overflow volume: 5768 gal
- Filled volume: 4377 gal
- Batch volume: 3400 gal
- Heel volume: 977 gal
- Influent rate (from MFPV): 50 gpm
- Effluent rate (to LMP): variable

3.1.3.4.2 Operating Logic - LAW Melter Feed Vessel

LFP-VSL-00002, LFP-VSL-00004 (24590-LAW-3YD-LFP-00001)

- Initial fill volume from the MFPV is to the high setpoint of 4377 gal with a fill time of 117 min
- Batch volume is 3400 gal
- MFV receives a melter feed batch from the MFPV at 50 gpm; fill time is approximately 67 min
- Mechanical agitators operate continually to suspend glass former solids
- The feed vessels provide slurry continuously to the melter at various flow rates for each batch as determined by waste loading in the glass
- The setpoint for receipt of subsequent feed batches is 142 gal above the heel (1119 gal)
- The ADS pumps are periodically flushed with demineralized water to prevent the accumulation of solids and plugging of the pumps (approximately 12 gal for every melter feed batch, 24590-LAW-M0C-20-00006)

3.1.3.4.3 Energy Contributions - LAW Melter Feed Vessel

These vessels are not actively heated or cooled (24590-LAW-MVC-LFP-00001).

3.1.3.4.4 Services - LAW Melter Feed Vessel

- Demineralized water: Used for line flushes following transfer and periodic vessel washes
- Sugar addition: Sugar can be added to the MFV and melter through the demineralized water line (24590-LAW-DCA-PR-02-005)

3.1.3.5 LAW Process Technology

3.1.3.5.1 Basis of Glass Formers

Each glass former exerts desirable and undesirable properties on the glass. The mixture of glass formers should compensate for the undesirable properties of the individual glass formers and waste constituents. A list of glass formers and their make-up is shown in Table 3.1-10.

Lithium carbonate (Li_2CO_3) is an inexpensive form of lithium that does not cause as many rheology problems as does lithium hydroxide (Kot and others 2000). Lithium decreases viscosity of the molten glass (Hrma and others 2001) but decreases glass durability. Lithium improves sulfate incorporation (24590-101-TSA-W000-0009-83-02). Higher concentrations of lithium results in accelerated corrosion of melter refractory.

Silica (SiO_2) is a primary glass forming constituent. Silica increases durability and decreases viscosity (Hrma and others 2001). Most commonly used form of silica is quartz sand.

Zinc oxide (ZnO) is an inexpensive form of zinc (Kot and others 2000). Zinc increases the durability of glass (McKeown and others 2001), but is mainly added to reduce corrosion of the melter's refractory by forming a spinel crystal-like coating on the refractories.

Boric acid (H_3BO_3) is an inexpensive source of boron (Kot and others 2000). Boric acid is used in LAW melter feed rather than borax ($Na_2B_4O_7$), so no additional sodium is added to LAW glass (24590-101-TSA-W000-0009-184-00001).

Kyanite (Al_2SiO_5) is an inexpensive source of aluminum with a high bulk density and diverse availability of particle sizes (24590-101-TSA-W000-0009-184-00001). Aluminum increases glass durability. Notice that it also adds some silica that needs to be accounted for.

Wollastonite ($CaSiO_3$) is an inexpensive source of calcium and, unlike calcium carbonate, does not promote foaming in the melter (24590-101-TSA-W000-0009-184-00001). Calcium increases sulfate incorporation (24590-101-TSA-W000-0009-83-02). Like kyanite, it supplies some silica to the constituent matrix.

Forsterite olivine (Mg_2SiO_4-Fe_2SiO_4) is an inexpensive source of magnesium and, unlike magnesium carbonate, does not promote foaming in the melter (24590-101-TSA-W000-0009-184-00001). Forsterite has a major iron impurity (24590-101-TSA-W000-0009-184-00001). Magnesium increases sulfate incorporation in the glass matrix (24590-101-TSA-W000-0009-83-02).

Hematite (Fe_2O_3) is an inexpensive source of small-grain iron (24590-101-TSA-W000-0009-184-00001). Iron increases durability relative to the waste constituents without decreasing viscosity (Hrma and others 2001). However, iron is associated with foaming in the melter (Bickford and Choi 1991) and many crystals in glass contain iron (24590-101-TSA-W000-0010-06-03A).

Rutile (TiO_2) is an inexpensive source of titanium (24590-101-TSA-W000-0009-184-00001). Titanium improves the glass resistance to acid, such as what was shown in the toxicity characteristic leaching test [TCLP]. The addition of titanium also improves the meltability of glass (Langowski 1996).

Zircon ($ZrSiO_4$) is an inexpensive source of zirconium (24590-101-TSA-W000-0009-184-00001). Zirconium improves glass durability (Hrma and others 2001). In addition, zircon contains trace quantities of uranium and thorium impurities (24590-101-TSA-W000-0009-184-00001). It also contains 7 % hafnium as HfO_2. However, hafnium's chemistry is so similar to zirconium's chemistry that no adverse impacts are noticed.

Sugar (or sucrose, $C_{12}H_{22}O_{11}$) is an inexpensive and effective reductant used to reduce the nitrates and nitrites in the waste. Furthermore, the oxidation of the sugar by the nitrates also adds heat in the cold cap and aids in glass production.

3.1.3.5.1.1 Impurities in Glass Former Minerals

Minerals are an inexpensive source of glass formers. Pure chemicals are not required since the process is treating waste materials to begin with. Some impurities in the minerals are significant and need to be tracked. Table 3.1-10 shows each mineral and the expected level of impurity it contains. This table is a compilation of Research and Technology (R&T) data documented in SCT-M0SRLE60-00-175-01, *Characterization of HLW and LAW Glass Formers*. The quantities in the table are shown in two different formats: standard parts per million and mass per kilogram of glass former. The quantities are based on a request for 1 kilogram (or 1 pound) of the glass former oxides. For example, if a glass recipe calls for 1 kg of the glass former MgO, then the table shows that the batch will get a little less than 1 kg of MgO because of its impurities. Actually, 0.98482 kg MgO is supplied along with 0.00390 kg Al_2O_3, 0.00041 kg CaO, 0.00267 kg Cr_2O_3, 0.00021 K_2O, 0.00041 kg Na_2O, and 0.00759 kg P_2O_3 as impurities for a total of 1 kg. Looking at the table again shows that MgO comes from the mineral olivine, which also contains SiO_2 and Fe_2O_3. Therefore, a total of 2.05128 kg of olivine needs to be requested for the 1 kg of MgO (and its impurities) and 0.89374 kg SiO_2 and 0.15754 kg of Fe_2O_3 needs to be subtracted from the SiO_2 and Fe_2O_3 glass former additive demands, respectively. This routine is done for each glass additive oxide in the recipe, with SiO_2 and Fe_2O_3 calculated last. Then the SiO_2 and Fe_2O_3 supplied by the other minerals are subtracted from the silica and hematite requirements, respectively.

Some of the minerals contain carbonate or hydrate that will be lost at the melter to the offgas. This needs to be accounted for in determining the glass former amounts. Note that boric acid and sugar do not actually contain molecular water, and that sugar, sodium carbonate, and lithium carbonate do not actually contain molecular carbon dioxide. They are tracked as having water and carbon dioxide in them because they can be broken down into mass units that have the same stoichiometry as water and carbon dioxide.

3.1.3.5.2 Waste Loading and Glass Formulation

Sulfate limits the waste loading for most LAW feed (24590-101-TSA-W000-0010-06-03A). Sulfate is problematic because molten sulfate salts can potentially form a separate phase on the melt surface. This molten salt phase promotes corrosion, is more electrically conductive than the melt (which could lead to an electrical short in the melter), is fluid, has a low viscosity, and could flow between the joints of the melter refractories if enough fluid is present. The sulfate issue is addressed by formulating glasses that minimize the formation of molten sulfate layers.

Sulfur exists as sulfate in glass and is surrounded by alkali and alkaline earth cations (McKeown and others 2001). Sulfate decreases the interaction of sodium with the silica in the glass, which in turn increases the polymerization of the glass (Stefanovskii and others 1993).

In addition to sulfate, waste loading could be limited by durability, liquidus temperature of crystalline phases, viscosity, or electrical conductivity. The WTP has developed property-composition models for ILAW product consistency test (PCT), vapor hydration test (VHT), viscosity, and electrical conductivity (EC) (24590-101-TSA-W000-0009-178-00001).

The WTP PCT specification requires that the normalized mass releases of boron, sodium, and silicon in a 7-day PCT at 90 °C individually be less than 2 gm/m^2. Of the 264 glasses with PCT data, generated during several years of product development, 9 had PCT boron releases above 2 gm/m^2 and 8 had PCT sodium releases above 2 gm/m^2. All of the PCT silicon releases were below the limit of 2 gm/m^2. Hence, no PCT silicon release model was developed. The dataset for VHT model development consisted of 181 glasses from waste simulant having VHT results ranging from 0.1 to 108.2 gm/m^2/day. The WTP Contract limit is <50 gm/m^2/day for VHT result. The viscosity dataset, containing 181 measurements, ranged from 6 to 2329 poise. The WTP Contract upper limit for viscosity is 150 poise at 1100 °C. The electrical conductivity of the glass melts in the dataset ranged from 0.073 to 0.732 S/cm. The WTP specified range for EC is from 0.1 to 0.7 S/cm in the temperature range of 1100 to 1200 °C.

Part of the available data was used for model development and the remaining data was used for model validation. The PCT modeling database contained a limited number of glasses with PCT-B and PCT-Na releases near the WTP Contract limit. The 17-term models recommended for PCT-B and PCT-Na predict the boron and sodium releases well except near the contract limit of 2 gm/m^2 due to limited data. A 15-term model was found to yield a good fit for the experimental dataset for VHT results. Due to uncertainties in VHT testing, there was a large scatter in the data points. A 26-term temperature dependent model was found to fit the available data on LAW glass viscosities. The property models were developed by estimating coefficients using least squares regression models. The natural logarithm of the property is obtained by summation of the product of the model term and the corresponding coefficient, where the glass forming oxides are expressed as normalized weight percent and the temperature as Kelvin. The general expression for each property is:

Equation 3.1-1

$$\mathrm{Ln}(P) = \mathrm{constant} + \sum_{i=1}^{i=\text{no. of oxides}} a_i x_i + \sum_{i,j=1}^{i,j=\text{no. of oxides}} b_{ij}\, x_i x_j + \sum_{i=1}^{i=\text{no. of oxides}} c_i x_i / T + \sum_{i=1}^{i=\text{no. of oxides}} d_i x_i / T^2$$

where P is the property, such as PCT or VHT; a_i, b_{ij}, c_i, and d_i are the coefficients; x_i is oxide concentration in normalized weight fraction; and T is the temperature in Kelvin. Constant = 1 - sum of weight fractions of oxides. The coefficients and the terms for each property are given in Table 3.1-1 and Table 3.1-2. The constant is referred to as others in Table 3.1-1 and Table 3.1-2.

Table 3.1-1 ILAW Glass Property Models for PCT-B, PCT-Na, and VHT

LN(PCT-B)			LN-(PCT-Na)			Ln(VHT)	
Model Terms	**Coefficients**		**Model Terms**	**Coefficients**		**Model Terms**	**Coefficients**
Al2O3	-31.3612		Al2O3	-20.7142		Al2O3	19.5685
B2O3	11.8101		B2O3	-6.5489		B2O3	18.5336

Table 3.1-1 ILAW Glass Property Models for PCT-B, PCT-Na, and VHT

LN(PCT-B)			LN-(PCT-Na)			Ln(VHT)	
Model Terms	**Coefficients**		**Model Terms**	**Coefficients**		**Model Terms**	**Coefficients**
CaO	-13.8404		CaO	0.0151		CaO	38.2412
Fe2O3	-16.5948		Fe2O3	-8.4617		Fe2O3	-8.4126
K2O	7.9687		K2O	0.8724		K2O	-39.3124
Li2O	83.3036		Li2O	44.7604		Li2O	-17.825
MgO	-21.2343		MgO	-13.8667		MgO	-8.3068
Na2O	46.1599		Na2O	9.9942		Na2O	-20.6518
P2O5	-19.254		P2O5	-14.5324		P2O5	0
SiO2	-1.6161		SiO2	-4.8834		SiO2	-0.5137
ZrO2	-6.6289		ZrO2	-0.62		Zr2O	-62.8457
Others	-5.169		Others	3.345		Others	-0.4293
CaOxLi2O	-251.2654		CaOxLiO2	-232.1695		K2OxK2OxNa2O	10138.282
B2O3xMgO	488.8612		CaOxFe2O3	182.6191		Na2OxNa2OxNa2O	872.6563
B2O3xLi2O	-374.9533		B2O3xMgO	437.4267		LiO2xNa2OxSiO2	2139.8048
Na2OxSiO2	-74.3462		B2O3xNa2O	87.6716		B2O3xCaOxNa2O	-1943.0687
CaOxFe2O3	212.0947		K2OxK2O	315.6867			

Table 3.1-2 ILAW Glass Property Models for Viscosity and Electrical Conductivity

Ln(Viscosity)			Ln(EC)	
Model Terms	**Coefficients**		**Model Terms**	**Coefficients**
Al2O3	5.5124		Al2O3	2.3854
B2O3	-42.3772		B2O3	7.975
CaO	-10.6445		CaO	5.2093
Fe2O3	-4.6229		Fe2O3	4.3935
K2O	-0.8689		K2O	7.6774
Li2O	10.939		Li2O	4.2464
MgO	-5.6188		MgO	15.1675
Na2O	0.9073		Na2O	-2.0291
P2O5	-0.8081		P2O5	0
SiO2	1.5575		SiO2	3.6811
ZrO2	-12.0741		Zr2O	7.874
Others	-9.3903		Others	11.2069

Table 3.1-2 ILAW Glass Property Models for Viscosity and Electrical Conductivity

Ln(Viscosity)			Ln(EC)	
Model Terms	**Coefficients**		**Model Terms**	**Coefficients**
Al2O3/(T/1000)^2	24.6423		Al2O3/(T/1000)	-9.0593
B2O3/(T/1000)^2	0		B2O3/(T/1000)	-11.0983
CaO/(T/1000)^2	13.7793		CaO/(T/1000)	-30.6535
Fe2O3/(T/1000)^2	15.2036		Fe2O3/(T/1000)	-9.2407
K2O/(T/1000)^2	0		K2O/(T/1000)	-11.5299
Li2O/(T/1000)^2	-82.4815		Li2O/(T/1000)	30.4827
MgO/(T/1000)^2	22.7608		MgO/(T/1000)	-25.0634
Na2O/(T/1000)^2	-14.5621		Na2O/(T/1000)	12.3822
P2O5/(T/1000)^2	24.0339		P2O5/(T/1000)	0
SiO2/(T/1000)^2	24.4077		SiO2/(T/1000)	-10.1563
ZrO2/(T/1000)^2	48.2286		Zr2O/(T/1000)	-16.539
Others/(T/1000)^2	17.38		Others/(T/1000)	-17.7117
B2O3xB2O3	198.736		CaOxLi2O	144.9519
LiO2xLiO2	133.6096		CaOxNa2O	79.019
Al2O3xLiO2	-136.5095		LiO2xNa2O	-130.1441
MgOxMgO	-179.8249			

The current equations for determining the quantity of LAW glass formers to add to a given batch of waste are described below, and are from 24590-LAW-RPT-RT-04-0003 and 24590-101-TSA-W000-0009-72-00012.

The nomenclature for this algorithm can be complicated, so brief descriptions of the variables that will be used in the equations to calculate the LAW glass formulation are provided below.

Table 3.1-3 Brief Descriptions of Equation Variables

Variable	Units	Description
C_i^{CRV}	g/L	Concentration of constituent oxide "i" in/from the CRV
M_i^{CRV} or M_i^{waste}	kg	Mass of waste oxide "i" in/from the CRV (for LAW) or Mass of waste oxide "i" entering the MFPV (for high-level waste)
M_i^{batch}	kg	Mass of waste oxide "i" in MFPV batch
M_{glass}	kg	Mass glass made from MFPV batch
A_i^{batch}	kg	Mass of glass-former "i" (also called Additive "i"), as oxide, necessary to make a batch of glass from the waste in MFPV batch
g_i^{batch}	kg/kg	Glass fraction constituent oxide "i"
DF_i	kg/kg	Decontamination factor for constituent oxide "i"

The quantity of each glass former is based on the ratio of Na_2O to SO_3 in the glass (Figure 3.1-2) over most of the waste composition region. The quantity of Na_2O loaded into the glass is a function of K_2O content of the waste when the SO_3 content of the waste is low. Figure 3.1-2 is a simplified depiction of the Na_2O loading in glass as a function of the SO_3 content of glass, embedded in the equations below (24590-LAW-RPT-RT-04-0003). Equation 3.1-2 through Equation 3.1-5 determine the conditions that are placed in the minimum statement (Equation 3.1-6). To use these equations, the amount of sulfate (as SO_3) needs to be determined as given in Equation 3.1-2.

Equation 3.1-2

$$M_{SO3}^{CRV} = \frac{\text{mol. wt.}(SO_3)}{\text{mol. wt.}(SO_4)} M_{SO4}^{CRV}$$

Equation 3.1-3

$$C_{K2O+Na2O}^{initial} = \frac{0.215}{1 + 0.66 \frac{M_{K2O}^{CRV}}{M_{Na2O}^{CRV}}}$$

Equation 3.1-4

$$C_{Transition}^{initial} = \frac{0.35875}{1 + 42.5 \frac{M_{SO3}^{CRV}}{M_{Na2O}^{CRV}}}$$

Equation 3.1-5

$$C_{HighSulfate}^{initial} = 0.0077 \frac{M_{Na2O}^{CRV}}{M_{SO3}^{CRV}}$$

The sodium oxide loading in the glass, which is the minimum of the above-described conditions, is determined in Equation 3.1-6 and Equation 3.1-7.

Equation 3.1-6

$$X_{Na2O} = \text{Min}\left\{0.21, C_{K2O+Na2O}^{initial}, C_{Transition}^{initial}, C_{HighSulfate}^{initial}\right\}$$

Equation 3.1-7

$$g_{Na2O}^{initial} = \text{Min}\left\{X_{Na2O}, 0.04 \frac{M_{Na2O}}{M_{K2O}^{initial}}\right\}$$

Equation 3.1-7 ensures that the K_2O concentration in the target glass will not exceed 4.0 wt % K_2O, which was the highest concentration of K_2O used in the testing program. The K_2O limitation was determined by realizing that if there is a high concentration of K_2O, Equation 3.1-3 will be the minimum condition in Equation 3.1-6. Therefore, starting with Equation 3.1-3:

Equation 3.1-8

$$C_{K2O+Na2O} = C_{K2O} + C_{Na2O}$$

The amount of glass based on these conditions is given in equation Equation 3.1-9.

Equation 3.1-9

$$M_{glass} = \frac{M_{Na2O}}{C_{Na2O}}$$

When the glass in equation Equation 3.1-9 contains 4 wt % K_2O, the equation can now be written as shown in Equation 3.1-10.

Equation 3.1-10

$$0.04 = M_{K2O} \Big/ \left(\frac{M_{Na2O}}{C_{Na2O}} \right)$$

Rearranging Equation 3.1-10 gives Equation 3.1-11, which is the limiting condition in Equation 3.1-7.

Equation 3.1-11

$$C_{Na2O} = 0.04 \frac{M_{Na2O}}{M_{K2O}}$$

The mass of the target glass can now be calculated as given in Equation 3.1-12. Equation 3.1-12 does not give the exact mass of the glass made by the melters because some of this mass is lost to the offgas. However, it is a very close approximation. This is why it is called the "target" glass mass.

Equation 3.1-12

$$M_{glass.p1} = \frac{M_{Na2O}^{CRV}}{g_{Na2O}^{initial}}$$

Notice that target glass has a *.p1* suffix designation. Recent studies (CNN 150795) have shown that higher concentration of halides, chromium, and phosphate can cause solids precipitation in the molten glass, which can hinder the melter's operation. Therefore, the target glass may need to be diluted to decrease the concentration of the affecting halide, chromium, or phosphate. This become the new target glass estimate, $M_{glass.p2}$.

Equation 3.1-13

$M_{glass.p2} = MAX(M_{glass.p1}, M_{K2O} / 0.05, M_{P2O5} / 0.025)$

where: M_{K2O} and M_{P2O5} are the masses of potassium and phosphorous in the waste as the oxide.

Note that CCN 150795 does not give an absolute upper limit for P_2O_5 but HLW studies have limited it to 2.5 wt% per report PNNL 18501, *Glass Property Data and Models for Estimating*

High-Level Waste Glass Volume (Vienna 2009). HLW glasses are limited to 6.5 combined wt% for P_2O_5 and CaO. Since LAW glasses uses significant amounts of CaO as a glass former, this limit will also be observed. Too much CaO and P_2O_5 can lead to a solids precipitate forming on the surface of the molten glass in the melter, which can greatly hinder melter operations.

Equation 3.1-14

$$g_{SO3} = M_{SO3} / M_{glass.p2}$$

where: M_{SO3} is the mass of sulfate in the waste as SO_3.

Equation 3.1-15

$$BC_{Halide} = IF(g_{SO3} > 0.0059, 0.0022, -2.1111\ g_{SO3} + 0.014656)$$

Equation 3.1-16

$$BC_{Cr2O3} = IF(M_{P2O5} / M_{glass.p2} > 0.02499, 0.0063, IF(M_{K2O} / M_{glass.p2} \leq 0.00540, 0.0063, 0.008))$$

Equation 3.1-17

$$M_{glass}^{batch} = (M_{glass.p2}, (M_{Cl} + 0.3M_F) / BC_{Halide}, M_{Cr2O3} / BC_{Cr2O3})$$

where: M_{Cl} and M_F are the masses of chlorine and fluorine in the waste.
M_{Cr2O3} is the mass of chromium in the waste as the oxide.

Equation 3.1-18

$$M_{glass}^{batch} = \frac{M_{Na2O}^{CRV}}{g_{Na2O}^{initial}}$$

The following equations give the glass former additives required to make a batch of target glass.

Equation 3.1-19

$$A_{Al2O3}^{batch} = Max\left\{0.061, \frac{M_{Al2O3}^{CRV}}{M_{glass}^{batch}}\right\} M_{glass}^{batch} - M_{Al2O3}^{CRV}$$

Equation 3.1-20

$$A_{B2O3}^{batch} = 0.100 M_{glass}^{batch} - M_{B2O3}^{CRV}$$

Equation 3.1-21

$$A_{Fe2O3}^{batch} = Max\left\{0.055, \frac{M_{Fe2O3}^{CRV}}{M_{glass}^{batch}}\right\} M_{glass}^{batch} - M_{Fe2O3}^{CRV}$$

Equation 3.1-22

$$A_{TiO2}^{batch} = 0.014 M_{glass}^{batch} - M_{TiO2}^{CRV}$$

Equation 3.1-23

$$A_{ZnO}^{batch} = 0.035 M_{glass}^{batch} - M_{ZnO}^{CRV}$$

Equation 3.1-24

$$A_{ZrO2}^{batch} = 0.030 M_{glass}^{batch} - M_{ZrO2}^{CRV}$$

Equation 3.1-25

$$A_{Na2O}^{batch} = \mathrm{Max}\left\{0.054,\ g_{Na2O}^{initial}\right\} M_{glass}^{batch} - M_{Na2O}^{CRV}$$

Equation 3.1-26

$$d = \frac{0.66 M_{K2O}^{CRV}}{M_{glass}^{batch}} + \mathrm{Max}\left\{0.054, g_{Na2O}^{initial}\right\}$$

Where: d is maximum glass alkali content constraint to limit the total alkali contribution from the waste.

Equation 3.1-27

$$A_{CaOX} = \left(0.015 + \frac{0.055}{1 + e^{\frac{d-0.17}{0.02}}} \right) M_{glass}^{batch} - M_{CaO}^{CRV}$$

The glass is checked to ensure the combined concentration of CaO and P_2O_5 in the glass does not exceed the 6.5 wt% cited above and the A_{CaOX} adjusted accordingly. Therefore:

Equation 3.1-28

$$A_{Cao}^{batch} = \mathrm{IF}((A_{CaOX} + (M_{CaO} + M_{P2O5}) / M_{glass}^{batch}) > 0.065,\ 0.065 - (M_{CaO} + M_{P2O5}) / M_{glass}^{batch},\ A_{CaOX}) * M_{glass}^{batch}$$

Equation 3.1-29

$$A_{CaO}^{batch} = \left(0.015 + \frac{0.055}{1 + e^{\frac{d-0.17}{0.02}}} \right) M_{glass}^{batch} - M_{CaO}^{CRV}$$

Equation 3.1-30

$$A_{Li2O}^{batch} = \mathrm{IF}\left(1 - \frac{(100d - 5.4)^2}{12.75^2} < 0.0,\ 0.0,\ \left\{ 0.043 \left[1 - \frac{(100d - 5.4)^2}{12.75^2} \right]^{0.7} \right\} M_{glass}^{batch} - M_{Li2O}^{CRV} \right)$$

Equation 3.1-31

$$A_{MgO}^{batch} = \left(0.0148 + \frac{0.0149}{1 + e^{100d-9}}\right) M_{glass}^{batch} - M_{MgO}^{CRV}$$

All the glass formers have now been determined except for silica. To determine the amount of silica, everything else in the glass needs to be accounted for. Then, the mass that is missing is silica. Therefore,

Equation 3.1-32

$$M_{Total}^{CRV} = \sum \text{Oxide Masses}$$

The silica can now be calculated using Equation 3.1-33.

Equation 3.1-33

$$A_{SiO2}^{batch} = M_{glass}^{batch} - M_{Total}^{CRV} - A_{Al2O3}^{batch} - A_{B2O3}^{batch} - A_{Fe2O3}^{batch} - A_{TiO2}^{batch} - A_{ZnO}^{batch} - A_{ZrO2}^{batch} - A_{Na2O}^{batch} - A_{CaO}^{batch} - A_{Li2O}^{batch} - A_{MgO}^{batch} + \frac{M_{SO3}^{CRV}}{DF_{Sulfur}} + \frac{M_{Cl}^{CRV}}{DF_{Cl}} + \frac{M_{F}^{CRV}}{DF_{F}}$$

Notice that the mass in Equation 3.1-33 was adjusted for SO_3, Cl, and F because these constituents are semi-volatile and the decontamination factors (DF) account for how much actually enters the glass. This can be significant if a large amount of these constituents is present.

3.1.3.5.3 Bridge Between Melters and Glass Chemistry Modules and the Compound-Based Flowsheet

The melters and the glass chemistry logic is largely based on a convention known as "glass oxides." These glass oxides are generally elemental oxides that, when combined together, form more complicated compounds. For example, combining calcium oxide and sulfur oxide to form calcium sulfate.

Equation 3.1-34

$$CaO + SO_3 \rightarrow CaSO_4$$

However, with a compound-based flowsheet, the reverse needs to be done to interface with the glass chemistry and melter modules.

Equation 3.1-35

$$CaSO_4 \rightarrow CaO + SO_3$$

This section discusses how the interface between the compound-based flowsheet and the melter and glass chemistry logic modules is done. A simplified compound-based stream from a CRV is given below. Steps for converting a compound-based system to an oxide-based system and interfacing with the melter and glass chemistry logic modules are provided below. These steps are to convert compounds to basic oxides, calculate the total mass of each oxide, use glass formulation logic to calculate glass former additives, and apply the DFs to the blend of water and glass formers.

Table 3.1-4 Simplified Compound-Based CRV Stream

Component	Mass, kg
$Na_6(SO_4)_2CO_3$	10.00
$Na_3NO_3SO_4$	20.00
$NaAlCO_3(OH)_2$	40.00
$Na_2U_2O_7$-S	20.00
Na_3FSO_4-S	10.00
Total	100.00

3.1.3.5.3.1 Step 1 - Convert Compounds to Basic Glass (Elemental) Oxides

Make sure that the compounds can be broken down into basic elemental or glass oxides given in Table 3.1-5. If not, adjustment needs to be made. An example is the halides. Each one of these will substitute 0.5 moles of oxygen. Here are the breakdown equations for the above components.

Equation 3.1-36

$$Na_6(SO_4)_2CO_3 \rightarrow 3\ Na_2O + 2\ SO_3 + CO_2$$

Equation 3.1-37

$$Na_3NO_3SO_4 \rightarrow 1.5\ Na_2O + 0.5\ N_2O_5 + SO_3$$

Equation 3.1-38

$$NaAlCO_3(OH)_2 \rightarrow 0.5\ Na_2O + 0.5\ Al_2O_3 + CO_2 + H_2O$$

Equation 3.1-39

$$Na_2U_2O_7 \rightarrow Na_2O + 2UO_3$$

Equation 3.1-40

$$Na_3FSO_4 \rightarrow Na_2O + SO_3 + NaF$$

Sometimes oxygen may need to be supplied or removed to form the basic oxides. This can be accomplished by adding or taking oxygen from the melter plenum. For example, let us look at sodium nitrite.

Equation 3.1-41

$$NaNO_2 + 0.5\ O_2 \rightarrow 0.5\ Na_2O + 0.5\ N_2O_5$$

3.1.3.5.3.2 Step 2 - Calculate the Total Masses (M_i) of Each Glass (Elemental) Oxide

Calculate the waste oxide mass, M_i, in glass-oxide equivalents for each ion. Equation 3.1-42 calculates the waste oxide mass for sodium.

Equation 3.1-42

$$M_{Na2O} = (3 * Na_6(SO_4)_2CO_3 / MW(Na_6(SO_4)_2CO_3) + 1.5 * Na_3NO_3SO_4 / MW(Na_3NO_3SO_4) + 0.5 * NaAlCO_3(OH)_2 / MW(NaAlCO_3(OH)_2) + 1.0 * Na_2U_2O_7\text{-}S / MW(Na_2U_2O_7) + 1.0 * Na_3FSO_4\text{-}S / MW(Na_3FSO_4)) * MW(Na_2O)$$

where: Compounds are in kilograms
MW(*i*) is the molecular weight of component "*i*"

$$M_{Na2O} = (3 * 10 / 390.075 + 1.5 * 20 / 227.0378 + 0.5 * 40 / 143.9952 + 1.0 * 20 / 634.0331 + 1 * 10 / 184.0313) * 61.97894$$

$$M_{Na2O} = 26.89 \text{ kg}$$

Each constituent in the *Simplified Compound-Based CRV Stream* is broken down into its elemental oxides in the list below.

Table 3.1-5 Waste Oxide Makeup of Constituents

Component	M_i kg	$Na_6(SO_4)_2CO_3$ kgmole	$Na_3NO_3SO_4$ kgmole	$NaAlCO_3(OH)_2$ kgmole	$Na_2U_2O_7$ kgmole	Na_3FSO_4 kgmole
Na_2O	26.89	0.0769	0.1321	0.1389	0.0315	0.0543
Al_2O_3	14.16	NA	NA	0.1389	NA	NA
SO_3	15.51	0.0513	0.0881	NA	NA	0.0543
UO_3	18.04	NA	NA	NA	0.0631	NA
CO_2	13.35	0.0256	NA	0.2778	NA	NA
N_2O_5	4.76	NA	0.0440	NA	NA	NA
NaF	2.28	NA	NA	NA	NA	0.0543
H_2O	5.00	NA	NA	0.2778	NA	NA
Total	100.00	NA	NA	NA	NA	NA

3.1.3.5.3.3 Step 3 - Use Glass Chemistry Logic Modules to Calculate the Glass Additives Necessary and Their Amounts

Use the M_i values in the glass modules to calculate amounts of glass formers. For now, let us say the following glass formers were calculated for making the glass.

$A_{Na2O} = 5$ kg
$A_{SiO2} = 95$ kg

3.1.3.5.3.4 Step 4 - Apply DFs to the M_i and A_i Values

Apply the DFs to the oxides. For example:

Equation 3.1-43

$$O(\text{"Na2O"}) = {}^{1}/_{DF_{Na}} * (M_{Na2O} + A_{Na2O})$$

Equation 3.1-44

$$G(\text{"Na2O"}) = (1 - {}^{1}/_{DF_{Na}}) * (M_{Na2O} + A_{Na2O})$$

where:

O("*i*") is the kilograms of component "*i*" sent to the offgas
G("*i*") is the kilograms of component "*i*" made into glass

The list below shows the partitioning of the waste oxides per the DFs. Notice that the components remain in compounds and they add up to the total of the wastes (M_i) in and the glass formers additive (A_i).

Table 3.1-6 Partitioning of Waste Oxides per DFs

Component	$M_i + A_i$	DF	G_i, glass kg	O_i, offgas kg
Na_2O	31.89	50	31.2500	0.6378
Al_2O_3	14.16	100	14.0201	0.1416
SO_3	15.51	4	11.6314	3.8771
UO_3	18.04	80	17.8194	0.2256
CO_2	13.35	1	0.0000	13.3536
N_2O_5	4.76	1	0.0000	4.7574
NaF	2.28	3	1.5211	0.7605
H_2O	5.00	1	0.0000	5.0044
SiO_2	95.00	120	94.2083	0.7917
Total	200.00		170.4503	29.5497

3.1.3.5.4 Sulfur Melter Decontamination Factor as a Function of Sulfate Concentration

R&T data showed that the amount of sulfate retained by the glass is dependent upon how much sulfate is present. For example, if little sulfate is present, essentially all of it is absorbed into the glass. If a modest amount of sulfate is present, the glass absorbs only a fraction of it and the remainder leaves with the offgas.

To obtain a correlation, sulfate retention data from all the available R&T data on LAW small and pilot-scale melters were plotted. A plot of the data is shown in Figure 3.1-3. The data comes from Sub-Envelopes A1, A2, A3, B1, C1, and C2 runs with nominal sugar additions (0.5 stoichiometric ratio of sugar to the sum of nitrates and nitrites) and nominal simulants use.

Linear regression was performed to fit the line shown in Figure 3.1-3. This line was then translated to a melter DF equation. All the details, including analysis, reference R&T reports, and the empirical data used to obtain the correlation, are presented in CCN 177339. The melter DF (Equation 3.1-45) is as follows:

Equation 3.1-45

$$\text{MelterDF}_{\text{sulfur}} = \frac{1}{0.735 C_{SO3@100\%} - 0.216}$$

For $C_{SO3@100\,\%} \leq 0.294$, set $\text{MelterDF}_{\text{sulfur}} = 8000$

where:

1. $C_{SO3@100\,\%}$ is the SO_3 wt % concentration in the glass if all the SO_3 were to enter the glass.
2. Equation 3.1-45 is valid between 0.295 and 0.720 target wt % SO_3 concentrations.

3.1.3.5.4.1 Step 5 - Apply DFs to Organics and Then Oxidize Them

Some organics can escape the melter by evaporating and existing in the "shadow" of the cold cap. This is modeled by applying the DFs to the organics. However, the organics that remain shall be modeled as completely oxidized. Incomplete combustion will be factored in later to match R&T results (see Section 3.1.3.5.4.2, Step 6 - Plenum Reactions). The organic, acetamide (C_2H_5NO), will be used as an example.

Assume there are 10 kg of acetamide in the CRV stream and its DF is 10. Then,

Equation 3.1-46

$$O(\text{"}C_2H_5NO\text{"}) = {}^{1}/_{DF_{C2H5NO}} * (M_{C2H5NO}) = 1/10 * (10\text{ kg}) = 1\text{ kg } C_2H_5NO$$

Equation 3.1-47

$$C_2H_5NO + 2.75\ O_2 \rightarrow 2\ CO_2 + 2.5\ H_2O + 0.5\ N_2$$

Equation 3.1-48

$$\Delta M_{C2H5NO} = -(1 - {}^{1}/_{DF_{C2H5NO}}) * (M_{C2H5NO}) = -(1 - 1/10) * (10\text{ kg})$$
$$= -9\text{ kg } C_2H_5NO \text{ (or } -0.1524\text{ kgmole)}$$

Equation 3.1-49

$$\Delta M_{CO2} = 13.41\text{ kg } CO_2 \text{ (or } 0.3047\text{ kgmole)}$$

Equation 3.1-50

$$\Delta M_{H2O} = 6.86\text{ kg } H_2O \text{ (or } 0.3809\text{ kgmole)}$$

Equation 3.1-51

$\Delta M_{N2} = 2.13$ kg N_2 (or 0.0762)

Equation 3.1-52

$\Delta M_{O2} = -2.13$ kg O_2 (or 0.0762 kgmole)

Equation 3.1-53

$$\Delta M_{Total} = \Delta M_{C2H5NO} + \Delta M_{CO2} + \Delta M_{H2O} + \Delta M_{N2} + \Delta M_{O2}$$
$$= -9.00 + 13.41 + 6.86 + 2.13 - 13.41$$
$$= 0$$

3.1.3.5.4.2 Step 6 - Plenum Reactions

Sum up all of the individual gases produced in the melter and then distribute the masses between the gases per the following equations to agree with R&T observations.

Equation 3.1-54

$R_2O \rightarrow R_2O_{solid}$ (particulate to the offgas are calculated in Step 4: Section 3.1.3.5.3.4)

Equation 3.1-55

$SO_3 \rightarrow 0.99\ SO_2 + 0.01\ SO_3 + 0.4950\ O_2$

Equation 3.1-56

$CO_2 \rightarrow 0.999\ CO_2 + 0.001\ CO + 0.0005\ O_2$

3.1.3.5.4.3 Nitrogen Balance

There are numerous nitrogen-based gases given off by the melter. R&T results are based on NO_2, not the N_2O_5 used in this section. The logic for nitrogen balance will be performed on an NO_2 basis. The equations below provide the reactions used to track the nitrogen balance in the melter. See Section 3.2 for the details of developing the nitrogen balance with ammonia production.

Equation 3.1-57

$NO_2 + 0.0363\ H_2O \rightarrow 0.2546\ N_2 + 0.4239\ NO + 0.0428\ NO_2 + 0.763\ O_2 + 0.0242\ NH_3$

Rewriting the above equation for the nitrogen balance, using N_2O_5, gives the following:

Equation 3.1-58

$N_2O_5 + 0.725\ H_2O \rightarrow 0.5092\ N_2 + 0.8478\ NO + 0.0855\ NO_2 + 1.991\ O_2 + 0.0483\ NH_3$

The plenum reactions are presently in the Aspen Custom Modeler (ACM) flowsheet in the NO_2 format. The N_2O_5 format could be used in ACM to maintain oxygen and compound balance with the glass.

3.1.3.5.4.4 Example Offgas Calculation

Results of applying the offgas reaction equations to the offgas constituents are shown in the list below. Notice that the mass of the offgas increased 10 kg when the organic was added. However, the mass of the offgas remained the same as further adjustments were made to add in the new constituents. Making these adjustments will produce a melter offgas similar to that seen with the R&T pilot melter.

Table 3.1-7 Example Offgas Calculation Results

Component	R_2O	+10kg Organic	SO_2/SO_3	CO/CO_2	NO_x+NH_3
Na_2O	0.64	0.64	0.64	0.64	0.64
Al_2O_3	0.14	0.14	0.14	0.14	0.14
SO_3	3.88	3.88	0.04	0.04	0.04
UO_3	0.23	0.23	0.23	0.23	0.23
CO_2	13.35	26.76	26.76	26.73	26.73
N_2O_5	4.76	4.76	4.76	4.76	--
NaF	0.76	0.76	0.76	0.76	0.76
H_2O	5.00	11.87	11.87	11.87	11.87
SiO_2	0.79	0.79	0.79	0.79	0.79
C_2H_5NO	NA	1.00	1.00	1.00	1.00
N_2	NA	2.13	2.13	2.13	2.76
O_2	NA	-13.41	-12.64	-12.63	-9.77
CO	NA	NA	NA	0.02	0.02
SO_2	NA	NA	3.07	3.07	3.07
NO	NA	NA	NA	NA	1.12
NO_2	NA	NA	NA	NA	0.17
NH_3	NA	NA	NA	NA	0.04
Total	29.55	39.55	39.55	39.55	39.55

3.1.3.5.5 Sugar Addition

The addition of reductants to high-nitrate feeds is necessary to control melt foaming. Sugar has been selected as the baseline reductant for the WTP. The amount of sugar required increases with the amount of nitrates present in the feed but decreases with the amount of waste organics present in the feed, assuming they act as reductants. Excessive reductants can be deleterious, leading to over-reduction of the melt and formation of sulfides and molten metals. Consequently, the oxidants and reductants in the feed must be balanced. A convention to describe the amount of reductant used was devised. The most reducing potential reaction was chosen as the basis and *definition* of a "sugar ratio" of 1.0. Such a reaction, using sodium salts as an example, is provided in (Equation 3.1-59).

Equation 3.1-59

$$C_{12}H_{22}O_{11} + 8NaNO_3 \rightarrow 8CO_2 + 4CO + 4N_2 + 11H_2O + 4Na_2O$$

The precise stoichiometry of the reactions involved is neither known nor constant under the conditions prevailing in the melter. However, with this convention, a sugar ratio of 1.0 corresponds to 1 mole of sucrose per 8 moles of nitrate or, more generally, 1.5 moles of organic carbon per mole of nitrate. It is then expected that significantly less sugar than this will be required in practice. The empirically determined amount required to successfully control melt foaming without significantly reducing the glass melt was found to correspond to a ratio of 0.5 when any nitrites present were counted as nitrates (i.e., 0.75 moles of organic carbon per mole of nitrate + nitrite).

As an example, the calculation of the amount of sugar needed for the present Sub-Envelope A1 feed to achieve a sugar ratio of 0.5 proceeds as follows:

- One liter of feed slurry contains 1.857 moles of nitrite and 2.048 moles of nitrate, giving a total of 3.905 moles of (NO_2^- + NO_3^-).
- Required total amount of organic carbon for a sugar ratio of 0.5 is 3.905 x 0.75 = 2.929 moles.
- One liter of simulant contains 0.174 moles of organic carbon.
- Therefore, 2.929 - 0.174 = 2.755 moles of organic carbon must be added to the melter feed.

Since the molecular weight of sucrose is 342 g per mole, 2.755 x 342/12 = 78.51 g sugar must be added per liter of waste slurry (24590-WTP-PL-RT-01-002).

This approach has been employed for all WTP melter testing and was developed by Vitreous State Laboratory of The Catholic University of America (VSL) based on waste that was low in organics. This empirical approach does not distinguish between the relative reducing powers of organics present in the waste and those added as a reductant (sugar). A test performed on LAW Sub-Envelope C2 waste evaluated the various organic compounds (blend of waste organics, ethylenediamine tetra-acetic acid [EDTA], glycolic acid, and sugar) at various concentrations (ratio of 0.5, 0.6, and 0.75) to determine the effectiveness of each as a reductant (24590-101-TSA-W000-0009-98-00008). Results showed that sugar was the most effective reductant; however, no foaming or secondary sulfur phase was observed after any of the tests. Sugar was the only organic compound that was effective in increasing the partitioning of sulfur from the glass to the exhaust stream. Sugar was also the only organic compound that increased the amount of reduced iron in the glass and the only organic compound to reduce iodine emissions. The concentration of byproducts (hydrogen, ammonia, hydrogen cyanide, acetonitrile, and carbon monoxide) was similar for most tests except for EDTA, which had the highest emission rates of the listed byproducts. These tests showed that the organic compounds in the LAW waste streams are not as effective of a reductant as sugar. However, the reducing effects of the waste organics would not be ignored as was found during testing of LAW Semi-Integrated Pilot Plant waste under bounding total organic carbon (spiked with EDTA) and the high reductant conditions (0.95 sugar ratio). Under these conditions, auto discharging of foamy glass was frequent and the Fe^{++}/total Fe increased (24590-101-TSA-W000-0009-155-00003).

R&T has indicated that if the waste is made up of higher molecular weight organics, such as EDTA, this needs to be taken into account in the sugar addition calculation. If, however, the waste organics are made up of lower molecular weight organics, then the reducing effects of waste organics will be less and it may be necessary to exclude or use a weighting factor for the waste organics in the sugar calculation (24590-101-TSA-W000-0009-155-00003). This is because the low molecular weight organics will vaporize and

leave the feed at low temperatures without significantly affecting the redox state of the glass melt. The relative reducing power of each waste organic has not been quantified, but for the two Envelope C tanks (102-AN and 107-AN) which are relatively high in waste organics, melter tests have been performed. In the case of Sub-Envelope C1 (107-AN) simulant with 88 % of the carbon from the waste and only 12 % from sugar (at 0.5 nominal sugar), it was found that 20 % more sugar was required to prevent an accumulation of sulfate (24590-101-TSA-W000-0009-32-06, Rev 00D; 24590-101-TSA-W000-0009-98-06). It is recommended that for processing Sub-Envelope C1 a sugar ratio of 0.6 be used. In the case of Sub-Envelope C2 (102-AN), which has less waste organics (46 % of the carbon from the waste), no problems were encountered while processing at the nominal 0.5 stoichiometric ratio (24590-101-TSA-W000-0009-98-00008). It is expected that slight variations from the nominal value of 0.5 may be necessary to account for differences in the reducing power of waste organics in comparison to sugar, particularly for LAW streams that are high in organics.

Tests have shown that varying the sugar ratio does not impact production rate. In pilot melter tests with simulated A3 waste, reducing the sugar ratio from 0.5 to 0.35 and 0.25 did not impact the production rate significantly (24590-101-TSA-W000-0009-106-19).

3.1.3.5.6 Iron Redox State vs. Sugar Addition and Sulfate Retention

VSL bench-scale studies have shown that there is a relationship between how sugar affects the redox and retention of sulfur in the melter glass pool. The data plots, Figure 3.1-4 and Figure 3.1-5, are from report 24590-101-TSA-W000-0009-102-01, *DuraMelter 100 LAW Sub-Envelope A3 Variation Tests*. Figure 3.1-5 shows a plot of the effects of sugar on reducing iron in the glass. The percentage of reduced iron (% divalent iron, Fe^{+2}) increased predictably with increasing sugar ratios during the tests. The bubbling rate and melt pool temperature held constant. The bubblers supplied enough oxygen to oxidize the iron from about 55 % divalent iron to only 13 % divalent iron. However, as the iron was reduced, less sulfate was retained in the glass and a sulfate layer formed during the end of the tests as a result of increasing the sugar addition. The iron in the glass was again allowed to re-oxidize during the end of the tests. The amount of sulfur dissolved in the glass also increased from 0.12 to 0.27 % SO_3, presumably due to incorporation of sulfur from the salt layer and any residual cold cap material as a result of the increased sulfate solubility. This trend was consistent with measurements made on LAW glasses in crucible melts that were saturated with sulfur under controlled oxygen fugacity conditions. Data has suggested that the divalent iron concentration increases rapidly with reductant concentration after a certain threshold is reached, which is between 0.5 and 0.75 stoichiometric ratio for sugar.

Table 3.1-11 and Figure 3.1-4 show the measured divalent iron content of select glass samples with various organic combinations used as the reductant. The relationship portrayed in data plots can be incorporated into the flowsheets if studies were expected to deviate from the standard 0.5 sugar ratio.

3.1.3.5.7 Relationship Between Waste Loading and System Capacity

With two MFVs and two melters operating at 15 MTG/day each, the MFVs need to supply enough feed to make 15 MTG/day/melter. In this section, glass throughput will be translated into a relationship between batch volume, cycle times, and glass yield. The glass to be made at the WTP is an oxide glass. Therefore, the glass yield (in glass mass made per volume) of the feed is the same as oxide yield of the feed. The feed throughput of the system (liters/day) is the glass production rate (15 MTG/day/melter) divided by the glass yield (mass/L). For the purpose of discussing throughput, operation of the MFPV will be analyzed.

Equation 3.1-60

$$\text{Feed Throughput} = \frac{\text{Glass production}\,(15\,\text{MTG / day per melter})}{\text{glass yield of feed}\,(\text{mass / L})}$$

Equation 3.1-60 is the average throughput rate of the system and also the average melter feed rate. The glass production rate is straightforward, but the glass yield is a complicated function of the glass waste loading and feed composition.

The MFPV operates as a batch operation, so the instantaneous throughput rate is not the same as the average throughput rate (because the MFPV is idle most of the time). The average throughput rate in Equation 3.1-60 must equal the volume of feed in a MFPV cycle divided by the time of the cycle.

Equation 3.1-61

$$\text{MFPV throughput} = \frac{\text{Feed volume per cycle}}{\text{cycle time}}$$

Equation 3.1-62

where:

$$\text{Feed volume per cycle} = \frac{\text{glass produced per cycle}}{\text{glass yield}}$$

The MFPV achieves the required throughput when the throughput calculated in Equation 3.1-61 ≥ Equation 3.1-60. In a batch-operated vessel, the feed volume in Equation 3.1-39 must equal the batch volume of feed slurry available in the vessel. This is expressed mathematically as:

Equation 3.1-63

$$\text{MFPV throughput} = \frac{\text{Batch volume per cycle}}{\text{cycle time}}$$

A consequence of Equation 3.1-63 is that the cycle time must decrease if the batch volume decreases, provided the melter feed rate remains constant. Conversely, the cycle time can increase if the batch volume increases. The cycle time of the MFPV includes pumping time and time for glass former addition (24590-LAW-M4C-20-00002).

Per Equation 3.1-64, the glass yield of the feed is an important parameter in relation to throughput. The glass yield is the mass of glass made per volume of melter feed. The glass yield of a melter feed is a function of the glass waste loading and the oxide densities of the LAW concentrate and the glass formers.

Equation 3.1-64

$$\text{Glass Yield} = \frac{(V_c * \rho_{o,c}) + (V_{gf} * \rho_{o,gf})}{\text{Total Volume}}$$

where:

V_{gf} is volume of glass former solids
V_c is volume of LAW concentrate
$\rho_{o,gf}$ is oxide densities of glass former solids
$\rho_{o,c}$ is oxide densities of LAW concentrate

The right side of Equation 3.1-64 is equal to the glass yield (oxide mass/volume), because the volume terms in the numerator are canceled out by the volumes in the density terms. Equation 3.1-64 is related to waste loading (WL) in that:

Equation 3.1-65

$$WL = \frac{(V_c * \rho_{o,c})}{(V_c * \rho_{o,c}) + (V_{gf} * \rho_{o,gf})}$$

The right side of Equation 3.1-65 is equal to WL because all of the volume terms cancel out; the numerator becomes mass of waste oxide; and the denominator becomes total mass of oxide (mass of waste oxide plus mass of glass former oxide). During operations the WL, waste oxide density, and glass former compositions (which define the oxide density) will be calculated from analytical data (24590-WTP-PL-RT-02-001). From these data, the volumes transferred to the MFPV will be calculated. The volume fraction of glass formers to waste can be calculated by rearranging Equation 3.1-65, resulting in Equation 3.1-66:

Equation 3.1-66

$$V_{gf}/V_c = \frac{(\rho_{o,c})}{WL(\rho_{o,gf})} - \frac{\rho_{o,c}}{\rho_{o,gf}} \text{ or } = \frac{(\rho_{o,c})}{(\rho_{o,gf})}\left(\frac{1}{WL} - 1\right)$$

3.1.3.5.8 Rheology and Physical Property Data

Rheological bounding conditions were developed for two LAW WTP streams: 1) pretreated LAW and 2) LAW melter feed (24590-101-TSA-W000-0004-72-13). The bounding conditions are based on actual waste data, theoretical/empirical correlations, and the need to reduce plant operational risk. Information from previous actual waste characterization efforts was compiled and compared against the bounding conditions. Correlations for dimensionless groups influencing the following unit operations were used to guide bounding viscosity selection:

- Fluid flow (piping and pumps)
- Fluid mixing (mechanical agitators)
- Heat transfer (evaporation)
- Mass transfer/fluid flow (ion exchange (IX) columns)

Recovery from upset conditions was also considered as part of the unit operation evaluation as a method of reducing operation risk during the selection of bounding conditions, as well as conditions considered by previous vitrification plant designs. Summaries of the bounding condition for these two streams are shown in Figure 3.1-7 and Figure 3.1-8.

3.1.3.5.9 Pretreated LAW Rheology

Rheology data is available from radioactive LAW concentrate samples of waste from tanks AW-101 and AN-107 (TRPT-W375-00-00018). This data is available at sodium concentrations of 6, 8, and 10 M. No solids were observed in these samples, except for the 10 M AN-107 sample, where 1 % (by volume) solids formed immediately, and 70 % formed after 2 weeks. At high concentrations of glass formers, the melter feed exhibits a substantial increase in shear strength after sitting (McKeown and others 2001). Thus, the MFV and MFPV need to be agitated continuously.

The bounding rheology recommended for pretreated LAW is described as a Newtonian fluid (24590-101-TSA-W000-0004-72-13) with the following parameters:

- Minimum yield stress = 0 Pa, consistency = 0.9 mPa·s
- Maximum yield stress = 0 Pa, consistency 15 mPa·s

The minimum bound for pretreated LAW was established based on an engineering evaluation of settling velocities for 164 μm particles with a particle density of 3.6 g/mL in a liquid with density of 1 g/mL, and is consistent with the current glass former chemicals that will be added to the pretreated waste. The maximum bound rheology for pretreated LAW was selected to minimize performance losses (excessive pressure drops, low heat, and mass transfer coefficients) because of fluid viscosity in the IX columns and evaporators. Pumping requirements through a packed bed were also considered in the selection of the maximum bound rheology for pretreated LAW.

3.1.3.5.10 LAW Melter Feed Rheology

The rheological properties of melter feeds can be divided into two broad categories: Newtonian fluids and non-Newtonian fluids. Newtonian fluids have a constant viscosity at all shears placed on the fluid, and thus are easier to describe mathematically. The non-Newtonian melter feeds can be approximated as "Bingham Plastics," which is a type of non-Newtonian fluid. The definition of a Bingham Plastic (Perry and Green 1999) is a fluid with a positive shear stress (τ_y) at zero shear rate ($\gamma = 0$), such as Equation 3.1-67.

Equation 3.1-67

$$\tau=\tau_y+\mu_c\lambda$$

Here, μ_c = the consistency. The consistency is a type of viscosity. For a Bingham Plastic fluid, an initial shear strength needs to be overcome but the fluid's behavior is otherwise Newtonian.

Physical and rheological properties of simulated LAW melter feeds were systematically investigated over a total solids content (TSC) ranging from approximately 50 to 70 % for LAW Sub-Envelope A1, A2, A3, B1, B2, C1, and C2 feeds. WLs varied from approximately 3 to 30 % (24590-101-TSA-W000-0009-152-00001). The TSC was found to be one of the most important feed properties in determining rheological properties. Other factors that were found to have significant effects on the rheological properties of the melter feeds were suspended solids, pH, organic species and quantity, and particle size distribution. Based on data analysis from these studies, several qualitative and quantitative relations were derived. The empirical equation for apparent viscosity is:

Equation 3.1-68

$$\eta = a^{*}e^{n^{*}S}$$

where a and n are constants for each Sub-Envelope (24590-101-TSA-W000-0009-152-00001, Table 3.11). Increased aging time (1, 8, and 30 days) significantly increased both the apparent viscosity and the yield stress at the nominal and high sodium molarities. An increase of temperature from 25 to 40 °C tends to reduce the apparent viscosity, most significantly for Sub-Envelope B2 feeds at high sodium concentration and for Sub-Envelope C2 feeds at both nominal and high sodium molarities. Additional regression analyses resulted in the following empirical equations for the apparent viscosity at a shear rate of 190 s^{-1}:

Equation 3.1-69a

$$\ln\eta = \ln\left(\frac{0.00063}{R/P} - 0.00456\right) + 2.012\left(\frac{S}{W}\right)\left(\frac{R}{P}\right)$$

Equation 3.1-69b

$$\ln\eta = \ln\left(\frac{0.00063}{R/P} - 0.00456\right) + \left(279(TSC - 34.5)\left(\frac{R}{P}\right)\right)$$

when η = apparent viscosity (P)
R = ratio of total suspended solids (TSS) to sum of TSS and total dissolved solids (TDS)
P = pH
TSC = total solids content (%)
S = sodium molarity in waste
W = waste loading (%)

3.1.3.5.11 Bounding Rheology

The recommended LAW melter feed bounding rheology is described as a Bingham Plastic (24590-101-TSA-W000-0004-72-13) with the following parameters:

- Minimum yield stress = 0 Pa, consistency = 0.9 mPa·s
- Maximum yield stress = 15 Pa, consistency = 90 mPa·s
- Maximum Hedstrom number in 2-in. pipe<10^8

The minimum bound for LAW melter feed was selected based on providing consistency with the minimum bound for pretreated LAW. The maximum bound was selected based on the increased likelihood that flow in pipelines will remain in the turbulent flow regime (reducing the potential for solids settling during transfer) at velocities considered unlikely to produce equipment erosion. The Hedstrom number limit increases the material that can be pumped with conventional pumps.

A recent report (24590-WTP-RPT-PO-03-007) demonstrated that melter feeds with high solids contents (from having low WL) are excessively difficult to mix and pump. The pilot facility in Columbia, Maryland has maintained the water content of the melter feed between 36 and 40 wt %, regardless of feed envelope. This is because melter feed pumpability and melter throughput targets are assured within this

range. Therefore, the flowsheet has adopted this same practice (24590-WTP-RPT-PO-03-007). Water contents of 36 to 40 wt % are typical of Envelope A melter feeds with 8 M Na in the interstitial liquid and 20 wt % Na_2O loading in the target glass (24590-WTP-RPT-PO-03-007). Any required dilution of the feed will occur at the MFPV, because diluting prior to the MFPV would result in more frequent cycling of the CRV, which leads to higher sampling costs.

Pilot melter tests have investigated the impact of dilution on melter throughput (24590-101-TSA-W000-0009-49-04 and 24590-101-TSA-W000-0009-106-19). The table below is a summary of the dilution tests versus production rate for each envelope. The dilution was measured by sodium concentration and the water content of the feeds was not reported. The tests reveal that the glass production rate is impacted by dilution of the feed; however, even with a dilution of 30 % the target production rate of 1.5 $MT/m^2/day$ was still achieved. These results indicate that the pilot melter can achieve its throughput target even while treating feeds that have sodium molarities below those estimated by the *Basis of Design* (24590-WTP-RPT-PO-03-007).

Table 3.1-8 Summary of Dilution Tests vs. Production Rate for Each Envelope

Sub-Envelope	Sodium (Na) Molarity	Production rate ($MT/m^2/day$)	Percent Change
*A2	8 M (Nominal)	2.02 ± 0.12	NA
*A2	6.8 M (85 % of Nominal)	1.98 ± 0.13	2 %
*A2	5.6 M (70 % of Nominal)	1.87 ± 0.17	7 %
*B1	2.75 (Nominal)	2.20 + 0.16	NA
*B1	2.34 M (85 % of Nominal)	2.17 ± 0.14	1 %
*B1	1.93 M (70 % of Nominal)	1.77 ± 0.29	20%
**C2	5 M (Nominal)	2.10 ± 0.22	NA
**C2	4.25 M (85 % of Nominal)	2.02 ± 0.13	4 %
**C2	3.5 M (70 % of Nominal)	1.68 ± 0.26	20 %

* 24590-101-TSA-W000-0009-49-04, Rev 00B, *RPP-Pilot Melter Sub-envelope A2-B1 Changeover Test Results Report*, 2003.

** 24590-101-TSA-W000-0009-106-19, Rev 00B, *RPP-WTP Pilot Melter Sub-envelope C2-A3 Changeover Test Results Report.*

3.1.3.5.12 LAW Melter Feed Physical Properties

For all seven sub-envelopes, the TSC (%), and density, ρ (g/cm^3), increases with sodium molarity in the waste (S (M)) and decreases with waste loading (W%), as shown in the following equations (24590-101-TSA-W000-0009-152-00001):

Equation 3.1-70

$$TSC = (0.687/W + 0.599)*S + 34.51$$

Equation 3.1-71

$$\rho = (0.0120/W + 0.0019*S + 1.256$$

Also, TSC (%) and density ρ (g/cm^3) are correlated as follows:

Equation 3.1-72

$$TSC = 57.32 * \rho = 35.86$$

Test results indicate that when TSC is within 50 to 70 %, Sub-Envelopes A1 and A2 have a pH level of 11-13; Sub-Envelopes A3, B2, and C1 have a pH level of 8-9; and Sub-Envelopes B1 and C1 have a pH of 7-8.

3.1.3.5.13 Settled Solids

As stated earlier, the MFPV and MFV are continuously agitated. In the event of an agitator failure, solids in these vessels may settle. These settled solids will have to be resuspended when the agitator is returned to operation. A shear strength needs to be overcome to resuspend the settled solids. It is recommended in (24590-101-TSA-W000-0004-72-13) that:

- Settled solids shear strength < 625 Pa

The settled solids shear strength is limited to the increase in the likelihood of successful startup after an inadvertent shutdown. The table below contains the shear strength of the settled solids for various samples of melter feed made from actual waste. The limited data available came from documents TRPT-W375-00-00018 for tank AW-101 and WTP-RPT-064 for tank AP-101. In all cases, the data in this table was obtained on solids that were allowed to settle for 2 days.

Table 3.1-9 Shear Strength of Settled Solids

Sample	Temperature (°C)	Shear Strength (Pa)
AP-101, 6 M Na	40	790
AP-101, 8 M Na	40	79
AP-101, 8 M Na, 1 week	40	610
AP-101, 8 M Na, 1 week	23	2600
AW-101, 8 M Na, loose[a]	25	4.0-5.2
AW-101, 8 M Na, tight[a]	25	3.5-5.7

[a] These values were extrapolated from the flow curve rather than measured directly.

The data points above support a relationship between shear strength of the settled solids in the melter feed and the temperature. The 40 °C sample of AP-101 8 M has a shear strength of 610 Pa and the 23 °C sample has a shear strength of 2600 Pa, a value that greatly exceeds 625, the Pa limit. The 8 M Na AP-101 sample has a shear strength that is lower than the 6 M (79 versus 790 Pa), indicating that shear strength of settled solids in the melter feed cannot be directly controlled by controlling sodium molarity. Thus, the settled solids shear strength does not appear to be sensitive to flowsheet variables (such as the sodium concentration).

3.1.4 Ongoing Work and Potential Changes

In 2006, the External Flowsheet Review Team (EFRT) identified issues with the sampling system that may prove inadequate for handling slurries (technical issue P9, Undemonstrated Sampling System). The EFRT recommended the completion of previously planned R&T testing to ensure the sampling system's overall effectiveness. These tests planned to use HLW and LAW waste and melter feed simulants representing the low and high bounds of rheology. The chemical analyses of the statistically designed matrix is used to establish the variability and bias in the measurements of simulant compositions in the agitated vessel, sample transfer line, and that obtained using the in-line Isolok sampler. Three LAW and all HLW tests have been completed.

3.1.5 References

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24590-LAW-M6C-LFP-00001, Rev 001, *LFP-VSL-00001 and LFP-VSL-00003 Sizing.*

24590-LAW-M6C-LFP-00002, Rev 001, *LAW Melter 1, 2 & 3 Feed Vessels: LFP-VSL-00002, 00004, & 00006.*

24590-LAW-MFD-LCP-00004, Rev 002, *24590-LAW-MF-LCP-AGT-00001-Agitator/Mixer.*

24590-LAW-MPD-LCP-00001, Rev 006, *LCP-PMP-00001A/B - Melter 1 Concentrate Receipt Pumps.*

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Table 3.1-10 Minerals Used as Glass Formers and Their Contaminants

Mineral	For	Bulk Formula	Al_2O_3	B_2O_3	CO_2	CaO	CdO	Cl	Cr_2O_3	Fe_2O_3	H_2Ob	HfO_2	K_2O	Li_2O	MgO	Mn_2O_3	Na_2O	Nb_2O_5	NiO	P_2O_5	PbO	SO_3	SiO_2	ThO_2	TiO_2	V_2O_5	ZnO	ZrO_2	Total	Total Glass Ox.
ppm (mass basis)																														
Kyanite	Al_2O_3	Al_2SiO_5	570,000			400				7100			700		400		400						410,500		10,500				1,000,000	1,000,000
Borax	B_2O_3	$Na_2B_4O_7{\cdot}10H_2O$		375,000				700		43	456,757						167,000					500							1,000,000	543,243
Boric Acid	B_2O_3	H_3BO_3		565,300				18		9	434,382											292							1,000,000	565,618
Wollastonite	CaO	$CaSiO_3$	2000			475,000				4000					1000	1113							516,687		200				1,000,000	1,000,000
Iron Oxide	Fe_2O_3	Fe_2O_3	15,000			400				965,373					1000	1293				2635		799	13,500						1,000,000	1,000,000
Lithium Carbonate	Li_2O	Li_2CO_3			596,454	14		100		400				402,000	995		4					33							1,000,000	403,546
Olivine	MgO	Mg_2SiO_4-Fe_2SiO_4	1900			200			1300	76,800			100		480,100		200		3700				435,700						1,000,000	1,000,000
Soda Ash	Na_2O	Na_2CO_3			414,300	49		182		3	200				41		585,168					56							1,000,000	585,500
Silica	SiO_2	SiO_2	1350			80				160			170		80		20						998,060		80				1,000,000	1,000,000
Rutile	TiO_2	TiO_2	5000						1600	7000								4000		458		250	22,000		936,192	4500		19,000	1,000,000	1,000,000
Zinc Oxide	ZnO	ZnO					50			10							200				10						999,730		1,000,000	1,000,000
Zircon Sand	ZrO_2	$ZrSiO_4$	2500							750		65,500											340,250	450	1050			589,500	1,000,000	1,000,000
Sugar	Reductant	$C_{12}H_{22}O_{11}$			421,069						578,931																		1,000,000	0
Lb/Lb (kg/kg) gf oxide requested																													gf Solids	Gases	Total
Kyanite-Al	Al_2O_3	Al_2SiO_5	0.96692			0.00068				0.01204			0.00119		0.00068		0.00068								0.01781				1.00000	0.00000	--
Kyanite-Si	Al_2O_3																						0.69635						0.69635	--	1.69635
Borax-B	B_2O_3	$Na_2B_4O_7{\cdot}10H_2O$		0.99670				0.00186		0.00011	1.21399											0.00133							1.00000	1.21399	--
Borax-Na	B_2O_3	$Na_2B_4O_7{\cdot}10H_2O$															0.44386												0.44386	0.00000	2.65786
Boric Acid	B_2O_3	H_3BO_3		0.99944				0.00003		0.00002	0.76798											0.00052							1.00000	0.76798	1.76798
Wollastonite-Ca	CaO	$CaSiO_3$	0.00414			0.98280				0.00828					0.00207	0.00230									0.00041				1.00000	0.00000	--
Wollastonite-Si	CaO	$CaSiO_3$																					1.06905						1.06905	--	2.06905
Iron Oxide	Fe_2O_3	Fe_2O_3	0.01500			0.00040				0.96537					0.00100	0.00129				0.00264		0.00080	0.01350						1.00000	0.00000	1.00000
Lithium Carbonate	Li_2O	Li_2CO_3			1.47803	0.00003		0.00025		0.00099				0.99617	0.00247		0.00001					0.00008							1.00000	1.47803	2.47803
Olivine-Mg	MgO	Mg_2SiO_4-Fe_2SiO_4	0.00390			0.00041			0.00267				0.00021		0.98482		0.00041		0.00759										1.00000	0.00000	
Olivine-Si	MgO	Mg_2SiO_4-Fe_2SiO_4																					0.89374						0.89374	--	--
Olivine-Fe	MgO	Mg_2SiO_4-Fe_2SiO_4								0.15754																			0.15754		2.05128
Soda Ash	Na_2O	Na_2CO_3			0.70760	0.00008		0.00031		0.00000	0.00034				0.00007		0.99943					0.00010							1.00000	0.70794	1.70794
Silica	SiO_2	SiO_2	0.00135			0.00008				0.00016			0.00017		0.00008		0.00002						0.99806		0.00008				1.00000	0.00000	1.00000
Rutile	TiO_2	TiO_2	0.00500						0.00160	0.00700								0.00400		0.00046		0.00025	0.02200		0.93619	0.00450		0.01900	1.00000	0.00000	1.00000
Zinc Oxide	ZnO	ZnO					0.00005			0.00001							0.00020				0.00001						0.99973		1.00000	0.00000	1.00000
Zircon-Zr	ZrO_2	$ZrSiO_4$	0.00379							0.00114		0.09928												0.00068	0.00159			0.89352	1.00000	0.00000	--
Zircon-Si	ZrO_2	$ZrSiO_4$																					0.51573						0.51573	--	1.51573
Sugar	Reductant	$C_{12}H_{22}O_{11}$			0.42107						0.57893																		0.00000	1.00000	1.00000

Note: Boric acid and sugar do not actually contain molecular water, and that sugar, sodium carbonate, and lithium carbonate do not actually contain molecular carbon dioxide. They are tracked as having water and carbon dioxide in them because they can be broken down into mass units that have the same stoichiometry as water and carbon dioxide.

Table 3.1-11 Summary of Stoichiometric Ratio vs. Fe + 2/Total Fe

Test	Stoichio-metric Ratio	Description	%Fe+2/ Total Fe
24590-101-TSA-W000-0009-155-00003	0.5	SIPP Sub-Envelope A2	4-6 %
	0.95	SIPP Sub-Envelope A2 with Sugar and added EDTA	16-30 %
24590-101-TSA-W000-0009-102-01	0.5	Sub-Envelope A3 with Sugar	<0.8 %
	0.75	Sub-Envelope A3 with Sugar	16-21 %
	1	Sub-Envelope A3 with Sugar	26-45 %
	1.25	Sub-Envelope A3 with Sugar	55-65 %
24590-101-TSA-W000-0009-98-00008	0.5	Sub-Envelope C2 with Sugar	3.7 %
	0.5	Sub-Envelope C2 with 48 % Sugar +52 % Waste Organics	3.1 %
	0.5	Sub-Envelope C2 with 24 % Sugar + 76 % Waste Organics	1.5 %
	0.5	Sub-Envelope C2 with only Waste Organics	<0.8
	0.6	Sub-Envelope C2 with Sugar	2.8-2.9 %
	0.6	Sub-Envelope C2 with 48 % Sugar/52 % Waste Organics	4.9-3.7 %
	0.6	Sub-Envelope C2 with Waste Organics	3.9-4.5 %
	0.6	Sub-Envelope C2 with EDTA	3 %
	0.75	Sub-Envelope C2 with Sugar	22-32 %
	0.75	Sub-Envelope C2 with 48 % Sugar + Waste Organics	6%
	0.75	Sub-Envelope C2 with only Waste Organics	3 %

Figure 3.1-1 LAW Melter Feed Process

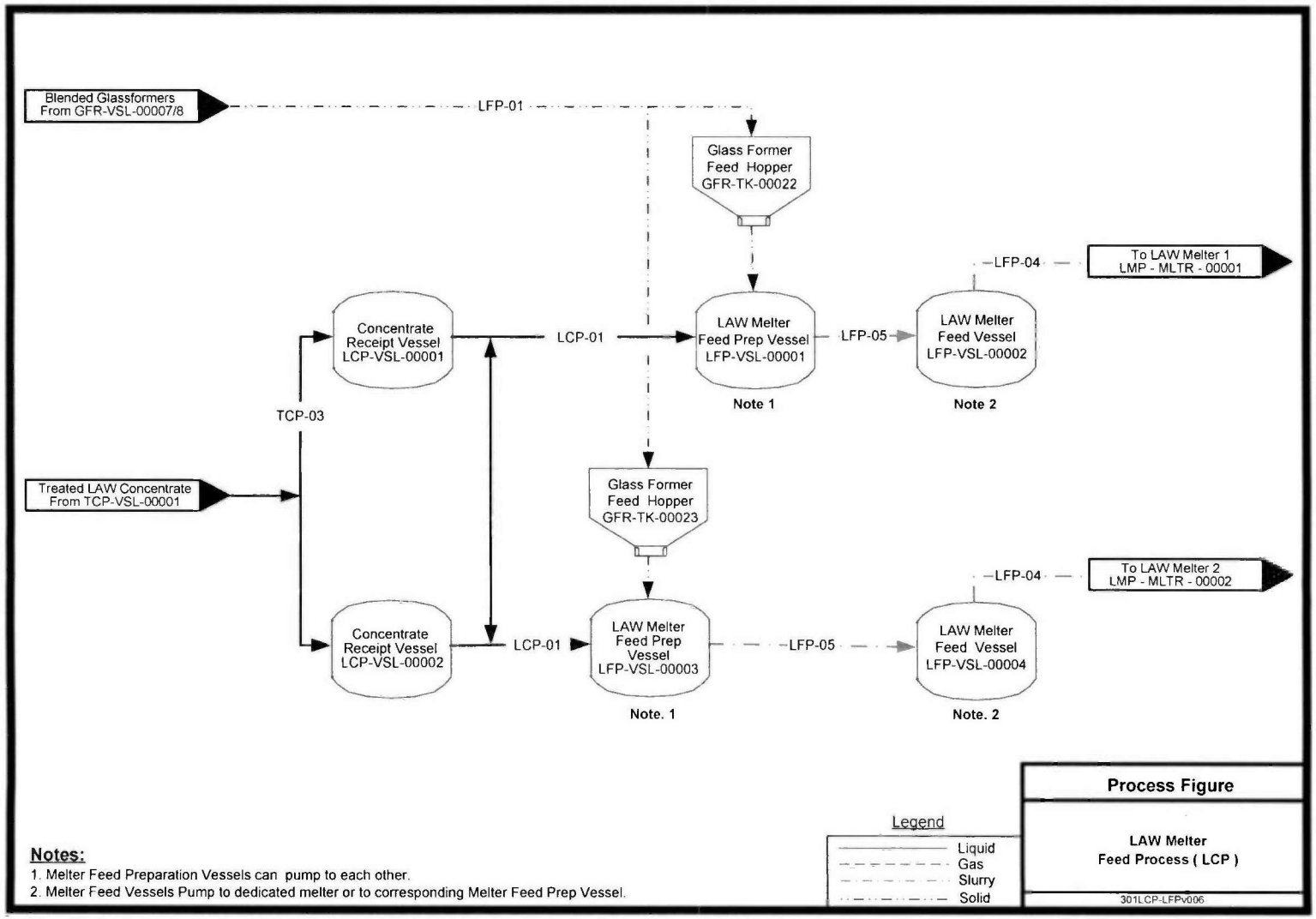


Figure 3.1-2 Na_2O Mass Fraction in ILAW as a Function of SO_3 Mass Fraction (24590-LAW-RPT-RT-04-0003)

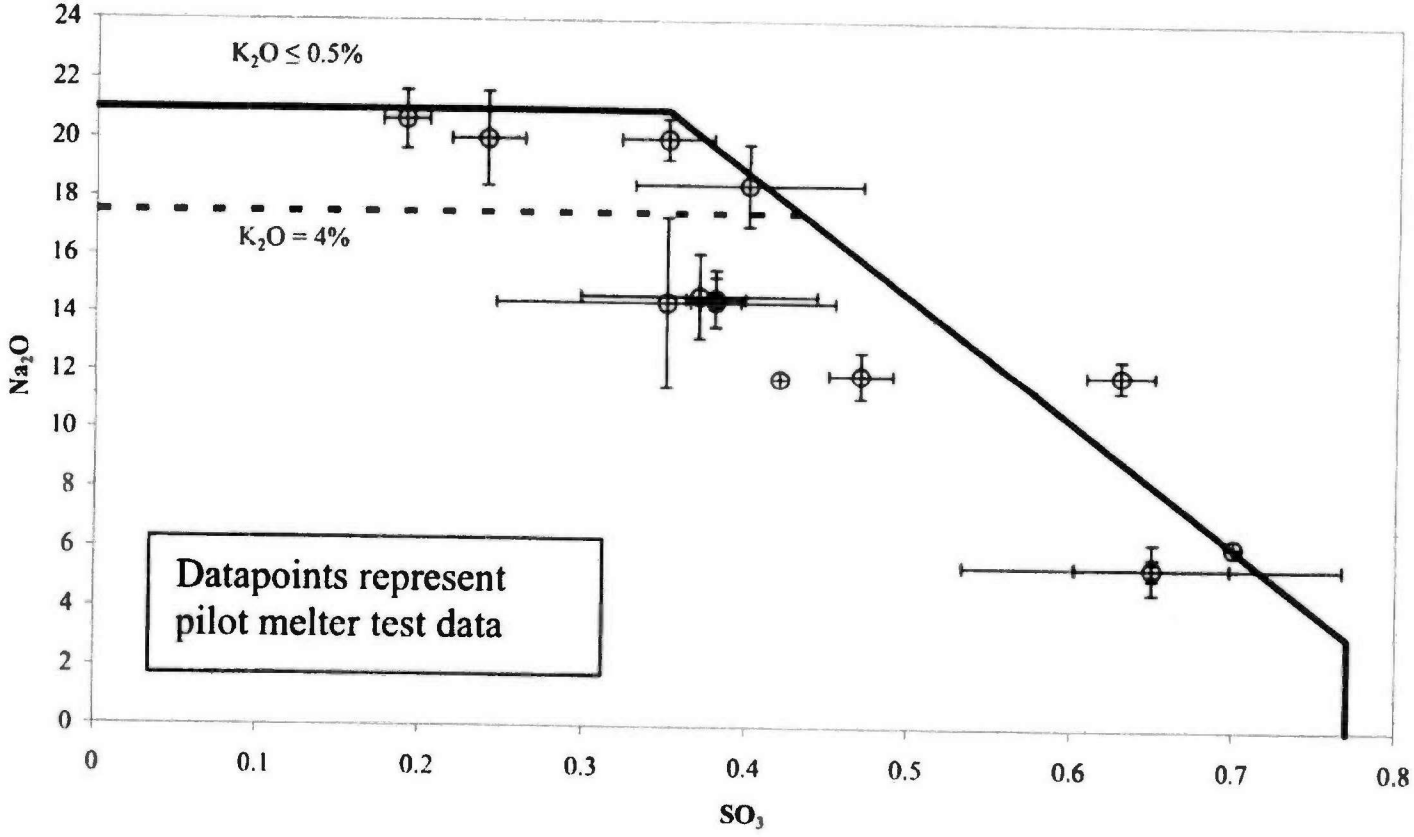


Figure 3.1-3 SO_3 Retention in Glass as Function of SO_3 Level

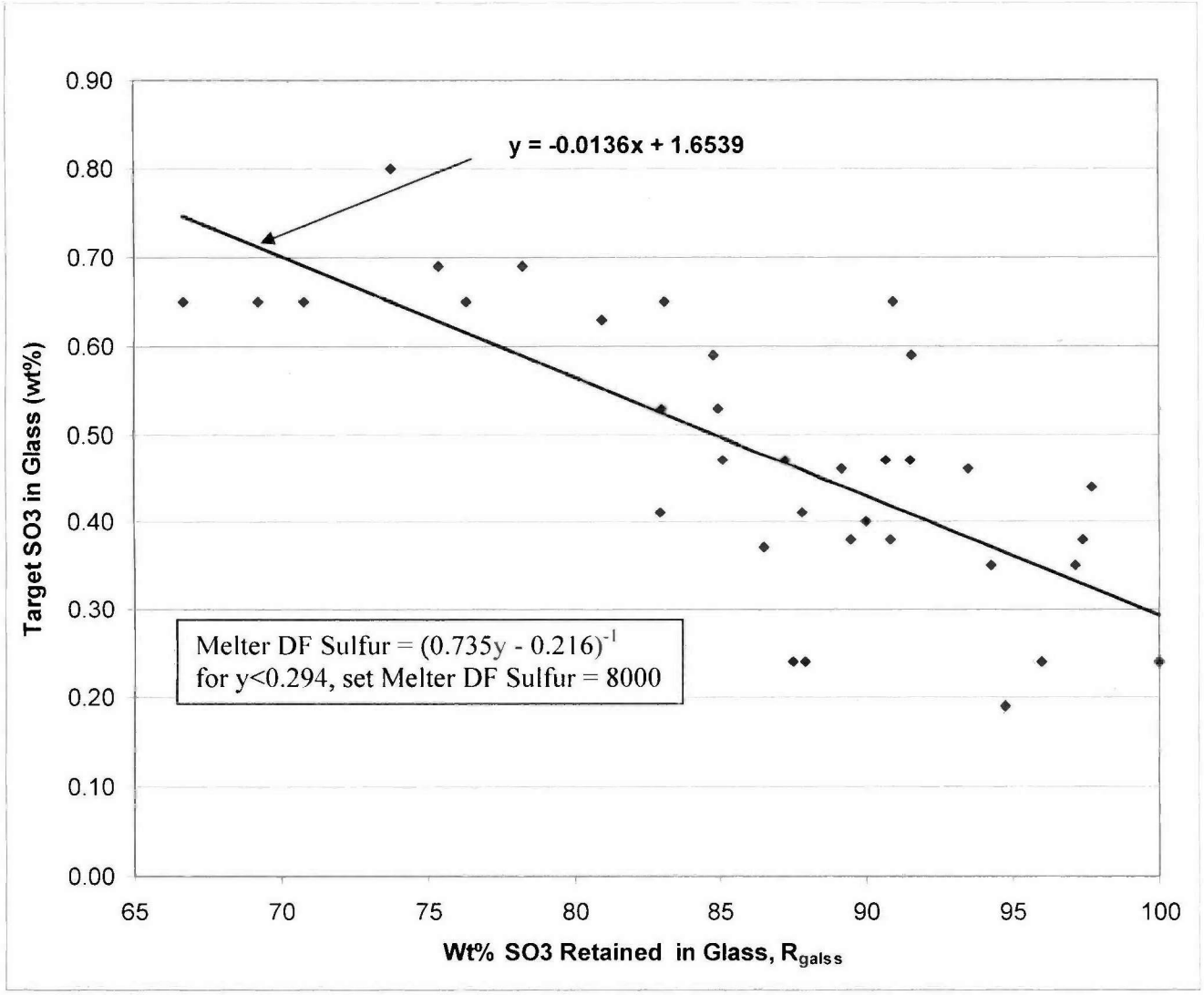


Figure 3.1-4 Sulfur Content of Discharged Glasses vs. Iron Oxidation State in Envelope A3 Glass

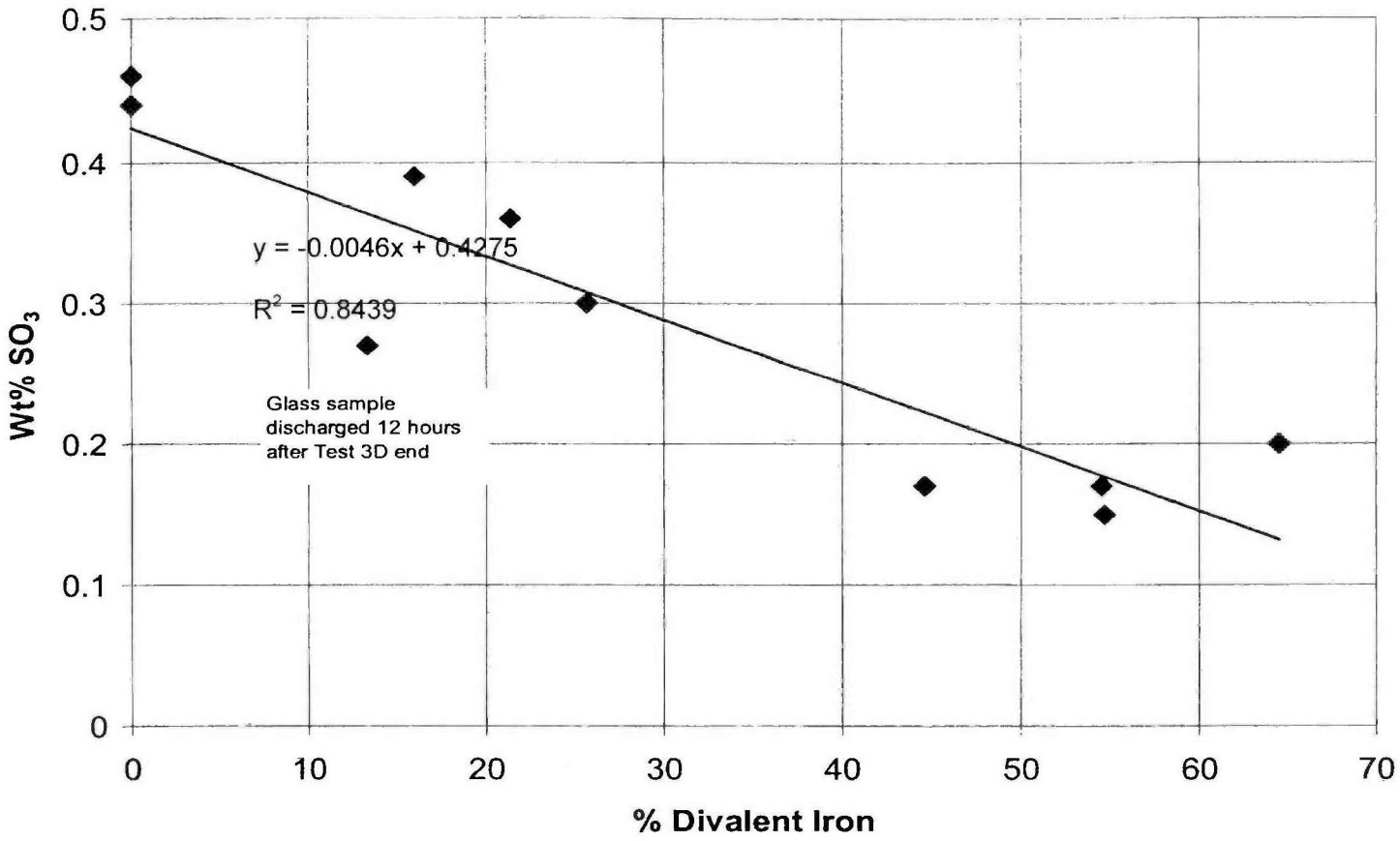


Figure 3.1-5 Effects of Sugar Ratio on Sulfur Emissions and Iron Oxidation State in Envelope A3 Glass

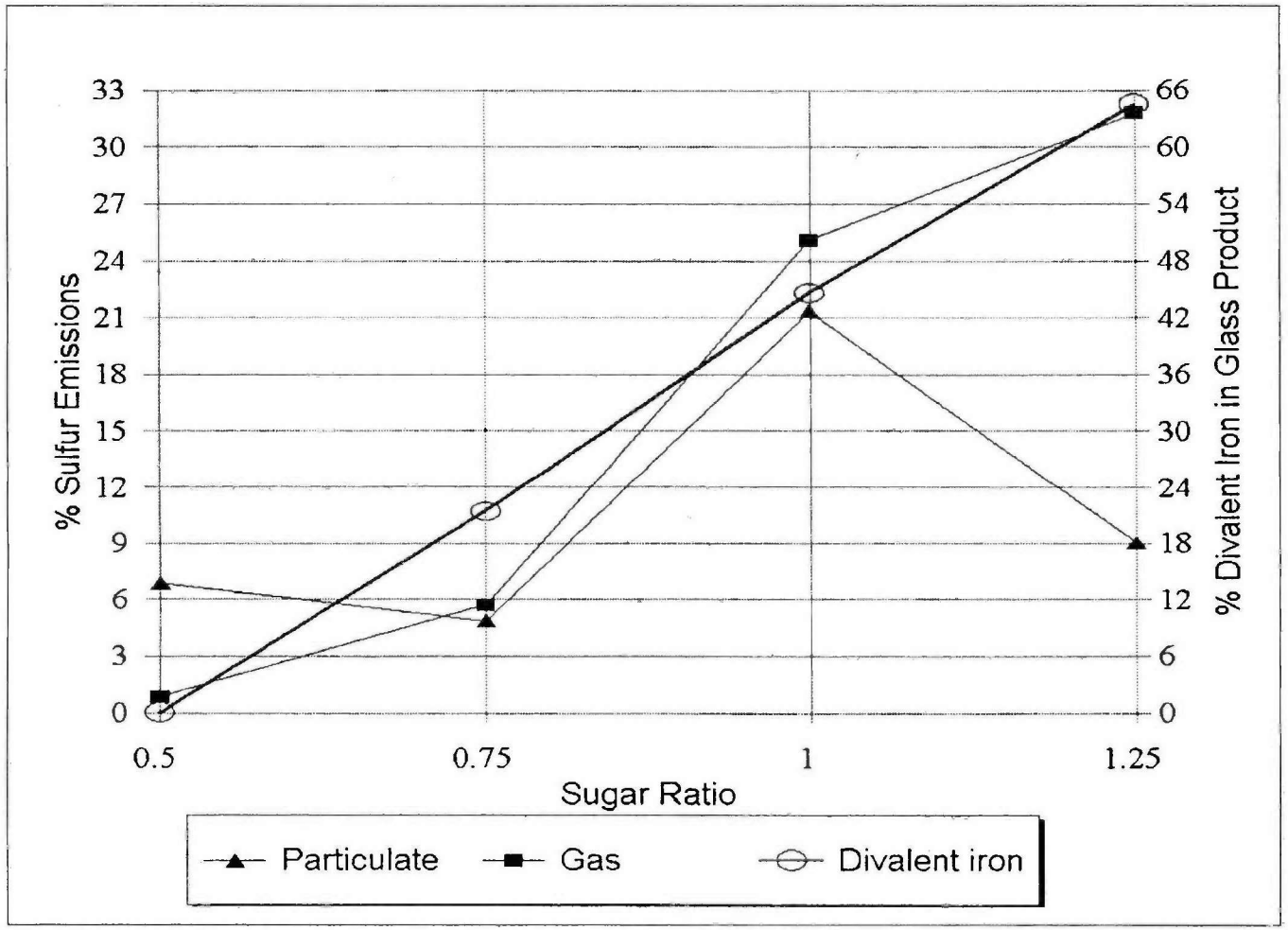


Figure 3.1-6 Sugar Ratio vs. % Fe + 2/Total Fe

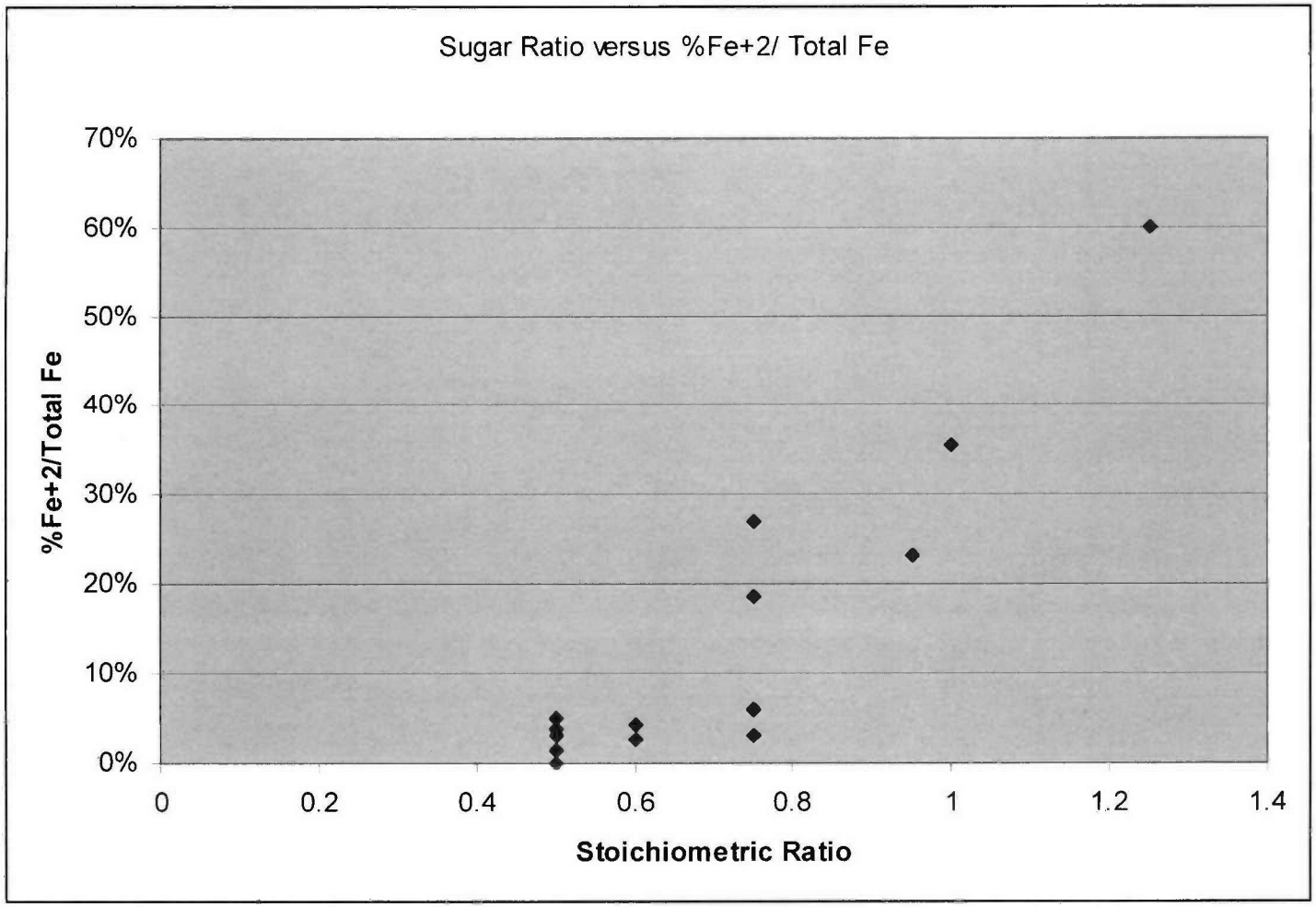
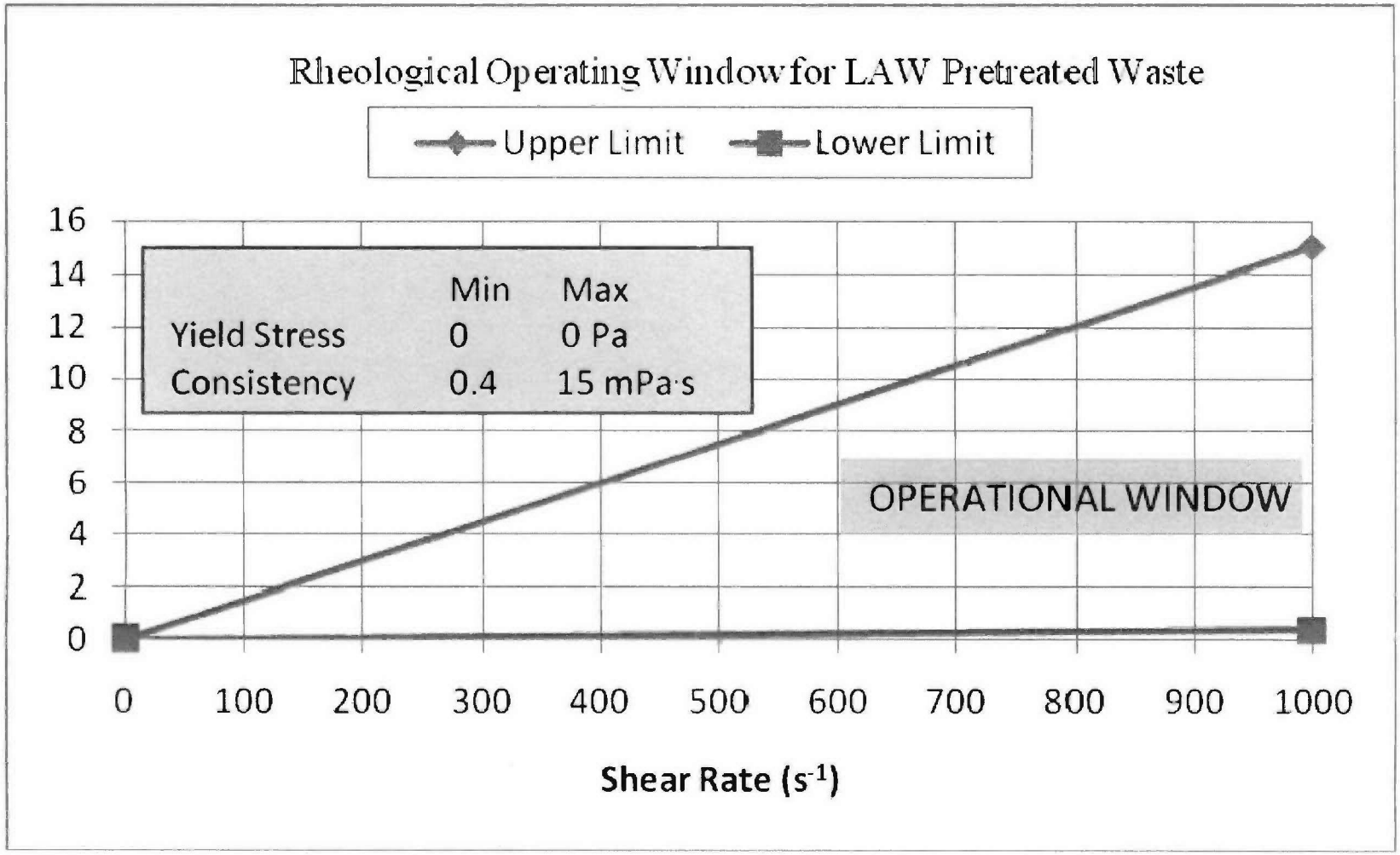
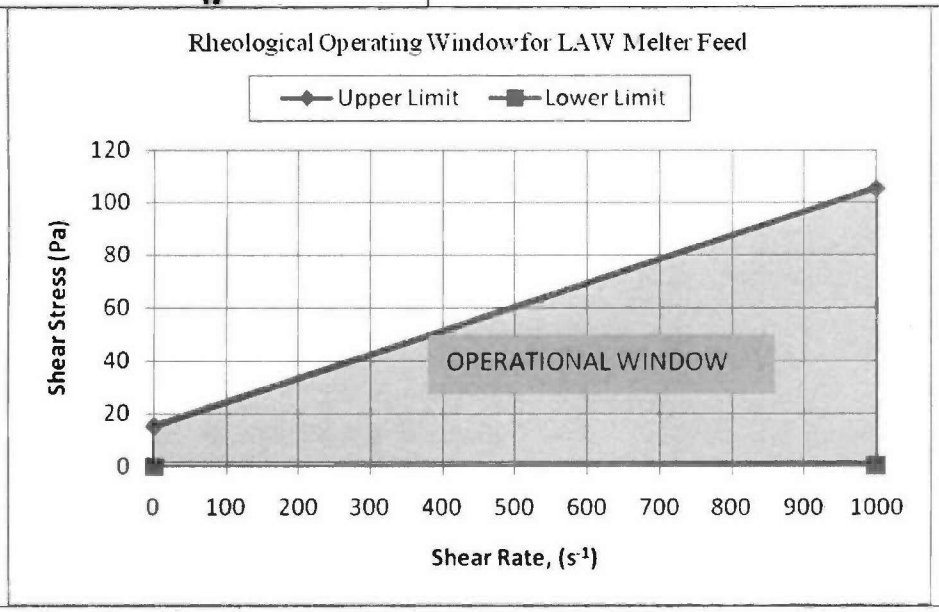


Figure 3.1-7 Summary of Bounding Conditions for LAW Pretreated Waste



Source: 24590-101-TSA-W000-0004-72-13, Rev B, *Technical Basis for LAW Vitrification Stream Physical and Rheological Property Bounding Conditions.*

Figure 3.1-8 Summary of Bounding Conditions for LAW Melter Feed

	Category	Value	Application
Bounding Conditions	Maximum Settled Solids Shear Strength	< 625 Pa	Plant Upset Conditions
	Maximum Hedstrom Number in 2-in. Pipe $N_{He} = \frac{D^2 \rho \tau_y}{K^2}$	$< 10^8$	Pumping
			Pumping, Mixing, Erosion, Settling in Pipes

Source: 24590-101-TSA-W000-0004-72-13, Rev. 00B, *Technical Basis for LAW Vitrification Stream Physical and Rheological Property Bounding Conditions.*

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3.2 System LMP: LAW Melter Process

3.2.1 Function and Requirements

3.2.1.1 Melter Facility Function and Requirements

The function of the low-activity waste (LAW) melter process system (LMP) is to convert LAW into glass via joule-heated melters. Heat decomposes the waste into elemental oxides (and other minor constituents), which dissolve into the glass pool in each melter and moist gases that exit each melter's plenum. Glass discharges from the melters into large cylindrical steel containers, where it cools. The sealed containers of glass become the immobilized low-activity waste (ILAW) for disposal at the Hanford Site.

Moist gases from the melter plenum enter a film cooler attached to each melter. The primary function of a film cooler is to help prevent deposits from forming in the offgas piping, as the offgas cools.

WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7(b)(2):

> *Initial Treatment Capacity Requirements: The LAW Vitrification Facility shall be designed to support a facility design capacity of 30 MTG/day. The LAW Vitrification Facility shall be capable of vitrifying treated LAW Envelopes A, B, and C in compliance with the waste loading specifications identified in Specification 2.2.2.2., Waste Loading.*

WTP SOW, Facility Specification, Section C.7(c)(1):

> *Waste Treatment and Immobilization Plant Expandability Requirements: The LAW facility design shall not preclude installation of a third melter, melter power and control systems, melter feed, offgas treatment, container handling, HVAC, and other systems and components not initially installed. The capacity to expand the waste treatment shall be consistent with an increase in the design capacity of 30 MTG/day to 45 MTG/day.*

WTP SOW, Operational Specification, Section C.8, Specification 2.2.2.2:

> *Waste Loading: The loading of waste sodium from Envelope A in the ILAW glass shall be greater than 14 weight percent based on Na_2O. The loading of waste sodium from Envelope B in the ILAW glass shall be greater than 3.0 weight percent based on Na_2O. The loading of waste sodium from Envelope C in the ILAW glass shall be greater than 10 weight percent based on Na_2O.*

WTP SOW, Operational Specification, Section C.8, Specification 2.2.2.4:

> *Mass: The mass of each package shall not exceed 10,000 kilograms.*

WTP SOW, Operational Specification, Section C.8, Specification 2.2.2.5:

> *Void Space: The void space in the container shall not exceed 10 percent of the total internal volume at the time of filling, excluding void space internal to the glass waste form (e.g., small bubbles in the glass). After cooling, if necessary, the container shall be filled with suitable inert dry filler such that the void space meets the requirements of*

Dangerous Waste Regulation WAC 173-303-665 (12); i.e., the container shall be at least ninety (90) percent full when placed in the landfill.

The waste treatment capacity for the LAW Facility is 21 metric tons of glass (MTG)/day, which is 70 % of the facility design capacity.

3.2.1.2 Glass Function and Requirements

The glass must be homogeneous and have the following qualities to be compatible with the melters (24590-LAW-3PS-AE00-T0001):

Viscosity:	10 to 150 poise at 1100 °C with 30 to 50 poise at 1150 °C optimal
Electrical conductivity:	0.1 to 0.7 S/cm at 1100 to 1200 °C
Liquidus temperature:	< 950 °C

The radionuclide concentration of the glass shall be less than the Class C limits as defined in 10 CFR 61.55 and as described in the US Nuclear Regulatory Commission's *Branch Technical Position on Concentration Averaging and Encapsulation.* In addition, the rolling average glass concentrations for the more significant nuclides are:

^{137}Cs is < 3 Ci/m^3 *
^{90}Sr is < 20 Ci/m^3

*A ten-fold reduction in this value is required by SOW Section C.7.d.1.iii, which reads: "In addition, ^{137}Cs will be further removed [in reference to the Cs exchange columns], to achieve a 0.3 Ci/m^3 in the ILAW product, to facilitate the maintenance concept established for the ILAW melter system."

The sodium waste loading (wt % Na_2O in glass) for Envelope A shall be greater than 14 wt %. For Envelope B it shall be greater than 3.0 wt %. For Envelope C it shall be greater than 10 wt % (SOW Section C.8 Specification 2.2.2.2).

The LAW glass must meet land disposal restriction (LDR) requirements in 40 CFR 268, *Land Disposal Restrictions*. The high level waste vitrification technology-based treatment standard (HLVIT) has been identified as the LDR treatment standard for a number of the ILAW metals and anions in Table 3.2-1. However, a few constituents of potential concern (COPC) (i.e., Be, Ni, Sb, and Tl) are not included in the HLVIT standard and still subject to the LDRs unless otherwise granted a variance under 40 CFR 268.44(h). In order to qualify Hanford tank waste for land disposal, the US Department of Energy (DOE) is seeking a treatability variance for the Hanford tank waste. The *Land Disposal Restriction Treatability Variance Petition for Hanford Tank Waste* (24590-WTP-RPT-ENV-03-003) requests a technology-based treatability variance for Be, Ni, Sb, and Tl based on data indicating that the WTP vitrification process is a best demonstrated available technology, the only commercially available technology, and will substantially diminish the toxicity and mobility of the hazardous constituents in the waste and the likelihood of their migration from the waste so that short-term and long-term threats to human health and the environment are minimized. Accordingly, glass function and requirements for compliance of ILAW with LDRs do not currently exist.

3.2.2 Process Description

Two melters are required to meet the SOW production rates. Each melter train consists of a dedicated melter feed vessel and film cooler. Each melter produces 15 MTG/day. A total of 30 MTG/day are made when both melters are operating. The equipment numbers are:

Melter Train	Melter Equipment No.	Film Cooler Equipment No.	Feed Vessel Equipment No.
Melter 1	LMP-MLTR-00001	LOP-FCLR-00001	LFP-VSL-00002
Melter 2	LMP-MLTR-00002	LOP-FCLR-00003	LFP-VSL-00004

Because the melters are identical, with the same functions and requirements, only one system is described.

The melters convert treated LAW concentrate with glass formers into molten glass. Each melter is supplied by its own melter feed vessel. The treated LAW with the appropriate glass formers is fed as a slurry to the melter via six nozzles and pumps. Up to six nozzles can be used to spread the slurry over the molten glass pool in the melter. The slurry feed system is described in Section 3.1. The film cooler is considered part of the primary offgas system, but is described here with the melter system. Offgases from the melter are described in Section 3.3. The glass is discharged into large stainless steel disposal containers. The handling of the containers is described in Section 3.7. The simplified LMP system is depicted in Figure 3.2-3.

The melter maintains a large pool of molten glass at approximately 1150 °C. During steady-state operating conditions, a cold cap forms on the molten glass. The following processes take place simultaneously within the cold cap and the top layer of the molten glass as the temperature increases from ambient to melt pool temperature:

- Volatile compounds in the feed evaporate
- Feed is dried
- Compounds of the dried feed such as hydroxides and carbonates decompose at higher temperatures and are converted into oxides and gases
- Oxides dissolve into the molten glass pool to form more glass
- Generated gases and evaporated water enter the melter plenum, typically at 350 to 600 °C

Slurry is fed to the LAW melter via air displacement slurry (ADS) pumps, which deliver the feed continuously in small pulses. Each melter feed vessel has six pumps that deliver slurry to the melter through six nozzles.

The film cooler reduces the amount of deposits accumulating in the offgas piping by creating a layer of gas along pipe walls where semi-volatile materials would normally condense.

Temperature in the glass pool is maintained by joule heating (electrical resistance heating). The joule heating is accomplished by passing alternating current directly through the molten waste glass. Electricity imparts its energy as heat as it passes through the glass pool. Electricity is delivered to large Inconel electrodes in the glass pool. Enough electricity (heat) needs to be supplied for dissolution of components into the glass pool, heating of components to glass pool temperature, decomposing the waste

and glass formers, vaporizing feed water, heating air in-leakage and air to bubblers and purges, and overcoming heat losses throughout the melter.

The "melters" do not melt glass, but are actually high-temperature "dissolvers." The waste (as oxides) dissolves in the glass. The glass acts as the solvent. Most of the oxides have higher melting points than the glass they make. Consequently, the oxides in the cold cap dissolve into the glass pool to form more glass. Glass can only be made at the rate that oxides in the cold cap can dissolve into the glass pool. Adding more heat to the melter has little effect on glass production rates (Hrma 1982). However, agitation can affect glass production rates. Bubblers are used to inject air that agitates the glass pool, delivering heat and fresh molten glass to the cold cap. Bubblers also help to maintain a consistent temperature profile throughout the molten pool, which in turn helps to control electrical current.

Glass discharges from the melter from one of two discharge chambers. The glass must first enter through a port near the bottom of the glass pool into a riser. Air is bubbled into the bottom of this chamber to displace molten glass and cause it to overflow a weir and flow down a trough. Glass falls off the edge of the trough into a disposal container. Glass is poured when the glass level in the melter is high, and is stopped when a low glass level is achieved. The discharge chambers are heated with electrical resistance heaters to keep the discharging glass hot and free-flowing.

The melter walls are lined with refractory bricks. Cooling panels for the melter walls and bottom are required to keep glass from creeping between the bricks to the outside. The discharge chamber walls have cooling panels. The melter lid previously lacked cooling panels, but they have since been incorporated into the lid design to meet operational safety requirements.

Three pneumatic probes positioned at various elevations in the melter detect glass pool level. The probes are fabricated from Inconel 690 and are designed to be replaceable. Level measurement is used to indicate when to start and stop glass discharge. Alarms are provided for high or low levels.

The melter offgas system maintains the melter plenum at a slightly negative pressure. Offgas could escape from the melter if the melter became pressurized. A standby offgas line backs up the main offgas line. If a steam surge were to occur that overwhelms both offgas lines, there is a relief vent that discharges to the wet process cell.

Power to the melter electrodes is single-phase alternating current applied across opposing electrodes. The average glass pool temperature is determined by averaging several thermocouples throughout the glass pool. Electrode power is controlled via a temperature loop cascaded to a power control loop.

3.2.3 Basis

3.2.3.1 General

The LAW process has two melters, each capable of producing 15 MTG/day for a nameplate rate of 30 MTG/day. Design life for each melter is 5 years; bubbler replacement is expected to be the most frequent maintenance task. There are 18 bubblers per melter that work continuously by injecting compressed air through nozzles submerged in the molten glass. Section 3.2.3.3 provides more details on bubblers.

The LAW melter and film cooler design values come from *90% Design - LAW Melter System Description* (24590-101-TSA-W000-0010-409-359).

The following are the process streams in the LAW melter process. Typical set values for some streams are given. Values for the streams are calculated on the basis of the set values and inputs from other streams in the flowsheet.

Melter Streams

Input

- Melter feed from melter feed vessel (temperature calculated)
- Melter air inleakage (typically at 27 °C)
- Melter injected air (supplied air, set at 16 °C)

Output

- Melter offgas (modeled at 400 °C with cold cap)
- Glass product (set at 1150 °C)

The glass pool temperature is normally set in the flowsheet. The glass chemistry is calculated and adjusted to a best fit (see Section 3.1). However, the glass production rate should be set for only one pair of melters, either LAW or high-level waste (HLW). The glass production rate for the other vitrification system is then calculated by the flowsheet, because each ultimately receives waste from the same source. If production rates are set for both pairs of melters, then the glass chemistry modules are forced to make adjustments that may result in less-than-optimum glass in one or both of the melter pairs.

The melter air in-leakage, instrument air, and purge air values come from the melter ventilation values in Section 3.2.3.4.1, *Melter Ventilation*. Air enters the melter from the shielded enclosure, where it is heated to about 400 to 600 °C during feeding and 900 °C during idling.

Film Cooler Streams

Input

- Rinse water for cleaning (10 gal/day)
- Melter offgas (approximately 400 °C)
- Film cooler compressed air supply (approximately 16 °C) (155 scfm for G2) (controlled to reach target temp below)

Output

- Film cooler offgas discharge (approximately 350 °C)

Control Air Mixing

Input

- Film cooler offgas discharge (350 °C)
- Control air addition (approximately 16 °C) (for G2 318 scfm) (controlled to reach target temp listed below)

Output

- Submerged bed scrubber (SBS) inlet offgas (approx. 280 °C)

Because sodium is the major constituent in the LAW waste, the sodium content ("sodium waste loading") of the glass is to be maximized. Sulfur in the waste can hinder glass production and sodium waste loading. Therefore, wastes with high sulfur content have a lower sodium waste loading. Table 3.2-3 compares the expected sodium waste loading to the sulfur concentration in the glass for the various Hanford tanks.

3.2.3.2 LAW Melter

The melter is a metal "box" with cooling panels and insulation that surround a region of ceramic blocks (the refractory). The refractory provides thermal insulation and resistance to chemical attack from waste and glass-forming chemicals.

The waste and glass-forming chemicals are melted by joule heating. The glass melt is electrically conductive, and current is passed through the melt using six electrodes (three on each side of the melter). Joule heating efficiently transfers heat from the molten glass to the unreacted batch (Hrma 1982).

Glass temperatures are measured by thermocouples at various depths. From this thermocouple matrix, an average glass pool is automatically calculated. The LAW melter glass pool temperature is maintained between 1125 and 1175 °C, with a set point of 1150 °C. Glass pool temperatures are controlled by automatic adjustment of the melter electrode electrical power.

Working depth of the glass pool is nominal melt line (30 in. above the refractory floor) and the nominal operating band of the pool depth is ±1.5 in. However, limiting glass level variation to less than these limits is recommended for routine discharges to minimize thermal shock of glass contact refractory at the slurry/glass interface near the melt line. The melter glass pool operating range is between 27.9 and 30 in. (a volume of 141 gal, which is the basis for a full air lift); refer to Section 3.2.3.6. The final air lift for filling the LAW canister to 90 % volume is calculated from the volume in the container.

- Design data (24590-LAW-3YD-LMP-00001):
  - Filled volume:[1] 269 ft^3 (2016 gal) nominal
  - Glass melt density:[2] 2.45 g/cm^3 1150 °C
  - Temperature (glass): 1150 °C (2102 °F)
  - Cooling water supply temperature:[3] 95 °F
  - Influent flowrate (from each feed nozzle): 2.8 gpm (maximum)

[1] Based on internal refractory dimensions of glass tank up to nominal melt-line in Table 4 of 24590-LAW-3YD-LMP-00001

[2] 24590-101-TSA-W000-0009-06-6A, CCN 036415

[3] 24590-QL-HC4-W000-00011-03-00644, Rev 00A

- Operating logic:
  - The melter is continuously fed with a slurry of waste and glass-forming chemicals from the melter feed vessel (Section 3.1) through six ADS pumps. Total feed rate depends on the oxide density of the melter feed (Section 3.1.3.5.4)
  - Glass pool temperature is set at 1150 °C. Temperature is controlled by applied voltage to joule heating system electrodes
- Services:
  - Plant Cooling Water (PCW) is used for cooling of melter refractory via water jacket system and feed nozzles.
  - Plant Service Air (PSA) is used for pressure control air, ADS pump blow down, film cooler, and offgas wash.
  - Instrument Service Air (ISA) is used for bubblers, airlift lances, electrode extensions, and plenum.
  - Demineralized Water (DIW) is used for feed nozzle flushes, plenum cooling, and film cooler washes.
  - Argon supplied by Miscellaneous Gases System (MXG) is used for airlift lances and glass melt level detection probes.
- Chemistry: See Section 3.2.3.4.

3.2.3.3 Bubblers

Air bubblers are used in the LAW melter to enhance the glass production rates. Bubblers work by continuously injecting compressed air through nozzles submerged in the molten glass. Each bubbler contains three bubbler blocks, and there are two air injection nozzles per block. As the bubbles rise, they carry hot glass upward to the cold cap, causing forced circulation within the glass pool. This circulation increases the rate of reaction of the feed material with the molten glass by means of heat transfer and mass transfer. However, uncontrolled bubbling could result in excessive glass agitation and particulate splattering that may enhance the risk of offgas plugging.

Bubbling rate adjustment tests have been performed to investigate melter turn-down and to compare melter scales. Table 3.2-6 provides a summary of bubbling rate adjustment test data. Figure 3.2-4 demonstrates the glass production rate for Sub-Envelopes A1 (LAWA44), B1 (LAWB83), and C1 (LAWC22) as a function of bubbling rate at the pilot scale (DM3300). The trends are similar in all three tests. The glass production rates increase with increasing bubbling rate. Based on the data, reducing the bubbling rate from the nominal 1.82 to 0.61 scfm/m^2 (a 66 % decrease) will reduce the processing rate of the melter by 21 %, 28 %, and 35 % for Sub-Envelopes A1, B1, and C1, respectively. It is not recommended to reduce the bubbling rate below 0.61 scfm/m^2, as this may result in glass pool temperature instability due to inadequate mixing, which may damage some of the installed melter components (24590-101-TSA-W000-0009-113-00001).

Additional data for bubbling rate adjustment tests are given in Table 3.2-6, and were generated to evaluate the scale-up of the LAW melters. Data from the smaller melters showed the same general trend as the pilot melter; however, in both DM100 and DM1200, glass production rates were slightly lower for a given bubbling rate. A summary and discussion of melter scale-up can be found in 24590-101-TSA-W000-0009-113-00001, Rev 00A.

Bubbler failure is the single most important event expected to interrupt the LAW melter operation. The *RPP Pilot Melter Bubbler Life Extension Test Results Report* (24590-101-TSA-W000-0009-23-10, Rev 00C) assessed the bubbler life and material of construction. Various bubbler material, coating, and protective sleeve combinations were tested to determine the impact of that modification on bubbler life.

This test report recommended that the WTP LAW Facility utilize a bubbler fabricated from MA-758 without platinum coating, and with chromium shin guards.

The current project baseline for LAW bubbler material is MA-758 with platinum coating and LT-1 shinguards. Each bubbler is estimated to have a 26-week life (CCN 103214). For each melter, half of the 18 bubblers are replaced at a time. The bubbler replacement time is estimated to be 75 hr for nine LAW bubblers. LAW bubbler reliability, availability, and maintainability data is listed in the LMP section of Appendix D.

3.2.3.4 Melter Mass Balance

3.2.3.4.1 Melter Ventilation-In-Leakage and Purge Flows

Since the melter is maintained under a vacuum, air will leak into the melter. However, some air in-leakage is desirable in the melter for purges, and is allowed through engineered openings in some of the melter lid components. The estimates of total air in-leakage and purges into the melter during normal operation vary between 369 and 406 scfm (24590-101-TSA-W000-0010-409-359, 24590-101-TSA-W000-0010-409-1488, and 24590-QL-HC4-W000-00011-03-00644). The estimates, based on Duratek mass and energy balance, (Table 4, 24590-QL-HC4-W000-00011-03-00644) are listed below.

Component(s)	90 % Design Review Flow Rates (scfm) Per Melter:
Lid In-Leakage:	
4 plenum-viewing closed circuit televisions	32
18 bubblers-gasket leakage	54
18 bubblers-weep holes	57
15 6-in. ports-gasket leakage	15
20 6-in. ports-weep holes	20
2 offgas port liners	4
Discharge chamber	18
86 jack bolts	86
3 electrode bus penetrations	18
	304 scfm

Purges:	
ADS feed blowdown	6
3 level/reference probes	0.06
Bubbler nozzles (18 each)	27
Air lifts (2 each)	~0
Backup offgas duct purge	32
Subtotal	65.06 scfm
Total In-leakage and Purges	369 scfm

However, melter air in-leakage predictions in Duratek mass and energy balance are for "new" melters and do not account for thermal effects known to increase melter in-leakage air over time. Melter in-leakage calculated by considering these thermal effects is listed below (24590-LAW-M4C-LOP-00001). Note that fixed air additions remain the same and closed circuit television purges are excluded from fixed air additions since they will not be normally installed (24590-LAW-M4C-LOP-00001). The following melter air input values will be used in the flowsheet.

- All scfm flowrates: 20 °C and 1 atm
- Melter air in-leakage: 402 scfm melter
- Fixed air addition: 38 scfm (bubblers not included)
- Bubbler air: 27 scfm

3.2.3.4.2 Partitioning in the Melter

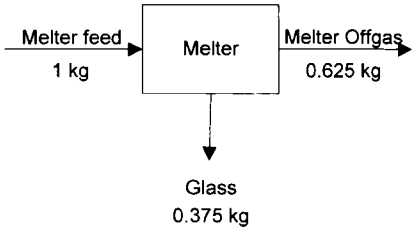
The waste and glass-forming additives enter the top of the melter as a water slurry. The slurry quickly dries and forms a cold cap on the molten glass pool. Heat decomposes the cold cap into elemental oxides (and other minor constituents) that dissolve into the glass pool, and gases (with evaporated water) that exit the melter plenum to the film cooler. In-leakage air enters the melter plenum and also exits with the other gases to the film cooler. Some dusting caused by drying of the cold cap and splatter is expected, and enters the offgas. These solids and gases of decomposition are discussed in Section 3.2.3.4.3. Table 3.2-2 contains decontamination factor (DF) values based on Research and Technology (R&T) reports for each LAW envelope and a list of revised DFs based on the average of the values reported by R&T. When empirical data are not available, a value is estimated depending on the particular species' volatility as described in 24590-WTP-M4C-V37T-00008, *Reconciliation of HLW and LAW Melter Decontamination Factors*. A supplemental explanation can also be found in 24590-HLW-MKC-HOP-00001, *Melter Decontamination Estimation*. An estimation of the volatility of the species at melter conditions is separated into three classifications: volatile, semi-volatile, and non-volatile. species that have no data were assigned DFs based on their volatility assessment. A DF value of 1 was assigned to those gaseous species lacking empirical data. 24590-WTP-M4C-V37T-00008 contains reference R&T reports, data analysis rationale, and the justification used for DF estimation.

Recycles Impact on Technetium and Other Decontamination Factors

A recent report RPP-RPT-53649, *Tc/LAW Melter Recycle Demonstration Project Summary*, implies that the decontamination factors for technetium and other semivolatile materials should be higher than the values shown in the DF table, Table 3.2-2. However, this is not the case. The report presented melter

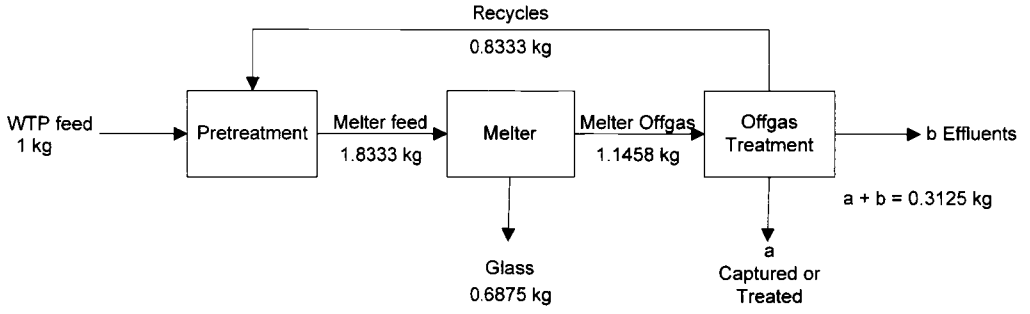
pilot study results where technetium captured in the offgas treatment system was recycled back to the melter feed. Figure 3.2-1 shows a technetium mass balance around an HLW melter without recycles. The mass balance uses 1 kg (per hour) of technetium in the feed as a basis. The figure illustrates DF is 1.6 as shown for technetium in Table 3.2-2. Figure 3.2-2 is a simple illustration that shows how recycles may impact the process. The recycle stream continues to rise until concentration of technetium in Pretreatment and melter feed streams again meets the DF_{melter} ratio of 1.6. This happens when the melter feed stream is at 1.8333 kg (per hour). The higher technetium concentration allows more technetium to leave the melter with the glass, which results in a process DF of 3.2. However, please notice that the melter DF is still correctly represented with the value of 1.6 as given in Table 3.2-2. Process modeling is required to accurately account for recycles and determine what the "process DFs" should be and what reports to the various plant effluents.

Figure 3.2-1 Diagram Illustrating Melter Technetium DF



DF_{melter} = 1kg / (1kg – 0.375 kg) = 1.6

Figure 3.2-2 Diagram Illustrating Melter Technetium DF with Recycles



$DF_{process}$ = 1kg / (1kg – 0.6875 kg) = 3.2

DF_{melter} = 1.8333kg / (1.8333kg – 0.6875 kg) = 1.6

3.2.3.4.3 Cold Cap Reactions

The molten glass pool, when fed typically forms a cold cap region that transitions from liquid (slurry), to solid, to molten glass. Chemical reactions take place in different regions of this cold cap. These include generation of steam from boiling of the water component of the slurry feed; burn-off of organics (including sugar, which is added to the waste and glass former chemicals to reduce NO_x); and oxidation of waste and glass former chemicals forming molten glass.

The cold cap acts as a thermal insulator between the hot molten glass and the melter plenum area (Hrma 1982). Chemical reaction logic is derived from descriptive chemistry references (Rock 1985, Miessler and Tarr 1991, and Weast 1975). Data on additional unreacted cold cap offgas constituents can

be found in 24590-101-TSA-W000-0009-106-13 and SCT-M0SRLE60-00-135-02; this data was prepared for use at Savannah River Technology Center (SRTC) in their cold cap chemistry and offgas flammability models. The offgas flammability assessment showed that significant overfeeding of sugar, sometimes as much as 300 %, combined with feed total organic carbon (TOC), normally does not produce more than a small fraction of the lower composite flammability limits for organic compounds in the melter plenum (SCT-M0SRLE60-00-135-02).

Additional data on flammable offgases can be found in 24590-101-TSA-W000-0009-87-12. In one portion of the test, AP-101 feed was tested in the DM10 melter at 11 kg/hr. The plenum temperature was reduced to 160 °C, with influent air controlled. Offgas samples were collected at the transition line. The collected data suggests that plenum temperatures below 200 °C are required to generate significant flammable gases. In another test in the report, AZ101 feed was tested in the DM1200 melter. Feed was done at 145 kg/hr for Run 1 and at 233 kg/hr for Run 2. The plenum was kept between 400 and 470 °C. An air-cooled probe was used to collect offgas samples at the cold cap surface, and at 14 and 28 in. above the cold cap surface. Exhaust gases were collected for film cooler and control air. The collected data suggested that concentrations of most gases increase as sampling moves closer to the cold cap. Data also suggested that hydrogen concentrations are not affected by distance from the cold cap. The overall conclusion is that if plenum temperatures are maintained above 200 °C, combined with small amounts of air dilution, significant generation of flammable gas concentrations will be precluded.

The melter reactions are used to estimate energy requirements and to balance mass flows in the flowsheet.

The melter operates so that approximately 90 % of the glass pool surface is covered with cold cap; this allows the plenum to be maintained between 350 and 600 °C, with a target of 400 °C. Depending on specific behavior of the cold cap, the rate of feed addition to the melter is adjusted to maintain this target temperature. This is the key real-time process control data point that determines melter throughput.

Empirical data from pilot studies at VSL and Duratek indicate that ammonia is also generated in addition to other nitrogen compounds during vitrification (24590-101-TSA-W000-0009-111-02). Ammonia easily reacts with water to form a basic solution. Like the metals, ammonia reacts with the acid gases to form ammonium salts. The ratios of these affect the pH of the SBS. The pH of the SBS solution is shown to be approximately neutral from the R&T pilot studies (CCN 035017).

Metal Oxides

Heat destroys most metal compounds, forming metal oxides. The mass balance and general flowsheet convention used for those metals with multiple oxide states is to report as the most oxidized state. Almost all of the metal oxide enters the molten glass pool and leaves as glass product. A very small amount is lost to the melter offgas stream as particulate. These metal oxides are partitioned in accordance to empirically determined DFs. As examples, metal oxides and hydroxides are shown:

Equation 3.2-1

$$R_2O \rightarrow (1 - 1/DF)R_2O\downarrow + (1/DF)R_2O\uparrow$$

Equation 3.2-2

$$2ROH \rightarrow (1 - 1/DF)R_2O\downarrow + (1/DF)R_2O\uparrow + H_2O\uparrow$$

where:

R represents any metal

DF is the decontamination factor for a given metal R or metal oxide

↓ means that the component listed to the left goes down into the glass

↑ means that the component listed to the left goes up with the offgases

The above equations can be written in terms of cations and anions; therefore, the equivalents for the above equations are:

Equation 3.2-3

$$2R^{+} + O^{-2} \rightarrow (1 - 1/DF)2R^{+}\downarrow + (1/DF)2R^{+}\uparrow + (1 - 1/DF)O^{-2}\downarrow + (1/DF)O^{-2}\uparrow$$

Equation 3.2-4

$$2R^{+} + 2OH^{-} \rightarrow (1\text{-}1/DF)2R^{+}\downarrow + (1/DF)2R^{+}\uparrow + 2H^{+}\uparrow + (1\text{-}1/DF)O^{-2}\downarrow + (1/DF)O^{-2}\uparrow$$

Then to balance charges between streams, the following needs to be done:

Equation 3.2-5

$$(n/2)O^{-2}\uparrow \rightarrow (n/2)O^{-2}\downarrow$$

where:

n is the total number of R^{+} ions minus all anions (such as Cl^{-}, SO_4^{-2}, including O^{-2}) in the glass. The appropriate amount of $O^{-2}\uparrow$ is then transferred from the offgas to the glass (i.e., $O^{-2}\downarrow$) by Equation 3.2-5.

Then to balance for water, the H+ ions must be reacted with remaining O^{-2} to produce water in the offgas:

Equation 3.2-6

$$2H^{+}\uparrow + O^{-2}\uparrow \rightarrow H_2O\uparrow$$

The DFs for the metals are in Table 3.2-2.

Mercury is an exception to the metal oxide behavior. Virtually all mercury that enters the melter is vaporized and sent to the offgas, (24590-WTP-RPT-PR-01-011, *Mercury Pathway and Treatment Assessment for the WTP*). If the melter feed molar ratio of [Hg/Cl] is 0.1 or less, virtually all the mercury is converted to soluble $HgCl_2$ gas in the melter plenum; if the ratio of Hg:Cl is greater than 0.5, the majority of the mercury remains in the elemental form (Hg^0) in the plenum (24590-101-TSA-W000-0004-125-00004, *WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant*).

Nitrates, Nitrites, and Ammonia

Nitrogen oxide (NO_x) gases are generated during vitrification from the decomposition of nitrates and nitrites in the feed. Table 3.2-4 is a compilation of NO_x melter emission data from several DM100 scale tests during processing of LAW Envelope A, B, and C feeds. The tests were performed each at a nominal sugar ratio of 0.5. Several of the tests were done varying the simulant feed by ± 15 % in which the actual sugar ratios were approximately 0.44 and 0.57, respectively. However the two ratios average to the nominal 0.5 ratio. The data shows an average 63 % (39 %-100 %) of the feed nitrogen oxides were emitted as NO_x (results include N_2O in the NO_x grouping). The majority of the NO_x leaving the melter gases is NO, averaging 82 % of the total NO_x emitted.

A comparison of nitrogen oxide emissions from melters of different scale (DM100, DM1200, and DM3300) was performed in 24590-101-TSA-W000-0009-87-00019. The data did not show a clear scale effect, except for a potential NO/NO_2 ratio, in which the ratio decreases with increasing melter size; however, even this trend was not consistent. The extent of oxidation of NO after its generation is likely dependent upon the time and the temperature at which the stream was sampled. The higher gas flow rates are in proportion to the feed rate, leading to a shorter residence times for the smaller melters; this may be responsible for the potential trend indicated above.

Additional nitrogen compounds such as NH_3 and HCN are formed in the offgas, which results largely from the reaction of the sugar in the feed with the nitrates and nitrites. Laboratory results have shown that the amount of HCN is negligible, while NH_3 formation, although small, is important downstream for SBS neutralization. Higher nitrates in the feed, as in Envelope A, should increase the amount of NH_3; however, laboratory tests have shown this is not always true.

Although the chemistry of the nitrates/nitrites in the melter is complex, a simplified equation is given below in Equation 3.2-7 and Equation 3.2-8, which combine the nitrate/nitrite destruction with the ammonia formation.

Equation 3.2-7

$$RNO_3 + 3/2H_2O \rightarrow 0.5R_2O\downarrow + aN_2\uparrow + cNO\uparrow + bNO_2\uparrow + dNH_3\uparrow + eO_2\uparrow$$

Equation 3.2-8

$$RNO_2 + 3/2H_2O \rightarrow 0.5R_2O\downarrow + aN_2\uparrow + cNO\uparrow + bNO_2\uparrow + dNH_3\uparrow + eO_2\uparrow$$

The volume percent of each of the nitrogen compounds leaving the melter is calculated in Table 3.2-4. The average volume percent from the data are NO 51.5 %, NO_2 5.7 %, N_2O 5.4 %, NH_3 3.2 %, and N_2 34.2 %. Assuming a basis of 100 M of feed NO_x, and using the average data from the stoichiometric coefficients, values for a, b, c, and d were calculated and are shown in Table 3.2-5. Nitrous oxide (N_2O) is not currently tracked by the flowsheet; hence the N_2O was added to the NO to maintain a constant value for the percent NO_x reported in the feed emitted as nitrogen oxides.

When a mass balance for oxygen is performed, the coefficient e is 1.013 for NO_3 and 0.518 for NO_2 destruction. The equations listed below show the balanced equation for nitrate/nitrite destruction.

Equation 3.2-9

$$RNO_3 + 0.0362H_2O \rightarrow 0.5R_2O\downarrow + 0.2546N_2\uparrow + 0.4239NO\uparrow + 00.0428NO_2\uparrow + 00.0242NH_3\uparrow + 1.013O_2\uparrow$$

Equation 3.2-10

$$RNO_2 + 0.0362H_2O \rightarrow 0.5R_2O\downarrow + 0.2546N_2\uparrow + 0.4239NO\uparrow + 00.0428NO_2\uparrow + 00.0242NH_3\uparrow + 0.513O_2\uparrow$$

R&T experimental data have demonstrated a near neutral pH in the SBS. In the flowsheet model, the actual ammonia produced from the melter is an iterative process with the SBS pH. A stoichiometric ammonia multiplier is used to increase or decrease the amount of ammonia generated, such that the SBS condensate is neutral. The multiplier is one plus the percentage increase or decrease. For example, if the NH_3 is required to increase 2 %; then the NH_3 multiplier would be 1.02. The nitrogen used to adjust the ammonia is taken or added to the amount of N_2 produced. Using the NH_3 multiplier (xNH3), Equation 3.2-10 can be written as follows:

Equation 3.2-11

$$RNO_2 + 0.0362(xNH3)\ H_2O \Longrightarrow 0.5R_2O + 0.2546 - 0.0121*(xNH3-1)\ N_2 + 0.4239\ NO + 0.0428NO_2 + 0.513 + 0.0181(xNH3-1)O_2 + 0.0242(xNH3)\ NH_3$$

The ammonia produced in Equation 3.2-11 cannot exceed the amount of N_2 produced; hence the value of the ammonia multiplier, xNH3, cannot exceed 22.1.

Sulfates and Sulfites

Most of the sulfates are destroyed in the cold cap to produce metal oxides that are absorbed by the glass pool and SO_x (primarily SO_2) gases released to the plenum.

Equation 3.2-12

$$R_2SO_4 \rightarrow R_2O\downarrow + aSO_3\uparrow + (1-a)SO_2\uparrow + [(1-a)/2]O_2\uparrow$$

Likewise, for sulfite:

Equation 3.2-13

$$R_2SO_3 \rightarrow R_2O\downarrow + SO_2\uparrow$$

With so much water present, some or most of the acidic gases form acids upon cooling, that is:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

Then some of the acids react with the metal oxide (and hydroxide) particulates to form salt particulates:

Equation 3.2-14

$$H_2SO_4 + R_2O \rightarrow R_2SO_4 + H_2O, \text{ or}$$

Equation 3.2-15

$$H_2SO_4 + 2ROH \rightarrow R_2SO_4 + 2H_2O$$

The VSL offgas pilot studies (24590-101-TSA-W000-0009-74-01) show that most of the sulfur comes off the melter as SO_2 gas, with little or no SO_3 in the offgas. Precipitates of sulfur in the SBS are reported as sulfate, even though sulfite may be present. The VSL studies do not make the distinction between

sulfate (SO_4^{-2}) and sulfite (SO_3^{-2}) in their analysis and reports. Thus, with SO_2 being the predominant SO_x specie in the melter offgas, it could be argued that more sulfite is produced in the SBS than sulfate. Adjustment of value "a" in Equation 3.2-12 will change the ratio between sulfates and sulfites.

Most of the sulfur emitted from the melter is in the particulate form rather than the gaseous form, as indicated from melter tests on Envelope A and C feeds in Table 3.2-7. The gaseous sulfur comes off as SO_2 as shown in Equation 3.2-13. The amount of sulfur retained in the glass increases with increased glass production rate (Figure 3.2-5).

Carbonates

Equation 3.2-16

$$R_2CO_3 \rightarrow R_2O\downarrow + aCO_2\uparrow + (1\text{-}a)CO\uparrow + [(1\text{-}a)/2]O_2\uparrow$$

The VSL offgas pilot studies (24590-101-TSA-W000-0009-74-01 and CCN 065273) show that most of the carbon becomes CO_2 with little or no CO in the offgas. The above reaction will account for this. Adjustment of value "a" may be necessary to more closely match the pilot studies. Some of the glass formers supply significant quantities of carbonates.

Boric Acid and Borates

Boric acid and borates mainly come from glass formers. The mass balance reactions for these are:

Equation 3.2-17

$$2H_3BO_3 + \rightarrow (1\text{-}1/DF)B_2O_3\downarrow + (1/DF)B_2O_3\uparrow(\text{particulate/solid}) + 3H_2O\uparrow$$

Or in flowsheet terms:

Equation 3.2-18

$$2B^{+3} + 3O^{-2} + 3H_2O \rightarrow (1\text{-}1/DF)2B^{+3}\downarrow + (1/DF)2B^{+3}\uparrow(\text{particulate/solid}) + 3H_2O\uparrow + (1 - 1/DF)3O^{-2}\downarrow + (1/DF)3O^{-2}\uparrow$$

The HLW process is converting from boric acid addition to borax. The equation for borax is:

Equation 3.2-19

$$Na2B4O7 \cdot 10H2O \rightarrow (1\text{-}1/DFNa+)Na2O\downarrow + (1\text{-}1/DFB+3)2B2O3\downarrow + (1/DFNa+)Na2O\uparrow + (1/DFB+3)2B2O3\uparrow + 10H2O\uparrow$$

Much of the boron that is emitted from the melter is in the form of a gas (Table 3.2-7). The percentage of gaseous boron was higher in the DM1200 than the DM100. The identity of the boron gas is unknown, but it can be reasonably speculated that it is BCl_3. According to Samsonov and others (1960) BCl_3 is easily formed under cold-cap conditions and boils at 13 °C. Boron tri-chloride decomposes in water at the SBS temperature into boric acid and HCl, which are the products observed in the SBS. Gas phase boron will be represented as sodium borate and hydrochloric acid in the flowsheet because the net boron reaction product (boric acid in the SBS) is the same as that obtained with BCl_3.

Selenium

Most of the selenium in the feed was emitted from the feed and reports to the offgas in one melter run (24590-101-TSA-W000-0009-111-02), but the results were not consistent, even for the same feed. Some of the selenium emitted was a particulate in a melter run with A1 feed that had limited selenium volatility, but most selenium was a gas in another A1 melter run that had high selenium volatility. The gaseous form of selenium is not known, but the behavior of selenium in the melter is consistent with the formation of gaseous elemental selenium. Selenite and selenate (the species of selenium in the feed) are both reduced to elemental selenium at melter temperatures. Elemental selenium boils at 690 °C, and is semi-volatile at all temperatures above its melting point of 220 °C (Hares 1974). The vapor pressure (P) of elemental selenium is a function of temperature (T) as given by Chizhikov and Shchastlivyi (1968):

Log P_{Se} (mm Hg) = 0.733 - 4722/ T for T > 220 °C but < 690 °C,

and

Log P_{Se} (mm Hg) = 13.578 - 7644/ T for T > 690 °C.

Other volatile selenium compounds are hydrogen selenide (H_2Se), selenium dioxide (SeO_2), and selenium chloride ($SeCl_4$). Selenium dioxide and selenium chloride, however, only form under highly acidic conditions (Nazarenko and Ermakov 1972; Molinski and Leddicotte 1965), and thus would not form in the melter. Hydrogen selenide only forms under very reducing conditions. While most of the cold cap is not highly reducing because of the presence of nitrate in the feed, the emission of hydrogen gas from the melter indicates that at least some parts of the cold cap are reducing. Most of the selenium in the feed is emitted from the melter. Therefore it is unlikely that hydrogen selenide, which would be generated from only a few highly reducing portions of the cold cap, is the dominant form of volatile selenium.

Hydroxides

See Metal Oxides in Section 3.2.3.4.3 for reactions.

Sugar and Organics

Sugar is used as a reductant in the melter. Sugar has been added during the R&T development efforts at VSL and Duratek at an average stoichiometric ratio of 0.5 (1 M sucrose to 16 M NO_x) after accounting for the carbon supplied by organics in the feed (24590-101-TSA-W000-0009-166-00001). The relationship is shown in the following equations:

Equation 3.2-20

$$Moles_{Sucrose\ Addition} = [(Moles_{NO3} + Moles_{NO2}) /16 - Moles_{TOC}/12]$$

Equation 3.2-21

$$M_{Sucrose\ Addition} = Moles_{Sucrose\ Addition} * 342.3$$

Equation 3.2-22

$$Moles_{TOC} = 2 * Moles_{C2O4}$$

where:

$Moles_{NO3}$ is moles of nitrate (NO_3^-) in the feed
$Moles_{NO2}$ is moles of nitrite (NO_2^-) in the feed
$Moles_{TOC}$ is moles of TOC
$Moles_{C2O4}$ is moles of oxalate ion ($C_2O_4^{-2}$) in the feed
12 is number of carbon atoms per molecule of sucrose
342.3 is molecular weight of sucrose

Organics present in the feed are mainly in the form of complexants which were used in the Hanford process for separation of species or are a decomposition product of these complexants. These compounds include ethylenediamine tetra-acetic acid (EDTA), N-(2-hydroxyethyl) ethylenediamine tri-acetic acid (HEDTA), acetate, formate, oxalate, gluconate, glycolic acid, citric acid, iminodiacetic acid (IDA), and nitrilotriacetic acid (NTA). The LAW Sub-Envelope C2 waste was evaluated in a test using various organic compounds (blend of waste organics, EDTA, glycolic acid, and sugar) at various concentrations (ratio of 0.5, 0.6, and 0.75) to determine the effectiveness of each as a reductant (24590-101-TSA-W000-0009-98-00008). Results showed that sugar was the most effective reductant. Sugar was the only organic compound that was effective in increasing the partitioning of sulfur from the glass to the exhaust stream. Sugar was also the only organic compound that increased the amount of reduced iron in the glass and the only organic compound to reduce iodine emissions. The concentration of byproducts (hydrogen, ammonia, hydrogen cyanide, acetonitrile, and carbon monoxide) was similar for most tests except for EDTA, which had the highest emission rates of the listed byproducts.

These tests showed that the organic compounds in the LAW waste streams are not as effective of a reductant as sugar. However, the reducing effects of the waste organics should not be ignored, as was found during testing of LAW Semi-Integrated Pilot Plant (SIPP) waste under bounding TOC (spiked with EDTA) and high reductant conditions (0.95 sugar ratio). Under these conditions, auto discharging of foamy glass was frequent and the Fe^{++}/total Fe increased (24590-101-TSA-W000-0009-155-00003).

Tests have shown that if organics of higher molecular weight (i.e., EDTA) with a high decomposition temperature comprise the waste, then the waste organics need to be included in the sugar addition calculation (as is the current procedure) to prevent unacceptable divalent iron concentration and foaming. If the waste organics are of lower molecular weight, then the reducing effects of the waste organics will be less and it may be necessary to exclude or use a weighting factor for the waste organics in the sugar calculation (24590-101-TSA-W000-0009-155-00003). Current practice is to include the waste organics in the sugar calculation.

The R&T pilot plant test data presented in documents 24590-101-TSA-W000-0009-106-18, 24590-101-TSA-W000-0009-107-01, 24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-111-02, and 24590-101-TSA-W000-0009-120-06 demonstrated that the organic compounds are not entirely oxidized in the melter or its plenum. As a result, these partially oxidized compounds may form intermediate products within the melter, prior to the thermal catalytic oxidizer. One prevalent intermediate product that has been detected in test runs is acetonitrile (also known as methyl cyanide). Acetonitrile is a partial decomposition product of EDTA, HEDTA, and IDA, and is contingent on the availability of nitrogen and sugar. A considerable number of other compounds that have been detected in the melter offgases are as follows:

1 Volatile organic compounds (e.g., acetone and acyrlonitrile) Figure 3.2-6
2 Chlorinated organic compounds (e.g., carbon tetrachloride and trichloroethene) Figure 3.2-7

3 Semi-volatile organic compounds (e.g., styrene, diethyl phthalate, nitrobenzene, and 2-nitrophenol) Figure 3.2-8 through Figure 3.2-10

4 Very small amounts of dioxins, furans, Figure 3.2-11

5 Polychlorinated biphenyls (PCB), Figure 3.2-12

Figure 3.2-14 and Figure 3.2-15 show some additional offgas products that have been detected. Figure 3.2-16 to Figure 3.2-20 show various relationships that exist between the organic melter feed and the offgas characteristics. Melter DFs for destroying spiking compounds such as chlorobenzene, trichloroethylene, and naphthalene are shown in Figure3.2-13.

Figure 3.2-6 shows that the melters are likely to produce significant quantities of organic offgas emissions in the form of acrylonitrile, acetone, and acetonitrile for all three LAW envelopes. The quantity of acetonitrile, on a mass per mass basis, that was produced ranged between 0.2 and 4.25 % of the total organic compound feed mass. Acrylonitrile ranged between 0.0014 and 0.3 % of the organic feed mass. Acetone ranged from about 75 % of the acrylonitrile mass to non-detectable levels. Bromomethane and benzene may be produced at 0.000006 to 0.02 % of the organic feed mass in Envelope A and C wastes.

Figure 3.2-7 shows the results from the DM1200 melter tests with A1 and C1 spiked samples. In the DM1200 AI-spiked test, chlorobenzene and trichloroethene were both at about 0.8 % of the organic feed to the melter. However, all the chlorinated organics other than chlorobenzene and trichloroethene were measured at $\leq$ 0.03 % of the organic feed mass.

Figure 3.2-8 shows the results for other organics, nearly all of which were created downstream of the melter. The largest constituent was xylene in the DM3300 Envelope A test at 0.02 % of the organic feed. All other values were below this point, and most other melter test organic masses were below 0.003 % of the organic feed mass.

Figure 3.2-9 shows some additional organics, which were likely created after the melter. The highest readings were for the DM3300 Envelope A test, at 0.0078 % of the organic feed (2,4-dinitrophenol) and at 0.0063 % of the organic feed (nitrobenzene). Most of the detections were at less than 0.001 % of the organic feed mass.

Figure 3.2-10 shows some semi-volatile compounds that were measured after the melter. The greatest concentration was for 2-nitrophenol at 0.0067 % of the organic feed mass (DM3300 Envelope A test). 2-nitrophenol was measured at concentrations ranging from 0.0067 % to a minimum of 0.000010 % mg/mg. 4-nitrophenol was measured from a high of 0.0059 % (DM3300 Envelope A test) to non-detection. The vast majority of the remaining compounds was at 0.001 % or lower of organic feed mass.

Figure 3.2-11 shows a distribution of dioxin and furan mass measurements ranging from a high of 1.14 E-10 mg/mg organic feed (DM3300 Envelope B test) to undetectable concentrations of some specific compounds in the melter offgases. Most of the dioxin/furan concentrations were less than 1.0 E-11 mg/mg and greater than 1.0 E-13 mg/mg of total organic feed. Figure 3.2-12 shows measured PCB concentrations for the melter offgas. Measured quantities varied from a maximum of 3.22 E-10 mg/mg organic feed (DM3300 Envelope B test) to undetectable levels for certain compounds.

Figure3.2-13 shows observed DFs for the organic spiking compounds in the DM1200 tests for Envelopes A and C from 24590-101-TSA-W000-0009-111-01 and 24590-101-TSA-W000-0009-111-02.

Figure 3.2-14 shows miscellaneous organic compounds detected in the offgas samples for the melters. Note that the only data received corresponds to the DM1200 melter processing Sub-Envelope C1 wastes. Values ranged from a high of 1.65 E-06 mg/mg of organic feed mass for 2-butenenitrile to a low of 9.64 E-08 mg/mg for 3-butenenitrile. Other detected compounds included ethenylcyclobutane, cyclohexene, benzaldehyde, and several simple hydrocarbon chains. Figure 3.2-15 shows additional miscellaneous organic compounds detected in the offgas samples for the melters. Values ranged from a high of 2.23 E-06 mg/mg of organic feed for acetophenone to a low of 4.48 E-08 mg/mg for 1-decanol. Other detected compounds included benzonitrile, iodobenzene, carbon disulfide, and several simple hydrocarbon chains (24590-101-TSA-W000-0009-111-02).

Figure 3.2-16 shows the relationship between the type of organic feed to the melter (e.g., sugar or complexants) and the generation of the three most prominent offgas constituents, such as acetonitrile. The graphs, based on the R&T reports, tend to show that sugar is by far the greatest contributor. When sugar feed was reduced by a factor of 10, the formation of these products of incomplete combustion (PIC) dropped by several orders of magnitude. However, when complexant feed was eliminated, there was only a minimal reduction in the PIC formation rate. Note that since sugar is not normally fed into the HLW melters, little generation of these PICs is expected from HLW vitrification.

Figure 3.2-17 shows the relationship between the type of organic feed to the melter (e.g., sugar or complexants) and the generation of chlorinated dibenzo dioxins (CDD), chlorinated dibenzo furans (CDF), and PCBs. The graphs, based on the R&T reports, tend to show that sugar is the greatest contributor; therefore, little generation of these compounds is expected from HLW vitrification. The graph also shows that complexants may actually retard the formation of these compounds.

Figure 3.2-18 shows the apparent lack of any relationship between the proportions of sugar and complexants in the organic feed and the overall organic destruction removal efficiencies (DRE) achieved in the melter. The implication of this is that sugar and complexants are equally oxidized in the melter and that the average DRE is about 98.5 % (average DF = 66.7 %). Small dips in the DREs were noticeable for the spiked tests (A12S and C12S) because of the lower DREs for the spiking compounds. See the discussion for Figure 3.2-12, above, for the spiking compound DFs.

Figure 3.2-19 shows the relationship that exists between the sugar feed, the complexant feed, the organic spikes, and the resultant total offgas mass flow. Note that the offgas mass flow increases to meet the spiked compounds mass flow data points for the DM1200 A1 (A12S) and for the DM1200 C1 (C12S) test runs. This increase is because of the poor destruction for the spiking compounds, when compared to the balance of the organic feed.

Figure 3.2-20 shows the relationship that exists between the sugar feed, the complexant feed, the organic spikes, and the resultant total chlorinated dibenzo dioxins, chlorinated dibenzo furans, and PCBs (CDD/CDF/PCB) production and resultant acetonitrile/acrylonitrile/acetone (ACE) production. Unlike the results for Figure 3.2-18 for total organic offgas mass flow, this figure better defines the source of certain priority offgas constituents. The figure indicates that when sugar feed mass exceeds complexant feed mass, generation of ACE compounds and of CDD/CDF/PCB is elevated. Conversely, when complexants are the dominant contributor to organic feed, ACE and CDD/CDF/PCB formation is reduced. ACE is reduced by about 3 orders of magnitude and CDD/CDF/PCB by about a factor of 5. Notable exceptions are with the spiked tests. In test A12S, both ACE and CDD/CDF/PCB were elevated above equivalent non-spiked generation rates. The same applies regarding CDD/CDF/PCB in the C12S test. Of interest is the fact that ACE in the C12S test was depressed further by the spikes. Conclusion: Sugar is a dominant precursor for ACE and a more important precursor for CDD/CDF/PCB formation than are the complexants. When complexant content is greater than sugar content, both offgas groups are

depressed. Spiking increases the production of CDD/CDF/PCB, but sometimes apparently suppresses the production of ACE. A conservative estimate is that sugar contributes to 100 times more ACE generation than complexants and 5 times more CDD/CDF/PCB production than complexants.

Conversion factors (CF) have been added to some of the sugar equations to simulate its completeness of oxidation. While the overall average DRE for the simulated organic feed was about 98.5 %, this was adjusted slightly to account for sugar's greater-than-average contribution to priority offgas products. (See Figure 3.2-19 discussion.) Therefore, the DRE for sugar has been adjusted downward. The CFs for the three equations (Equation 3.2-23, Equation 3.2-24, and Equation 3.2-25) total to 1.00. Other products, due to very small quantities, have been disregarded.

Equation 3.2-23

$$8\ NO_3^- + C_{12}H_{22}O_{11} = 12\ CO_2 + 11\ H_2O_{(g)} + 4\ N_2 \qquad CF = 0.9841$$

The R&T data has shown that when the reaction shown in Equation 3.2-23 does not run to completion, PICs, such as acetonitrile, acrylonitrile, and acetone, can be created, as shown in Equation 3.2-24. To simplify very complicated modeling scenarios, acetonitrile is used as the flowsheet indicator. The average rate of acetonitrile generation is shown by the accompanying conversion factor. The formation of acetonitrile is typical for this type of reaction. See Figure 3.2-5. Data from the reports, when plotted (Figure 3.2-15 and Figure 3.2-19), tend to indicate that about 99 % of the formation of these compounds is due to sugar and nitrates. (24590-101-TSA-W000-0009-106-18, 24590-101-TSA-W000-0009-107-01, 24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-111-02, 24590-101-TSA-W000-0009-120-06, 24590-101-TSA-W000-0009-143-01)

Equation 3.2-24

$$2\ CO_{2(g)} + 1.5\ H_2O_{(g)} + 0.5\ N_{2(g)} \rightarrow C_2H_3N_{(g)} + 2.75\ O_{2(g)} \qquad CF = 0.0159$$

$$C_2H_3N_{(l)} + 3.75\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 1.5\ H_2O_{(g)} + NO_{2(g)} \qquad CF = 1.0000\ (recycle)$$

The R&T data has also shown that when not all of the reaction in Equation 3.2-23 runs to completion and there is a significant presence of chloride, PCBs and similar compounds can be created, as shown in the Equation 3.2-25. The average rate of PCB generation is shown by the accompanying conversion factor (Equation 3.2-25). The formation of hexachloro-biphenyl is typical for this type of reaction. The formation of polychlorinated dioxins and furans is similar and can probably be modeled as PCB generation. However, dioxin and furan generation is normally one to two orders of magnitude less. See Figure 3.2-10 and Figure 3.2-11. (24590-101-TSA-W000-0009-106-18, 24590-101-TSA-W000-0009-107-01, 24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-111-02, 24590-101-TSA-W000-0009-120-06, 24590-101-TSA-W000-0009-143-01)

Based on information presented in Figure 3.2-19, it appears that sugar is the precursor for about 80 % of the total CDD/CDF/PCB generation, and the overall formation rate of these compounds has been adjusted accordingly by Equation 3.2-25.

Equation 3.2-25

$$12\ CO_{2(g)} + 2\ H_2O_{(g)} + 6\ Cl^-_{(g)} \rightarrow C_{12}H_4Cl_{6(g)} + 13\ O_{2(g)} \qquad CF = 3.79\ E\text{-}10$$

$$C_{12}H_4Cl_{6(l)} + H_{2(g)} + 12\ O_{2(g)} > 12\ CO_{2(g)} + 6\ HCl_{(g)} \qquad CF = 1.0000\ (recycle)$$

Equation 3.2-26

$$8\ NO_3^- + 12\ C = 12\ CO_2 + 4\ N_2$$

From Equation 3.2-23, addition of 1 M sugar to 8 M NO_3^- results in a stoichiometric ratio of 1.0. Therefore, addition of 1 Mole of sugar for every 16 M NO_3^- results in a stoichiometric ratio of 0.5.

From Equation 3.2-26, addition of 12 M of carbon to 8 M NO_3^- results in a stoichiometric ratio of 1.0. Therefore, addition of 6 M of carbon for every 8 M of NO_3^- results in a stoichiometric ratio of 0.5.

Note that Equation 3.2-23 and Equation 3.2-26 are not charge balanced; however, they are used in this form by VSL and Duratek to mathematically determine the amount of sugar to be added to the melter.

In the Envelope A1 tests on the DM1200 melter, organic offgas products were equal to 0.22 % of the organic feed mass for the non-spiked melter and 2.36 % for the spiked melter. In all tests, non-spiked organic feed consisted of sugar plus complexants and spiked feed consisted of sugar, complexants, and the three spiking compounds (chlorobenzene, trichloroethylene, and naphthalene). In the DM1200 tests for Envelope C1, the equivalent of 0.00195 % of the unspiked mass and 1.26 % of the spiked mass were recorded as offgas products. In the DM3300 melter test for Envelope A, the mass of offgas products equaled 4.77 % of the organic waste feed. In the DM3300 melter test for Envelope C, the offgas product mass was about 1.34 % of the organic feed mass. And in the DM3300 test for Envelope B, the offgas product mass was about 0.25 % of the total organic feed mass. (24590-101-TSA-W000-0009-111-02, 24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-107-01, and 24590-101-TSA-W000-0009-120-06)

The overall averages were 1.32 % for non-spiked feed and 1.86 % for spiked feed.

Until confirming or conflicting data is received, a DF of 66.67 (98.5 % DRE) will be used to forecast destruction for all of the complexants in Equation 3.2-24 through Equation 3.2-31. The equations for oxidation of organics follow. Some of the oxygen for combusting comes from the nitrates in the waste. Pilot studies indicate that the nitrates are not fully reduced. Also, not all organics burn to completion (that is, to H_2O, CO_2, and N_2) in the melter. Adjustments for lack of complete combustion and nitrate reduction are made. The adjustments are given in the nitrates, nitrites, and carbonates sections.

The following oxidation equations for the complexants are presented in two steps. The first step represents the intermediate products (i.e., PICs) that may be produced. Acetonitrile, which has been readily detected in the pilot melters, has been used as an indicator compound for modeling purposes. The second step oxidizes the rest of the offgas products to basic compounds, (e.g., H_2O, CO_2, HCl). In nearly all cases, the complete two-step reaction occurs in the melter (CF = 0.985056). However, in a few cases (an average CF = 0.014944) the reaction is unable to run to completion and the intermediate products continue as offgases. The subsequent PICs must be processed in the offgas system to meet air permit conditions.

It is important to note that R&T data tend to indicate that sugar is the source of most of the offgas products, such as acetonitrile, acrylonitrile, acetone, and constituents such as PCB, dioxins, and furans. Figure 3.2-15 shows that acetonitrile production, for example, is more dependent on sugar feed content than complexant content. Test B33N (Envelope B, DM3300 melter, non-spiked) had no EDTA or HEDTA in the feed, but still had significant acetonitrile, acrylonitrile, and acetone offgas content. Other tests which had significant EDTA and HEDTA feed had little or none of those products in the offgas (Envelope C tests on DM1200 melter [C12N and C12S], for example). It is estimated that EDTA and

HEDTA contribute to only about 1 % of the acetonitrile, acrylonitrile, and acetone formation. Figure 3.2-16 indicates that total PCB/dioxin/furan production is not reduced when complexant content is reduced. In fact, the DM3300 test of Envelope B (B33N) shows an increase in those offgas constituents when the complexants are reduced. Conversely, PCB/dioxin/furan production appears to be reduced when the complexant feed approaches the mass of the sugar feed.

The equations below have been assigned CFs to model the extent of the reactions. The overall average for simulant organics and sugar is 98.5 % complete oxidation with the rest (1.49 %) going to offgas products. Sodium oxalate, tested without the presence of other complexants, showed a 99.7 % oxidation rate, and 0.25 % of the mass went to the formation of ACE compounds. Formation of CDD/CDF/PCB was not estimated for any of the complexants due to extremely small quantities.

Equation 3.2-27

Sodium Oxalate

$$C_2O_4^{-}{}_{(s)} \rightarrow 2\ CO_{2(g)} \qquad CF = 1.0000$$

Equation 3.2-28

Sodium Formate

$$CHO_2^{-}{}_{(s)} \rightarrow 0.25\ O_2 \rightarrow CO_{2(g)} + 0.5\ H_2O_{(g)} \qquad CF = 1.0000$$

Equation 3.2-29

Sodium Acetate

$$C_2H_3O_2^{-}{}_{(s)} + 1.75\ O_2 \rightarrow 2\ CO_{2(g)} + 1.5\ H_2O_{(g)} \qquad CF = 1.0000$$

Equation 3.2-30

Glycolic Acid

$$C_2H_3O_{3(s)}^{-} + 1.25\ O_2 \rightarrow 2\ CO_{2(g)} + 1.5\ H_2O_{(g)} \qquad CF = 1.0000$$

Equation 3.2-31

IDA

$$C_4H_7NO_{4(s)} + 3.75\ O_2 \rightarrow 4\ CO_{2(g)} + 3.5\ H_2O_{(g)} + 0.5\ N_{2(g)} \qquad CF = 0.985056$$

$$C_4H_7NO_{4(s)} + O_2 \rightarrow C_2H_3N_{(g)} + 2\ CO_{2(g)} + 2\ H_{2\ (g)} \qquad CF = 0.014944$$

$\Delta N_2 = -(0.492528$ moles $C_4H_7NO_4)$

$\Delta O_2 = -(0.985056$ moles $C_4H_7NO_4)$

$\Delta NO_2 = +(0.985056$ moles $C_4H_7NO_4)$

Equation 3.2-32

Citric Acid

$C_6H_5O_7^{-3}{}_{(s)} + 3.75\ O_2 \rightarrow 6\ CO_{2(g)} + 2.5\ H_2O_{(g)}$ CF = 0.985056

$C_6H_5O_7^{-3}{}_{(s)} \rightarrow 0.833\ C_6H_{6(g)} + CO_{2(g)} + 2.5\ O_{2(g)}$ CF = 0.014944

Equation 3.2-33

HEDTA

$C_{10}H_{15}N_2O_7^{-3}{}_{(s)} + 10.25\ O_2 \rightarrow 10\ CO_{2(g)} + 7.5\ H_2O_{(g)} + N_{2(g)}$ CF = 0.985056

$C_{10}H_{15}N_2O_7^{-3}{}_{(s)} + 4.75\ O_2 \rightarrow 2\ C_2H_3N_{(g)} + 6\ CO_{2(g)} + 4.5\ H_2O_{(g)}$ CF = 0.014944

$0.985056\ N_2 + 1.970112\ O_2 \rightarrow 1.970112\ NO_2$ CF = 1.0000

ΔN_2 = -(0.985056 moles $C_{10}H_{15}N_2O_7^{-3}$)

ΔO_2 = -(1.970112 moles $C_{10}H_{15}N_2O_7^{-3}$)

ΔNO_2 = +(1.970112 moles $C_{10}H_{15}N_2O_7^{-3}$)

Equation 3.2-34

EDTA

$C_{10}H_{12}N_2O_8^{-4}{}_{(s)} + 9\ O_2 \rightarrow 10\ CO_{2(g)} + 6\ H_2O_{(g)} + N_{2(g)}$ CF = 0.985056

$C_{10}H_{12}N_2O_8^{-4}{}_{(s)} \rightarrow 2\ C_2H_3N_{(g)} + C_6H_{6(g)} + 4\ O_{2(g)}$ CF = 0.014944

$0.985056\ N_2 + 1.970112\ O_2 \rightarrow 1.970112\ NO_2$ CF = 1.0000

ΔN_2 = -(0.985056 moles $C_{10}H_{12}N_2O_8^{-4}$)

ΔO_2 = -(1.970112 moles $C_{10}H_{12}N_2O_8^{-4}$)

ΔNO_2 = +(1.970112 moles $C_{10}H_{12}N_2O_8^{-4}$)

The following are oxidation reactions for organic tracking compounds currently used in the Aspen Engineering Suite flowsheet. Each compound represents one of the tracking groups used in the emissions runs. These reactions represent complete oxidation, whether in the melter or the thermal catalytic oxidizer. The PICs resulting from partial oxidation of these compounds, are not shown and will be included as they are identified. Some of these compounds are themselves formed as PICs from the partial oxidation of waste feed organics, such as the complexants, in the melter plenum. The DFs will be used to determine the extent of oxidation of these compounds in the melters.

Tracking Compound Oxidation Reactions

CAS Number	Compound	Formula	Oxidation Reaction
126-73-8	Tributyl phosphate	$C_{12}H_{27}O_4P$	$C_{12}H_{27}O_4P + 18.75O_2 \rightarrow 12CO_2 + 13.5H_2O + PO_4$
84-66-2	Diethyl phthalate	$C_{12}H_{14}O_4$	$C_{12}H_{14}O_4 + 13.5O_2 \rightarrow 12CO_2 + 7H_2O$
62-75-9	N-Nitroso-N,N-dimethylamine	$C_2H_6N_2O$	$C_2H_6N_2O + 5O_2 \rightarrow 2CO_2 + 3H_2O + 2NO_2$

CAS Number	Compound	Formula	Oxidation Reaction
58-90-2	2,3,4,6-Tetrachlorophenol	$C_6H_2Cl_4O$	$C_6H_2Cl_4O + H_2O + 5O_2 \rightarrow 6CO_2 + 4HCl$
75-05-8	Acetonitrile	C_2H_3N	$C_2H_3N + 3.75O_2 \rightarrow 2CO_2 + 1.5H_2O + NO_2$
208-96-8	Acenaphthylene	$C_{12}H_8$	$C_{12}H_8 + 14O_2 \rightarrow 12CO_2 + 4H_2O$
132-64-9	Dibenzofuran	$C_{12}H_8O$	$C_{12}H_8O + 13.5O_2 \rightarrow 12CO_2 + 4H_2O$
91-20-3	Naphthalene	$C_{10}H_8$	$C_{10}H_8 + 12O_2 \rightarrow 10CO_2 + 4H_2O$
120-82-1	1,2,4-Trichlorobenzene	$C_6H_3Cl_3$	$C_6H_3Cl_3 + 6O_2 \rightarrow 6CO_2 + 3HCl$
71-43-2	Benzene	C_6H_6	$C_6H_6 + 7.5O_2 \rightarrow 6CO_2 + 3H_2O$
79-01-6	Trichloroethylene	C_2HCl_3	$2C_2HCl_3 + 2.5H_2O + 2.75O_2 \rightarrow 4CO_2 + 6HCl$
127-18-4	Perchloroethylene	C_2Cl_4	$C_2Cl_4 + 2H_2O \rightarrow 2CO_2 + 4HCl$
56-23-5	Carbon Tetrachloride	CCl_4	$CCl_4 + 2H_2O \rightarrow CO_2 + 4HCl$
110-82-7	Cyclohexane	C_6H_{12}	$C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$
106-97-8	Butane	C_4H_{10}	$C_4H_{10} + 6.5O_2 \rightarrow 4CO_2 + 5H_2O$
111-84-2	n-Nonane	C_9H_{20}	$C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$
50-32-8	Benzo(a)pyrene	$C_{20}H_{12}$	$C_{20}H_{12} + 23O_2 \rightarrow 20CO_2 + 6H_2O$
84-74-2	Di-n-butyl phthalate	$C_{16}H_{22}O_4$	$C_{16}H_{22}O_4 + 19.5O_2 \rightarrow 16CO_2 + 11H_2O$
129-00-0	Pyrene	$C_{16}H_{10}$	$C_{16}H_{10} + 18.5O_2 \rightarrow 16CO_2 + 5H_2O$
1336-36-3	Polychlorinated biphenyls (PCBs)	$C_{12}H_4Cl_6$	$C_{12}H_4Cl_6 + 12O_2 + H_2 \rightarrow 12CO_2 + 6HCl$
629-50-5	Tridecane	$C_{13}H_{28}$	$C_{13}H_{28(l)} + 20\ O_2 \rightarrow 13\ CO_2 + 14\ H_2O$ (CF = 0.9091) $C_{13}H_{28(l)} + 5\ O_2 \rightarrow 2\ C_6H_{6(g)} + CO_2 + 8\ H_2O$ (CF = 0.0909)

Offgas constituent compounds, mostly PICs, that have been identified in VSL and Duratek reports on the processing of WTP Envelope A, B, or C waste simulants are shown in the following table along with their corresponding Chemical Abstract Service (CAS) number and chemical formula. The reaction for complete oxidation of the compound is also shown. Due to the large number of these compounds and limited capacity of the flowsheets to handle constituents, not all of these are tracked in the flowsheets.

PIC Oxidation Reactions

CAS Number	Compound	Formula	Oxidation Reaction
100-02-7	4-Nitro-phenol	$C_6H_5NO_3$	$C_6H_5NO_3 + 6.75O_2 \rightarrow 6CO_2 + 2.5H_2O + NO_2$
105-67-9	2,4 Dimethylphenol	$C_8H_{11}O$	$C_8H_{11}O + 10.25O_2 \rightarrow 8CO_2 + 5.5H_2O$
121-14-2	2,4 Dinitrotoluene	$C_7H_6N_2O_4$	$C_7H_6N_2O_4 + 8.5O_2 \rightarrow 7CO_2 + 3H_2O + 2NO_2$
1746-01-6	2,3,7,8-TCDD	$C_{12}Cl_4O_2$	$C_{12}Cl_4O_2 + 2H_2 + 10O_2 \rightarrow 12CO_2 + 4\ HCl$

CAS Number	Compound	Formula	Oxidation Reaction
19408-74-3	1,2,3,7,8,9-HxCDD	$C_{12}Cl_6O_2$	$C_{12}Cl_6O_2 + 3H_2 + 9.5O_2 \rightarrow 12CO_2 + 6\ HCl$
31508-00-06	PCB 118	$C_{12}H_5Cl_5$	$C_{12}H_5Cl_5 + 12O_2 \rightarrow 12CO_2 + 5HCl$
32598-13-3	PCB 77	$C_{12}H_6Cl_4$	$C_{12}H_6Cl_4 + 12.5O_2 \rightarrow 12CO_2 + H_2O + 4HCl$
32598-14-4	PCB 105	$C_{12}H_5Cl_5$	$C_{12}H_5Cl_5 + 12O_2 \rightarrow 12CO_2 + 5HCl$
3268-87-9	OCDD	$C_{12}Cl_8O_2$	$C_{12}Cl_8O_2 + 4H_2 + 9O_2 \rightarrow 12CO_2 + 8HCl$
32774-16-6	PCB 169	$C_{12}H_4Cl_6$	$C_{12}H_4Cl_6 + H_2 + 11.5O_2 \rightarrow 12CO_2 + 6HCl$
35822-46-9	1,2,3,4,6,7,8-HpCDD	$C_{12}Cl_7O_2$	$C_{12}Cl_7O_2 + 3.5H_2 + 9.25O_2 \rightarrow 12CO_2 + 7HCl$
38380-08-4	PCB 156	$C_{12}H_4Cl_6$	$C_{12}H_4Cl_6 + H_2 + 11.5O_2 \rightarrow 12CO_2 + 6HCl$
69782-90-7	PCB 157	$C_{12}H_4Cl_6$	$C_{12}H_4Cl_6 + H_2 + 11.5O_2 \rightarrow 12CO_2 + 6HCl$
39001-02-0	OCDF	$C_{12}H_4Cl_8O$	$C_{12}H_4Cl_8O + 2H_2 + 10.5O_2 \rightarrow 12CO_2 + 8\ HCl$
39227-28-6	1,2,3,4,7,8-HxCDD	$C_{12}Cl_6O_2$	$C_{12}Cl_6O_2 + 3H_2 + 9.5O_2 \rightarrow 12CO_2 + 6\ HCl$
40321-76-4	1,2,3,7,8-PeCDD	$C_{12}Cl_5O_2$	$C_{12}Cl_5O_2 + 2.5H_2 + 9.75O_2 \rightarrow 12CO_2 + 5\ HCl$
51207-31-9	2,3,7,8-TCDF	$C_{12}H_4Cl_4O$	$C_{12}H_4CL_4O + 11.5O_2 \rightarrow 12CO_2 + 4\ HCl$
51-28-5	2,4-Dinitro-phenol	$C_6H_4N_2O_5$	$C_6H_4N_2O_5 + 6.5O_2 \rightarrow 6CO_2 + 2H_2O + 2NO_2$
534-52-1	4,6-Dinitro-2-methyl-phenol	$C_7H_6N_2O_5$	$C_7H_6N_2O_5 + 8O_2 \rightarrow 7CO_2 + 3H_2O + 2\ NO_2$
55673-89-7	1,2,3,4,7,8,9-HpCDF	$C_{12}H_4Cl_7O$	$C_{12}H_4Cl_7O + 1.5H_2 + 10.75O_2 \rightarrow 12CO_2 + 7HCl$
57117-31-4	2,3,4,7,8-PeCDF	$C_{12}H_4Cl_5O$	$C_{12}H_4Cl_5O + 0.5H_2 + 11.25O_2 \rightarrow 12CO_2 + 5\ HCl$
57117-41-6	1,2,3,7,8-PeCDF	$C_{12}H_4Cl_5O$	$C_{12}H_4Cl_5O + 0.5H_2 + 11.25O_2 \rightarrow 12CO_2 + 5HCl$
57117-44-9	1,2,3,6,7,8-HxCDF	$C_{12}H_4Cl_6O$	$C_{12}H_4Cl_6O + H_2 + 11O_2 \rightarrow 12CO_2 + 6\ HCl$
57653-85-7	1,2,3,6,7,8-HxCDD	$C_{12}Cl_6O_2$	$C_{12}Cl_6O_2 + 3H_2 + 9.5O_2 \rightarrow 12CO_2 + 6\ HCl$
60851-34-5	2,3,4,6,7,8-HxCDF	$C_{12}H_4Cl_6O$	$C_{12}H_4Cl_6O + H_2 + 11O_2 \rightarrow 12CO_2 + 6\ HCl$
67562-39-4	1,2,3,4,6,7,8-HpCDF	$C_{12}H_4Cl_7O$	$C_{12}H_4Cl_7O + 1.5H_2 + 10.75O_2 \rightarrow 12CO_2 + 7\ HCl$
70648-26-9	1,2,3,4,7,8-HxCDF	$C_{12}H_4Cl_6O$	$C_{12}H_4Cl_6O + H_2 + 11O_2 \rightarrow 12CO_2 + 6\ HCl$
72918-21-9	1,2,3,7,8,9-HxCDF	$C_{12}H_4Cl_6O$	$C_{12}H_4Cl_6O + H_2 + 11O_2 \rightarrow 12CO_2 + 6\ HCl$
74-88-4	Iodomethane	CH_3I	$CH_3I + 1.5O_2 \rightarrow CO_2 + H_2O + HI$
91-57-6	2-Methyl-naphthalene	$C_{11}H_{10}$	$C_{11}H_{10} + 13.5O_2 \rightarrow 11CO_2 + 5H_2O$
57465-28-8	PCB 126	$C_{12}H_5Cl_5$	$C_{12}H_5Cl_5 + 12O_2 \rightarrow 12CO_2 + 5HCl$
70362-50-4	PCB 81	$C_{12}H_6Cl_4$	$C_{12}H_6Cl_4 + 12.5O_2 \rightarrow 12CO_2 + H_2O + 4HCl$
74472-37-0	PCB 114	$C_{12}H_5Cl_5$	$C_{12}H_5Cl_5 + 12O_2 \rightarrow 12CO_2 + 5\ HCl$
65510-44-3	PCB 123	$C_{12}H_5Cl_5$	$C_{12}H_5Cl_5 + 12O_2 \rightarrow 12CO_2 + 5\ HCl$
52663-72-6	PCB 167	$C_{12}H_4Cl_6$	$C_{12}H_4Cl_6 + H_2 + 11.5O_2 \rightarrow 12CO_2 + 6\ HCl$
39635-31-9	PCB 189	$C_{12}H_4Cl_6$	$C_{12}H_4Cl_6 + H_2 + 11.5O_2 \rightarrow 12CO_2 + 6\ HCl$

Phosphates

Most of the phosphates go into the glass. However, a small fraction is lost to the offgas per the following equation:

Equation 3.2-35

$$2\ PO_4^{-3} \rightarrow P_2O_5(\text{solid})\uparrow + 3\ O^{-2}\downarrow$$

Halides

The acid gases behave like the sulfate. Some is expected to form acid gases and salt particulates. Iodine, however, can be expected to also form elemental iodine gas. Ratios between the acid and salt are adjusted to approximate what is seen in the melter pilot results.

Equation 3.2-36

$$2\ Cl^- + H_2O \rightarrow 2\ HCl(g)\uparrow + O^{-2}\downarrow \text{ and}$$

Equation 3.2-37

$$Cl^- \rightarrow Cl^-\uparrow \text{ (particulate, g)}$$

Equation 3.2-38

$$2\ F^- + H_2O \rightarrow 2\ HF(g)\uparrow + O^{-2}\downarrow \text{ and}$$

Equation 3.2-39

$$F^- \rightarrow F^-\uparrow\text{(particulate, g)}$$

Equation 3.2-40

$$2\ I^- + H_2O \rightarrow 2\ HI(g)\uparrow + O^{-2}\downarrow \text{ and}$$

Equation 3.2-41

$$I^- \rightarrow I^-\uparrow\text{(particulate, g) and}$$

Equation 3.2-42

$$2I^- \rightarrow I_2\uparrow(g)$$

Most of the chlorine and fluorine are emitted from the melter as particulates, though a higher percentage of fluorine comes off as a gas than chlorine Table 3.2-7. The gaseous species of these two elements is primarily hydrofluoric acid (HF) and hydrochloric acid (HCl), though some Cl_2 is frequently detected. Essentially 100 % of the iodine emitted from the melter is gaseous rather than particulate. The amount of HF emitted from the melter is a function of plenum temperature, as indicated in Figure 3.2-21, which was generated from tests with the Al feed in the DM100 melter. In this figure, HF is expressed as a ratio to NO in the offgas because NO emissions were found to be independent of plenum temperature and feed

rate. There is no data comparable to the HF data for HCl or HI, but the retention of iodine and chlorine in the glass appears to decrease with production rate in this run, and the melter plenum temperature tended to increase with production rate in that test.

Radionuclides

Radionuclides follow their non-radionuclide components, if present. For example, all ^{14}C forms $^{14}CO_2$ in the melter, so ^{14}C follows CO_2 in the offgas system.

3.2.3.4.4 Enhanced Cesium Volatility In the Presence of Technetium

Literature data and previous tests with LAW waste samples have shown that volatility of cesium (Cs) in a melter environment can be enhanced under the presence of high technetium concentrations. Due to the deletion of the technetium ion exchange system from the Pretreatment Facility flowsheet, the technetium to cesium (Tc:Cs) mass ratios dramatically increased in the LAW flowsheet. Tests performed by R&T at the VSL DM100 melter to determine the impacts of these increased ratios in the LAW and HLW flowsheets using rhenium as surrogate for technetium (24590-101-TSA-W000-0009-157-00001). Rhenium was selected based on documented similarities in chemical and physical behavior. Although prototypical Tc:Cs mass ratios were used, the actual concentrations on the LAW tests were three orders of magnitude higher than prototypical concentrations due to analytical constraints.

Tc:Cs volatility relationships have been previously studied at Hanford with actual waste samples. Test results from theses waste samples showed that this phenomenon has the potential to occur at Tc:Cs mass ratios higher than 10,000:1(Table 6.1- 6.3, 24590-101-TSA-W000-0009-157-00001). Literature review mentioned in 24590-101-TSA-W000-0009-157-00001 also indicated that the mechanism of the Cs volatility enhancement is thought to be through the formation of Cs pertechnetate. Therefore, it is likely that the magnitude of the effect not only depends on Tc:Cs ratio, but also on the actual Cs and technetium concentrations.

DM100 results showed that there is a significant effect of increased rhenium to cesium (Re:Cs) mass ratios on increased Cs volatility, but no change in volatility with increasing chlorine and sugar concentrations. The enhanced Cs volatility in HLW was observed at Tc:Cs ratios higher than 1:1 and 100:1 for LAW feeds. Based on these results, an empirical model was developed on the assumption that the enhancement is due to formation of Cs pertechnetate. The model performs well over the range of data available, but extrapolation is required to address high Tc:Cs ratios and low concentrations expected for the LAW flowsheet.

Two models were generated, a base model and a model with an adjusted equilibrium constant to better fit data for high Tc:Cs mass ratios. For LAW, the base model predicts that, because of very low Cs concentration, very high technetium concentrations are required to form appreciable amounts of $CsTcO_4$, and therefore the Cs volatility enhancements are insignificant for typical LAW flowsheet Tc:Cs levels. In contrast, the adjusted equilibrium constant model predicts earlier rise in volatility with significant enhancement in a technetium concentration range that may be relevant for LAW. However, the adjusted equilibrium constant model is purely empirical and is driven by high volatilities observed in the DM100 test data. Additional data would be required to assess the validity of these rather different extrapolated predictions.

The WTP Project Engineering department has concluded that, for LAW, additional Cs volatility could become a source term issue, but the effect of additional Cs volatility would occur at very low Cs concentrations that are not expected to affect the LAW source term. As no additional testing was

approved to explore this phenomenon at prototypic LAW Tc:Cs concentrations, WTP Engineering identified two mitigation strategies that could be performed if this becomes an issue during the operation phase of the plant. Samples from the LAW concentrate receipt vessels would indicate when these mitigation strategies would need to be executed. These strategies are: (1) add cold Cs with the glass forming chemical so that the Tc:Cs ratio decreases (current design has provision to do this manual addition); and (2) recycle the SBS condensate to the waste feed evaporation process system (FEP) evaporator so that it is treated through the Cs ion exchange system for removal of the extra Cs. Current design strategy has the provision to route the SBS condensate from RLD-VSL-00005 to RLD-VSL-00003, which transfers to the FEP system evaporator. Based on the WTP path forward on this matter, no changes are required in the WTP flowsheet models at this time.

3.2.3.5 Film Cooler

The water and gases produced by vitrification are collected in the melter plenum and directed to the film cooler, LOP-FCLR-00001/3, which helps prevent deposits from forming in the offgas piping (24590-LAW-3YD-LOP-00001). If the film cooler fails, a standby film cooler system (LOP-FCLR-00002/4) handles melter offgas flows. Gases enter at 400 °C, typically. Air is also injected into the film cooler for pressure control. Resultant offgas exits the film cooler. An offgas flow velocity of greater than 50 ft/sec is normally maintained between the melter and the SBS. This velocity helps to minimize solids deposition within the film cooler and the offgas line. Water spray into the film cooler and the offgas line is one method to clean the offgas line from the film cooler to the SBS. The energy contributors/absorbers for these pieces of equipment are:

- Film cooler compressed air injection: 16 °C
- Film cooler air: 16 °C
- Film cooler offgas discharge: 350 °C
  Mass flow determined by mass balance
- Injection air for pressure control: 16 °C
  Injection air is first to maintain pressure in the line, and second to lower temperature of the offgas. Since flowsheets do not model transient line pressures, enough injection air shall be added to maintain desired SBS inlet temperature (approximately 300 scfm).
- SBS inlet: 280 °C
  Mass determined by mass balance

Cooling air and control air values come from the LAW primary offgas process system (LOP) and LAW secondary offgas/vessel vent process system (LVP) design descriptions for LAW melter offgas (24590-LAW-M4C-LOP-00001).

3.2.3.6 LAW Container

The glass disposal containers are stainless steel, 4 ft in diameter and 7.5 ft tall (24590-LAW-M0-LRH-00004002) right circular cylinders. To allow the glass to flow uniformly to the periphery of the container, the glass is poured into the container at a rate of about 2.7 times the average glass production rate (40 MTG/day or 1670 kg/hr). Therefore, the glass discharge is controlled in a batch mode, while slurry feeding to the melter is continuous.

The determination of when to start and stop a glass pour is based upon glass pool level. The operating band of the pool depth is approximately ± 1.5 in. Due to restrictions in melt level change, multiple pours are necessary to fill a LAW container.

- Design data: LAW container
  - Total volume[1] (100 %): 626 gal (83.7ft^3)
  - Filled volume (90 %): 564 gal
  - Average glass density:[2] 2.58 g/cm^3 at 20 °C
  - Glass mass flowrate: 625 kg/hr (at 15 MTG/day)
  - Temperature (glass pour): 1150 °C (2102 °F)
  - Glass flow volume: 165 gal/hr
  - Glass pour time: 0.853 hr (51min) duration of pour, 1423 kg/pour
  - Glass level drop/pour: 2.1 in.*

[1] 24590-LAW-M0C-LRH-00004

[2] Density calculated from the median value of available R&T crucible density data and estimated volume percent void content from 24590-101-TSA-W000-0009-72-04. The basis for vessel information is derived from engineering drawings and mechanical systems calculations in accordance with the SOW. Operating data and parameters are based on 90 % design (24590-101-TSA-W000-0010-409-359). Calculation of cycle time between start of pour for each new container is determined based on operational requirements of the mechanical handling system.

* Note: The 2.1 in. assumes no glass is being added to the melter and with a glass density of 2.58 g/cm^3. Assuming glass melt density of 2.45 g/cm^3, the drop in glass level will be more (2.21 in). If glass formers are being added, the drop in level per pour will be less. For example, the glass level will increase 1.0 in./hr at the glass production rate of 625 kg/hr, then the actual glass level drop is 2.21 in -1.0 in./hr x (0.824 hr) = 1.38 in.

3.2.3.6.1 Radioactive Decay Heat in LAW Glass

The flowsheet includes the heat from Sr, Tc, Am, and Cs decay. These are summed together to calculate the radioactive decay heat or q_{rad} in the energy balance. The heat production is small when compared to joule heating by the electrodes. Like electrical power, radioactive decay heat is an input term, since heat is produced.

The specific heat of radionuclides of interest can be determined by the following relationship:

Equation 3.2-43

$$q_{\text{decay heat},\, i} = (\text{W/Ci})_i * (\text{Ci} / 3.70 \times 10^{10}\ \text{Bq}) * (1.0 \times 10^{12}\ \text{Bq/TBq}) * (\text{TBq/kgmol})_i$$
$$= (\text{W/kgmol})$$

Where the individual values for the significant heat generators are:

Isotope	W/Ci	TBq/kgmol
^{90}Sr	6.69 x 10^{-3}	4.60 x 10^5
^{99}Tc	5.01 x 10^{-4}	6.21 x 10^1

^{137}Cs	4.95×10^{-3}	4.40×10^{5}
^{241}Am	3.28×10^{-2}	3.06×10^{4}

The ^{90}Sr and ^{137}Cs decay heats also contain heat generated from the daughter products in secular equilibrium.

The mass of the glass containing the radionuclides is the glass pool in the melter. This mass can be calculated from volume and density values given for the glass pool in Section 3.2.3.2, *LAW Melter*. The concentration of radionuclides in the glass is calculated by the flowsheet.

3.2.3.7 Waste Qualification

Several tests have been done to develop LAW glass formulation with subsequent waste qualification. Due to the cost and complexity of working with actual radioactive wastes, the majority of LAW glass formulation tests have used simulants. A comparison of the properties of glasses made from samples of actual and simulated waste was conducted in 24590-101-TSA-W000-0009-157-00002, Rev A. Over 55 different samples of glasses representing each of the LAW sub-envelopes were reviewed. Product quality properties were compared for samples of glasses that were prepared from a variety of tests, performed at four different institutions over a period of about 5 years. The comparison reviewed samples that were prepared from crucible melts as well as melter tests (DM100, DM1200, DM3300); simulants as well as real waste; and dry chemicals as well as wet slurries. The product consistency test (PCT) response was used as the primary basis for product quality comparison, but vapor hydration test (VHT) and TCLP responses were also compared. The sample treatment included quenching and heat treatment according to the centerline cooling curve (CCC), as well as redox adjustment.

The PCT response for B, Na, and Si remained well below the contract limit of 2 g/m^2, the VHT response remained well below the contract limit of 50 $g/m^2/d$, and the TCLP was well below the UTS limits. The study indicated that there is not a significant difference in the PCT response of samples of similar composition that were prepared from simulants in crucibles, actual waste samples in crucibles, in melters of various scales, or from wet or dry chemicals. The results also indicated that heat treatment according to LAW CCC profiles has no significant effect on the glass PCT response. The adjusted redox states of the glass samples (~ 20 %) also had no effect on the PCT test.

Comparison of the target compositions of similar sub-envelope glass formulation are presented in 24590-101-TSA-W000-0009-157-00002 as well as the analyzed compositions of each sample. Glass oxide compositions within a sub-envelope were in good agreement regardless of the scale, preparation method, or simulant vs. radioactive.

For most non-volatile species, the crucible and melter glasses should, in principle, have the same concentrations. For some volatile species, however, the concentrations might be different. Some analysis performed on glasses made from actual samples of waste from tank 241-AN-102 can be used to evaluate this difference (SCT-M0SRLE60-00-01-02; SCT-M0SRLE60-00-133-01). Table 3.2-8 compares the non-radionuclides in the target glass and between the crucible and bench scale melter glasses. Table 3.2-9 contains the radionuclides for the crucible and bench scale tests. The glass made in a crucible was generally similar to the target glass for most constituents, but the glass made in the bench scale melter was different from the target. The waste constituents in the glass made in a bench scale melter were generally lower than the target glass, and most of elements added as glass formers were greater than the target glass. This indicates that the glass was not batched correctly for the bench scale melter test. Nonetheless, the data is still useful for evaluating the volatility of some species. The last column of

Table 3.2-7 and Table 3.2-8 contains the ratio of the constituents as measured in the crucible glass to the glass produced in the bench scale melter. The ratio is roughly the same (~1.25 mg/mg or pCi/pCi) for most waste constituents, as can be observed in Table 3.2-7. This indicates that most waste constituents were retained in the glass regardless of the synthesis method (melter or crucible). Technicium-99, however, had a higher concentration in the crucible glass than the melter glass (ratio was 2.83 Ci in crucible glass/Ci in bench scale melter glass). Technetium is known to be volatile in the melter. The difference in technetium retention can be explained by the difference between how a feed batch melts in a crucible versus a melter. In a crucible, the outside edges of the batch melt first, creating a condensed phase surrounding the batch that captures volatile species in the glass. In a melter, however, the condensed phase is beneath the cold cap, and the volatile components are free to diffuse up through the gas filled pores in the cold cap. The significance of this is that the retention of volatile radionuclides will be greater in crucible glasses so qualification analyses from crucible glasses are very conservative.

3.2.3.8 Bulk Melt Pool Foaming

The melter is periodically idled at temperatures below the melt temperature (~1000 °C) for various reasons, such as the replacement of bubblers. The LAW pilot facility has observed melt foaming during the processing of one glass (LAWA30) when idled. The melter parameters at the time of that foaming event were not recorded, so a more comprehensive test was undertaken in *RPP-WTP LAW Pilot Melter Glass Pool Foaming Control Test Results Report* (24590-101-TSA-W000-0009-96-02). These tests investigated different bubbler gases and heat up rates, but no bulk foaming was observed, indicating that the melter heat up rate can be fast without foaming being an issue. The heat-up rate of 20 °C/hr using bubbled air was selected for the Operations Research Flowsheet, to be consistent with the successful results while processing C2 glass, documented in the report cited above. The operators may have the flexibility to increase the heat-up rate for glasses with low viscosity at the melt pool temperature. Bubbling with nitrogen and argon gas was investigated as an alternative to the baseline air to determine if the heat up rate could be increased with this mixture. These alternative gases were investigated because laboratory studies from the open literature indicated that nitrogen gas is less likely to induce foaming than air (Fedorov and Pilon 2002). There was no compelling reason seen in the melter tests, however, to switch the bubbler gas from the air, because regular air did not induce foaming in the pilot melter even at high heat-up rates.

Bulk foaming in the melter is caused by small bubbles from bubbling or generated by releasing oxygen from glass during the reduction of multivalent elements (like Fe and Cr) in response to melt temperature increases (24590-101-TSA-W000-0009-96-02, Fedorov and Pilon 2002). The melter tests indicated that iron (the most prevalent multivalent element in LAW glass) was not reduced appreciably in the LAW pilot melter, even at 1150 °C and low oxygen conditions. This is consistent with the low foaming tendencies of the melts studied. Sugar water was effective at dissipating melt surface foam by heating the surface to decrease the melt viscosity.

The bulk foaming event for glass LAWA30 did not occur from excessive heat-up rate; rather, it came from bubbling at low temperature (~950 °C) where the melt viscosity was high. The bulk foaming in LAWA30 was mitigated by increasing the melt temperature to decrease melt viscosity.

3.2.4 Effects of Melter Scale on Melter Emissions

A comparison of offgas emissions from tests with LAW simulants on the DM100 (1 % scale), DM1200 (12 % scale), and DM3300 (33 % scale) melters showed that there was good consistency between the melter scales and emission data (24590-101-TSA-W000-0009-87-00019). The halogens (CL, F, I) comprise a large fraction of elemental emissions due to their volatility. Issues with early development of

analysis methods made it difficult to compare halogen emissions; however, there was a general consistency across the various melter scales. Total particulate and elemental emissions also showed good agreement between melter scales; however, the DM100 melter may slightly over-predict the amounts of particulate and elemental emissions. The particle size distribution data, despite significant variability in runs from the same melter (DM1200 and DM3300), showed a trend for all envelopes that a major fraction of particles at a range greater than 10 to 13 microns and another fraction with a maximum size of about 0.5 to 1 micron. Emissions data for gaseous CO, NO_x, SO_2, HCN, and NH_3, were collected for all three melters. No clear trend was apparent for these gases across the melter scales. It was concluded that extrapolation of gaseous emissions of the pilot scale melters to the full-scale LAW melter is reasonable.

3.2.5 Ongoing Work and Potential Changes

No ongoing studies are in progress for LAW melters.

3.2.6 References

10 CFR 61, *Licensing Requirements for Land Disposal of Radioactive Waste*, Code of Federal Regulations, as amended.

40 CFR 261, *Identification and Listing of Hazardous Waste*, Code of Federal Regulations, as amended.

40 CFR 268, *Land Disposal Restrictions*, Code of Federal Regulations, as amended.

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24590-101-TSA-W000-0009-106-18, Rev 00C, *RPP-WTP Pilot Melter Envelope C Melter Emissions Test Results Report*, TRR-PLT-077, Rev 0.

24590-101-TSA-W000-0009-107-01, Rev 00C, *Report - RPP-WTP Pilot Melter Envelope A Melter Emissions Test Results Report*, TRR-PLT-062, Rev 1.

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24590-101-TSA-W000-0009-147-01, Rev 00B, *Report - RPP Pilot Melter Sub-Envelope C1 Production Verification Test Results Report.*

24590-101-TSA-W000-0009-155-00003, Rev 00A, *Final Report - DuraMelter 100 Tests with LAW AP-101/AY-102 Blended Feed from the Semi-Integrated Pilot Plant.*

24590-101-TSA-W000-0009-157-00001, Rev 00A, *Final Report - DM100 HLW and LAW Tests of the Influence of Technetium on Cesium Volatility Using Rhenium as a Technetium Surrogate.*

24590-101-TSA-W000-0009-157-00002, Rev 00A, *Final Report - Comparison of LAW Simulant, Actual Waste, and Melter Glasses.*

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Table 3.2-1 Metal and Anions UTS-TCLP Limits [a]

CAS #	Metal	Release Rate	ILAW Action Level[b] TCLP Leachate (mg/L)
57-5-12	Cyanide	Unknown	590 mg/kg (total)[e] 30 mg/kg (amenable)
7429-90-5	Aluminum	Slow/Irregular	NA
7440-36-0	Antimony	Retarded	1.15
7440-38-2	Arsenic	Slow/Irregular	5.0 HLVIT[c]
7440-39-3	Barium	Advanced	21 HLVIT[c]
7440-41-7	Beryllium	Unknown	1.22
7440-43-9	Cadmium	Advanced	0.11 HLVIT[c]
7440-70-2	Calcium	Advanced	NA
7440-47-3	Chromium	Slow/Irregular	0.6 HLVIT[c]
7440-50-8	Copper	Advanced	NA
7439-92-1	Lead	Retarded	0.75 HLVIT[c]
7439-97-6	Mercury[d]	Unknown	0.025 HLVIT[c]
7440-02-0	Nickel	Advanced	11
7723-14-0	Phosphorus	Unknown	NA
7440-09-7	Potassium	Advanced	NA
7782-49-2	Selenium[d]	Unknown	1.0 HLVIT[c]
7440-22-4	Silver	Advanced	0.14 HLVIT[c]
7440-23-5	Sodium	Unknown	NA
7440-28-0	Thallium	Retarded	0.20
7440-62-2	Vanadium	Unknown	NA
7440-66-6	Zinc	Advanced	NA

NA = Not applicable, no limit established (maximum analytical estimated quantization limit [EQL] or minimum detection limit should correspond to limits published in SW-846).

[a] Table excerpted from LDR/Delisting DQO, Table 3-7 and Table 5-2.

[b] Action level presented serves as the target level for the maximum analytical EQL or applicable reporting limit (RL), target EQLs/RLs shall be less than (3 to 5 times below) the action levels shown. Concentrations greater than the MDL, but less than the EQL/RL shall be reported and qualified as estimated values.

[c] Vitrification is the LDR technology-based standard (40 CFR 268.40). Target analytical EQLs shall equate to the UTS (40 CFR 268.48) on an opportunistic basis.

[d] COPC is toxicity characteristic limited. Action level is the toxicity characteristic (40 CFR 261.24).

[e] Total cyanide does not require preparation per TCLP. Analysis is of glass product.

Table 3.2-2 LAW Melter Decontamination Factors by Components

Type	Components	Revised LAW Melter DF Envelope A*	Revised LAW Melter DF Envelope B*	Revised LAW Melter DF Envelope C*
Cations				
	Al3+	520	2750	1380
	Ag+	54	103	77
	Am3+	54	103	77
	As5+	4.1	3.5	4.4
	B3+	134 †	347	282
	Ba2+	106	570	136
	Be2+	106	570	136
	Bi3+	54	103	77
	Ca2+	800	2050	1140
	Cd2+	117	570	136
	Ce4+	106	570	136
	Co2+	106	570	136
	Cr3+	14	85	16
	Cr6+	14	85	16
	Cr(OH)4-	14	85	16
	Cr(TOTAL)	14	85	16
	Cs+	7	43	14
	Cu2+	11	570	136
	Eu3+	11	570	136
	Fe2+	540	1560	680
	Fe3+	540	1560	680
	H+	1 & Destroyed	1 & Destroyed	1 & Destroyed
	Hg2+	1	1	1
	K+	20	68	22
	La3+	106	570	136
	Li+	105	650	250
	Mg2+	6350	11400	6200
	Mn4+	106	570	136
	MnO2	106	570	136
	MnO4-	106	570	136
	Mo6+	54	103	77
	Na+	78	260	130
	Nd3+	106	570	136
	Ni2+	106	570	188
	Pb2+	54	103	77

Table 3.2-2 LAW Melter Decontamination Factors by Components

Type	Components	Revised LAW Melter DF Envelope A*	Revised LAW Melter DF Envelope B*	Revised LAW Melter DF Envelope C*
	Pd2+	106	570	136
	Pr4+	106	570	136
	Pu4+	106	570	136
	Ra2+	4.1	3.5	4.4
	Rb+	54	103	77
	Rh3+	106	570	136
	Ru4+	106	570	136
	S+6	7.7 †	16	7.7
	Sb3+	4.1	3.5	4.4
	Se4+	4.1	3.5	4.4
	Si4+	860	2830	1750
	Sr2+	106	570	136
	Ta5+	106	570	136
	Tc4+	1.6	1.6	1.6
	Te4+	4.1	3.5	4.4
	Th4+	106	570	136
	Ti4+	340	1000	430
	Tl5+	4.1	3.5	4.4
	U4+	106	570	136
	U(TOTAL)	106	570	136
	V3+	54	103	77
	W6+	106	570	136
	Y3+	106	570	135
	Zn2+	350	780	510
	Zr4+	4600	11620	5630
Anions				
	Cl-	2.1 †	3.9	2.7
	CO32-	Destroyed	Destroyed	Destroyed
	F-	2.8 †	9	8.1
	I-	63 †	2040	190
	CN-	54	103	77
	NH4+	1.6	Destroyed	Destroyed
	NO2-	Destroyed	Destroyed	Destroyed
	NO3-	Destroyed	Destroyed	Destroyed
	O2-	Calculated	Calculated	Calculated
	OH-(aq)	1 & Destroyed	1 & Destroyed	1 & Destroyed

Table 3.2-2 LAW Melter Decontamination Factors by Components

Type	Components	Revised LAW Melter DF Envelope A*	Revised LAW Melter DF Envelope B*	Revised LAW Melter DF Envelope C*
	OH-(s)	1 & Destroyed	1 & Destroyed	1 & Destroyed
	PO43-	84	115	160
	SiO4-4	860	2830	1750
	SO42-	7.7 †	16	7.7
Organics				
	acetate	Destroyed	Destroyed	Destroyed
	oxalate	Destroyed	Destroyed	Destroyed
	citrate	Destroyed	Destroyed	Destroyed
	EDTA	Destroyed	Destroyed	Destroyed
	formate	Destroyed	Destroyed	Destroyed
	glycolate	Destroyed	Destroyed	Destroyed
	HEDTA	Destroyed	Destroyed	Destroyed
	IDA	Destroyed	Destroyed	Destroyed
	Sucrose	Destroyed	Destroyed	Destroyed
	Chlorobenzene	n/a	n/a	n/a7
	Allyl Alcohol	4.99	4.99	4.991
	Naphthalene	1.08	1.08	1.08
Water				
	H2O	1 & Produced	1 & Produced	1 & Produced
Gases				
	CO	1 & Produced	1 & Produced	1 & Produced
	CO2	1	1	1
	HCl	38.2 †	1.7	10.4
	HF	5.7 †	3.1	7.3
	HI	2.5 †	1.4	1.6
	I2	2.5 †	1.4	1.6
	N2	1 & Produced	1 & Produced	1 & Produced
	NH3	Destroyed/Produced	Destroyed/Produced	Destroyed/Produced
	NO	1 & Produced	1 & Produced	1 & Produced
	NO2	1 & Produced	1 & Produced	1 & Produced
	O2	1 & Produced	1 & Produced	1 & Produced
	P2O5(s)	84	115	160
	SO2	56 †	16.2	7.7
Radionuclides				
	3H	1	1	1
	14C	1	1	1

Table 3.2-2 LAW Melter Decontamination Factors by Components

Type	Components	Revised LAW Melter DF Envelope A*	Revised LAW Melter DF Envelope B*	Revised LAW Melter DF Envelope C*
	59Ni	106.3	570	136
	60Co	106	570	136
	63Ni	106.3	570	136
	79Se	4.1	3.5	4.4
	90Sr	106	570	136
	90Y	106	570	136
	93Zr	4660	11600	5630
	93mNb	106	570	136
	99Tc	1.6	1.6	1.6
	103Ru	54	106	77
	106Ru	54	106	77
	113mCd	117	570	136
	125Sb	4.1	3.5	4.4
	126Sn	106	570	136
	129I	2.5 †	1.4	1.6
	134Cs	4.1	3.5	4.4
	137Cs	4.1	3.5	4.4
	137mBa	4.1	3.5	4.4
	151Sm	106	570	136
	152Eu	106	570	136
	154Eu	106	570	136
	155Eu	106	570	136
	226Ra	4.1	3.5	4.4
	227Ac	106	570	136
	228Ra	4.1	3.5	4.4
	229Th	106	570	136
	231Pa	106	570	136
	232Th	106	570	136
	232U	106	570	136
	233U	106	570	136
	234U	106	570	136
	235U	106	570	136
	236U	106	570	136
	237Np	106	570	136
	238Pu	106	570	136
	238U	106	570	136

Table 3.2-2 LAW Melter Decontamination Factors by Components

Type	Components	Revised LAW Melter DF Envelope A*	Revised LAW Melter DF Envelope B*	Revised LAW Melter DF Envelope C*
	239Pu	106	570	136
	240Pu	106	570	136
	241Am	54	103	77
	241Pu	106	570	136
	242Cm	106	570	136
	242Pu	106	570	136
	243Am	54	103	77
	243Cm	106	570	136
	244Cm	106	570	136

* Engineering calculation 24590-WTP-M4C-V37T-00008, Rev 0, provides the justification, data analysis, and reference Research and Technology reports used to calculate HLW and LAW decontamination factors. DFs of inorganic oxide compounds are used in Steady-State flowsheet and have same DF values as corresponding cations, anions, and gases.

† The Halide DFs utilized for the LAW melter implements a DF that is composed of solid, liquid, and a gaseous components. The process of combining these component term is described to some extent in Appendix J of 24590-WTP-M4C-V37T-00008, Rev 0. Additional discussion of the use of component DFs is provided in BARD Section 3.3.

Table 3.2-3 Categories of LAW Waste and Glass Waste Loading[a]

Current Envelope Designation	Envelope A			Envelope B		Envelope C	
Sub-envelope	**A1**	**A2**	**A3**	**B1**	**B2[b]**	**C1**	**C2**
Tanks Applicable to this Subset	AN-105 SY-101 AN-103	AP-101 AW-101	AN-104 possibly AP-108	Blended AZ-101 & AZ-102	AZ-102	AN-107	AN-102 Possibly S-102
Na_2O Waste Loading, wt %	20		14.8	6.5	5	~14	11.2
K_2O, wt %	0.3 to 0.7	~2	~0.3	~0.2	~0.2	~0.3	~0.2
SO_3, wt %	0.1 to 0.2	0.1 to 0.2	~0.35	0.75	~1	~0.35	~0.45

a Data from engineering calculation 24590-WTP-M4C-V37T-00008, Rev 0, Attachment C.

b The B2 glasses with these concentrations can be made to meet the glass specifications, but these glasses appear to be too corrosive/erosive to the melter refractories. Design life may be 1 or 2 years as opposed to the 5 year design life. Therefore, 3 to 3.5 wt % Na_2O loading or blending with other sub-envelopes is being suggested.

The sodium and sulfur element weights in Table 3.2-2 are as oxides.

Table 3.2-4 Summary of DM100 Nitrogen Oxides and Ammonia Data

		Envelope A								Envelope B				Envelope C					Avg.
		A1 +15%[1]	A1 -15%[1]	A2 +15%[2]	A2 -15%[2]	A3 SIPP[3]	A3 +15%[4]	A3 -15%[4]	A3[4]	B1-1[5]	B1-2[5]	*B2 +15%[6]	*B2 -15%[6]	C1 +15%[7]	C1 -15%[7]	*C2 +15%[8]	C2 -15%[8]	C2 48% Sugar[8]	
Stoichiometric Sugar		0.44	0.57	0.44	0.57	0.5	0.44	0.57	0.5	0.5	0.41	0.44	0.58	0.49	0.51	0.47	0.54	0.50	0.50
% Sugar in Organic C		82.1%	86.1%	86.7%	90.0%	86.9%	92.8%	94.5%	93.7%	94.0%	92.7%	88.1%	90.9%	10.4%	13.6%	42.1%	49.6%	48.0%	73.1%
Ppmv	NO	2240	1430	1600	1100	1100	535.4	1071.9	691.1	414	532	220	120	1054	870	1100	700	844	
	NO_2	443	157	270	148	110	59.9	130.9	44	28	36	0	0	125	80	140	57	77	
	N_2O	231	266	138	127	64	66.6	94.5	82.2	60	63	24	21	111	88	77	59	65.6	
	NH_3	69.2	119	94.4	85.7	40	82.9	102.8	116.9	0.7	0.4	0	0	106	45	43	21	31	
	N_2	436.99	835.58	958.58	1224.85	268.61	579.00	306.87	668.35	588.60	537.12	253.96	220.54	1133.41	1125.51	-45.63	286.97	209.51	
	Total	3420.19	2807.58	3060.98	2685.55	1582.61	1323.80	1706.97	1602.55	1091.30	1168.52	497.96	361.54	2529.41	2208.51	1314.37	1123.97	1227.11	
moles/hr NOx in Feed		29.80	26.20	28.50	25.00	20.00	13.30	16.90	15.8	8.17	8.86	3.58	2.65	25	22	15.2	13	14.2	
% of Feed NO_x emitted as Nitrogen Oxides (includes N_2O)		85.2%	66.0%	65.6%	51.2%	80.5%	50.0%	76.0%	51.0%	46.0%	54.0%	49.0%	39.0%	51.0%	47.0%	100.2%	72.6%	80.4%	62.61%
Envelope Average % Feed No_x emitted as Nitrogen Oxide		Envelope A Average							65.7%	Envelope B Average			47.0%	Envelope C Average				70.2%	
%NO/Nox (w N_2O)		76.9%	77.2%	79.7%	80.0%	86.3%	80.9%	82.6%	84.6%	82.5%	84.3%	90.2%	85.1%	81.7%	83.8%	83.5%	85.8%	85.5%	82.3%
mol/Vol% NO		65.49%	50.93%	52.27%	40.96%	69.51%	40.44%	62.80%	43.13%	37.94%	45.53%	44.18%	33.19%	41.67%	39.39%	83.69%	62.28%	68.78%	51.51%
mol/Vol% NO_2		12.95%	5.59%	8.82%	5.51%	6.95%	4.52%	7.67%	2.75%	2.57%	3.08%	0.00%	0.00%	4.94%	3.62%	10.65%	5.07%	6.27%	5.74%
mol/Vol% N_2O		6.75%	9.47%	4.51%	4.73%	4.04%	5.03%	5.54%	5.13%	5.50%	5.39%	4.82%	5.81%	4.39%	3.98%	5.86%	5.25%	5.35%	5.36%
mol/Vol% NH_3		2.02%	4.24%	3.08%	3.19%	2.53%	6.26%	6.02%	7.29%	0.06%	0.03%	0.00%	0.00%	4.19%	2.04%	3.27%	1.87%	2.53%	3.24%

Table 3.2-4 Summary of DM100 Nitrogen Oxides and Ammonia Data

	Envelope A								Envelope B				Envelope C					Avg.
	A1 +15%[1]	A1 -15%[1]	A2 +15%[2]	A2 -15%[2]	A3 SIPP[3]	A3 +15%[4]	A3 -15%[4]	A3[4]	B1-1[5]	B1-2[5]	*B2 +15%[6]	*B2 -15%[6]	C1 +15%[7]	C1 -15%[7]	*C2 +15%[8]	C2 -15%[8]	C2 48% Sugar[8]	
mol/Vol% N_2	12.78%	29.76%	31.32%	45.61%	16.97%	43.74%	17.98%	41.71%	53.94%	45.97%	51.00%	61.00%	44.81%	50.96%	-3.47%	25.53%	17.07%	34.15%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	10.00%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* B2 data not included in overall average since no NO_2 was detected and is not consistent with other data, also C2 +15% is not included in the overall average as 100% of the feed NO_x was emitted as NO_x.

[1] 24590-101-TSA-W000-0009-128-02, *Final Report- Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A1 Feed (LAWA44Glass) in Support of the LAW Pilot Melter*, 2002

[2] 24590-101-TSA-W000-0009-53-01, Rev 00E, *Final Report - Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A2 Feed (LAWA88Glass) in Support of the LAW Pilot Melter*, 2003

[3] 24590-101-TSA-W000-0009-155-00003, Rev 00A, *DuraMelter 100 Tests with LAW AP-101/AY-102 Blended Feed from Semi-Integrated Pilot Plant*, 2005

[4] 24590-101-TSA-W000-0009-102-01, Rev 00D, *Data Summary Report- Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A3 Feed in Support of the LAW Pilot Melter*

[5] 24590-101-TSA-W000-0009-66-06, Rev 00B, *Final Report- Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope B1 Feed in Support of the LAW Pilot Melter*, 2003

[6] 24590-101-TSA-W000-0009-135-04, Rev 00B, *Final Report- Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope B2 Feed in Support of the LAW Pilot Melter*, 2003

[7] 24590-101-TSA-W000-0009-98-06, Rev 00B, *Final Report- Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope C1 Feed (LAWC22Glass) in Support of the LAW Pilot Melter*, 2002

[8] 24590-101-TSA-W000-0009-98-00008, Rev 00A, *Final Report - Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope C2 Feed in Support of the LAW Pilot Melter*, 2004

Table 3.2-5 Derivation of Nitrogen Compounds Stoichiometric Coefficients (Average 100 Data)

		Moles Emitted per 100 moles Feed Nox	Moles N	Normalized	Stoichiometric Coefficients
a	N_2	34.15	68.31	0.51	0.2546
b	NO_2	5.74	5.74	0.04	0.0428
c	NO	56.87	56.87	0.42	0.4239
d	NH_3	3.24	3.24	0.02	0.0242
Total		100.00	134.15	1.00	0.7454

O_2 Balance	NO_3	NO_2
H_2O Required	0.0362	0.0362
Moles O In	3.036	2.036
Moles O Out Used	1.009	1.009
Moles O as O_2	2.027	1.027
Coefficient e	1.013	0.513

$$RNO_3 + 0.0362H_2O \rightarrow 0.5R_2O\downarrow + 0.2546N_2\uparrow + 0.4239NO\uparrow + 0.0428NO_2\uparrow + 0.0242NH_3\uparrow + 1.013O_2\uparrow$$

$$RNO_2 + 0.0362H_2O \rightarrow 0.5R_2O\downarrow + 0.2546N_2\uparrow + 0.4239NO\uparrow + 0.0428NO_2\uparrow + 0.0242NH_3\uparrow + 0.513O_2\uparrow$$

*N_2O moles were added to the NO moles, since N_2O is not tracked in the flowsheet.

Table 3.2-6 Summary of Bubbling Rate Adjustment Test

Bubbling Rate, scfm/m^2	LAW Pilot Melter (DM3300)			HLW Pilot Melter (DM1200)	DM100
	[1]Sub-Envelope A1 LAWA44 MT/m^2/day	[2]Sub-Envelope B1 LAWB83 MT/m^2/day	[3]Sub-Envelope C1 LAWC22 MT/m^2/day	[4]LAWC22 DM1200 MT/m^2/day	[5]Sub-Envelope A1 LAWA44 MT/m^2/day
0.61	1.68 ± 0.24	1.59 ± 0.12	1.19 ± 0.01	0.75	1.50
0.97	1.89 ± 0.12	-	-	-	-
1.21	2.01 ± 0.25	1.77 ± 0.15	1.41 ± 0.11	1.15	1.75
1.45	2.02 ± 0.11	-	-	-	-
1.82	2.12 ± 0.15	2.20 ± 0.16	1.83 ± 0.14	1.55	1.75
2.68	-	-	-	2.10	-
3.03	-	-	2.09 ± 0.11	2.32	-
3.27	-	-	-	-	2.25
5.23	-	-	-	-	3.30

24590-101-TSA-W000-0009-113-00001, Rev 00A, *RPP-WTP LAW Pilot Melter Testing Summary.*

Source Data:

[1] 24590-101-TSA-W000-0009-84-02, Rev 00B, *RPP-WTP Pilot Melter Sub-Envelope C1-A1 Changeover Test Results Report.*

[2] 24590-101-TSA-W000-0009-49-04, Rev 00B, *RPP Pilot Melter Sub-Envelope A2-B1 changeover test Results Report.*

[3] 24590-101-TSA-W000-0009-147-01, *RPP Pilot Melter Sub-Envelope C1 Production Verification Test Results Report.*

[4] 24590-101-TSA-W000-0009-105-00006, Rev 00A, *Bubbling Rate and Foaming Tests on the Duramelter 1200 with LAWC22 and LAWA30 Glasses.*

[5] 24590-101-TSA-W000-0009-106-07, Rev 00C, *DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelopes A1 and C1 Feeds in Support of LAW Pilot Melter.*

Table 3.2-7 Weight Percent of the Elemental Emissions from the DM100 and DM1200 Melter in the Gaseous Form

	C1 DM 100[a]	A1 DM 100[a]	C1 DM1200[b]	A1 DM 1200[c]
wt-% Gas B	44.11	38.83	59.19	74.21
wt-% Gas Cl	8.87	47.35	0.52	4.13
wt-% Gas F	61.74	43.77	28.51	14.57
wt-% Gas I	100.00	100.00	100.00	100.00
wt-% Gas S	6.13	0.00	2.99	0.89

[a] Data from 24590-101-TSA-W000-0009-106-07

[b] Data from 24590-101-TSA-W000-0009-111-01

[c] Data from 24590-101-TSA-W000-0009-111-02

Table 3.2-8 Comparison of Average Concentrations of Non-Radionuclides Between Crucible and Melter Scale Glasses

Element	Target (mg/g)	Crucible Average[c] (mg/g)	Crucible Standard Deviation	Melter Average[c] (mg/g)	Melter Standard Deviation	Ratio Crucible/Melter (mg/mg)
Al	3.30E+04	3.35E+04	5.77E+02	2.76E+04	2.44E+03	1.22E+00
Ca	4.60E+04	4.68E+04	1.71E+03	4.05E+04	5.57E+03	1.15E+00
Cu[a]	3.6	8.88E+01	2.60E+01[a]	2.80E+02	7.44E+01[a]	3.17E-01
Fe	4.50E+04	4.48E+04	9.57E+02	4.11E+04	1.37E+03	1.09E+00
Li	1.40E+04	1.28E+04	5.00E+02	1.48E+04	2.15E+03	8.61E-01
Mg	9.10E+03	9.23E+03	2.06E+02	8.13E+03	3.77E+02	1.14E+00
Mn[a]	7.70E-01	4.58E+02	2.87E+02[a]	8.03E+02	7.59E+02[a]	5.70E-01
Na[b]	8.80E+04	9.10E+04	1.41E+03	7.19E+04	5.66E+02	1.27E+00
P	5.60E+02	5.65E+02	5.00E+01	6.53E+02	3.40E+01	8.66E-01
S	1.40E+03	1.80E+03	8.16E+01	1.43E+03	1.19E+02	1.26E+00
Si	2.20E+05	2.03E+05	1.26E+04	2.32E+05	9.42E+03	8.73E-01
Zn	2.40E+04	2.35E+04	5.77E+02	2.37E+04	4.35E+02	9.91E-01
Zr	2.20E+04	2.33E+04	5.00E+02	2.55E+04	1.45E+03	9.11E-01
Weight Percent Na_2O in glass	11.86086957	12.26521739	0.190611393	9.69086957	0.076245	1.27E+00

[a] Mn and Cu had large discrepancies between the acid and fusion digests.

[b] Na was only analyzed in the acid digests.

[c] Average of four analyses (two acid digest and two fusion) on glasses prepared from Tank 241-AN-102 using bench scale Savannah River Technology Center Melter.

Table 3.2-9 Comparison of Average Concentrations of Radionuclides Between Crucible and Melter Scale Glasses

Radionuclide	Crucible Average[a](pCi/g)	Standard Deviation	Melter Average[a] (pCi/g)	Standard Deviation	Ratio Crucible/Melter (pCi/pCi)
Am-241	1.02E+04	1.00E+03	8.33E+03	2.22E+02	1.23E+00
Cs-137	3.20E+04	1.63E+03	2.33E+04	1.89E+03	1.38E+00
Co-60	2.73E+04	1.26E+03	1.98E+04	1.26E+03	1.38E+00
Eu-154	2.75E+04	5.77E+02	2.01E+04	1.94E+03	1.37E+00
Eu-155	1.63E+04	1.26E+03	1.11E+04	9.81E+02	1.47E+00
Total Alpha	2.50E+04	6.58E+03	2.12E+04	3.04E+03	1.18E+00
Total Beta	1.93E+06	9.57E+04	1.30E+06	7.64E+05	1.48E+00
Sr-90 (Y-90)	1.01E+06	1.32E+05	8.23E+05	8.46E+04	1.22E+00
Tc-99	1.65E+04	5.77E+02	5.83E+03	2.06E+02	2.83E+00
Pu-238	5.10E+02	3.74E+01	4.60E+02	1.97E+01	1.11E+00
Pu-239/240	6.30E+02	2.45E+01	5.50E+02	2.16E+01	1.15E+00
Cm-244	8.08E+03	6.99E+02	5.80E+03	7.59E+01	1.39E+00
Cm-242	5.20E+01	1.48E+01	5.95E+01	4.10E+01	8.74E-01

[a] Average of four analyses (two acid digest and two fusion) on glasses prepared from Tank 241-AN-102 using bench scale Savannah River Technology Center melter.

Table 3.2-10 Semivolatiles' Combined Solids and Gas Decontamination Factors

Ion/Element	LAW
Fluorine	1.88
Chlorine	1.99
Iodine	2.40

This data is taken from 24590-WTP-M4C-V37T-00008, Rev 1, Attachment J.

Legend for Figures

The legend for use with Figures 3.2-3 to 3.2-17, is as follows:

A12N	DM1200 melter, Envelope A, non-spiked
A12S	DM1200 melter, Envelope A, spiked
B12N	DM1200 melter, Envelope B, non-spiked
C12N	DM1200 melter, Envelope C, non-spiked
C12S	DM1200 melter, Envelope C, spiked
A33N	DM3300 melter, Envelope A, non-spiked
B33N	DM3300 melter, Envelope B, non-spiked
C33N	DM3300 melter, Envelope C, non-spiked
Spare	unassigned field
TCDD	tetrachlorodibenzodioxin
PeCDD	pentachlorodibenzodioxin
HxCDD	hexachlorodibenzodioxin
HpCDD	heptachlorodibenzodioxin
OCDD	octachlorodibenzodioxin
TCDF	tetrachlorodibenzofuran
PeCDF	pentachlorodibenzofuran
HxCDF	hexachlorodibenzofuran
HpCDF	heptachlorodibenzofuran
OCDF	octachlorodibenzofuran
PCB	polychlorinated biphenyl
EDTA	ethylenediamine tetra-acetic acid
HEDTA	N-(2-hydroxyethyl) ethylenediamine tri-acetic acid
CDD/CDF/PCB	chlorodibenzodioxin/chlorodibenzofuran/polychlorinated biphenyl
DRE	destruction removal efficiency
ACE	acetonitrile/acrylonitrile/acetone

Figure 3.2-3 LAW Melter Process System

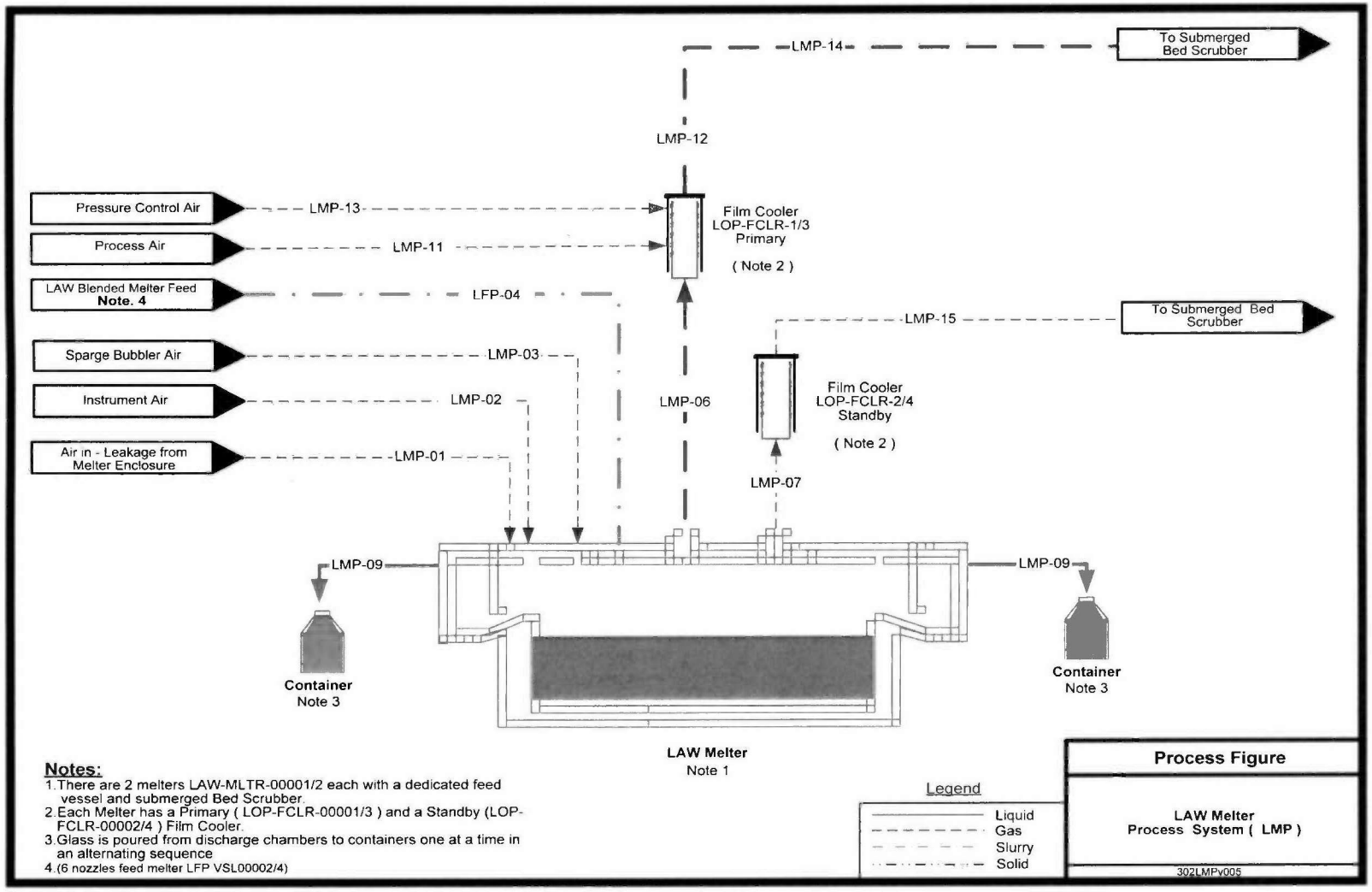


Figure 3.2-4 DM3300 Bubbling Rate vs. Glass Production

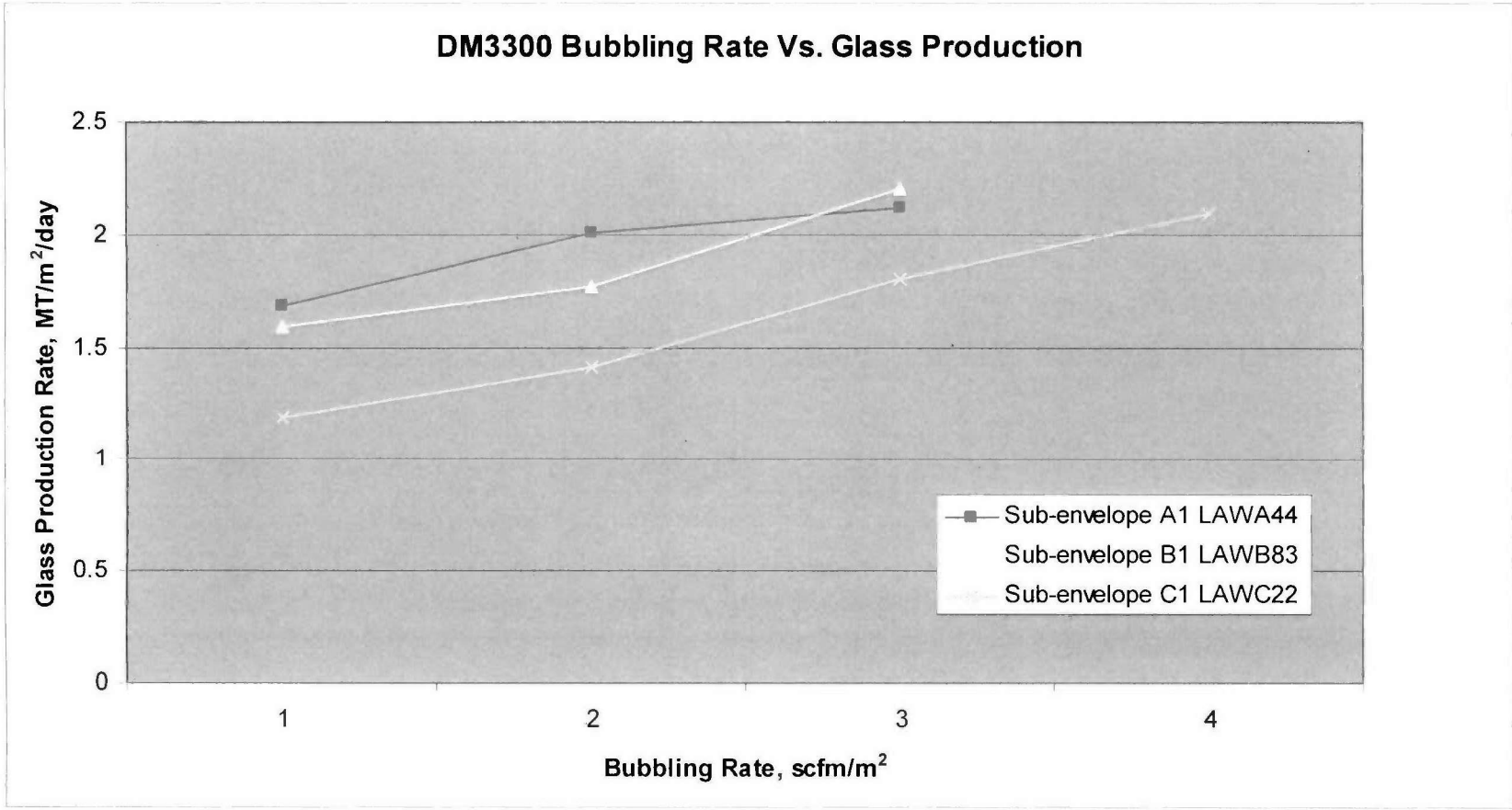


Figure 3.2-5 Element Retention in A1 Glass as a Function of Glass Production Rate in DM100 Melter

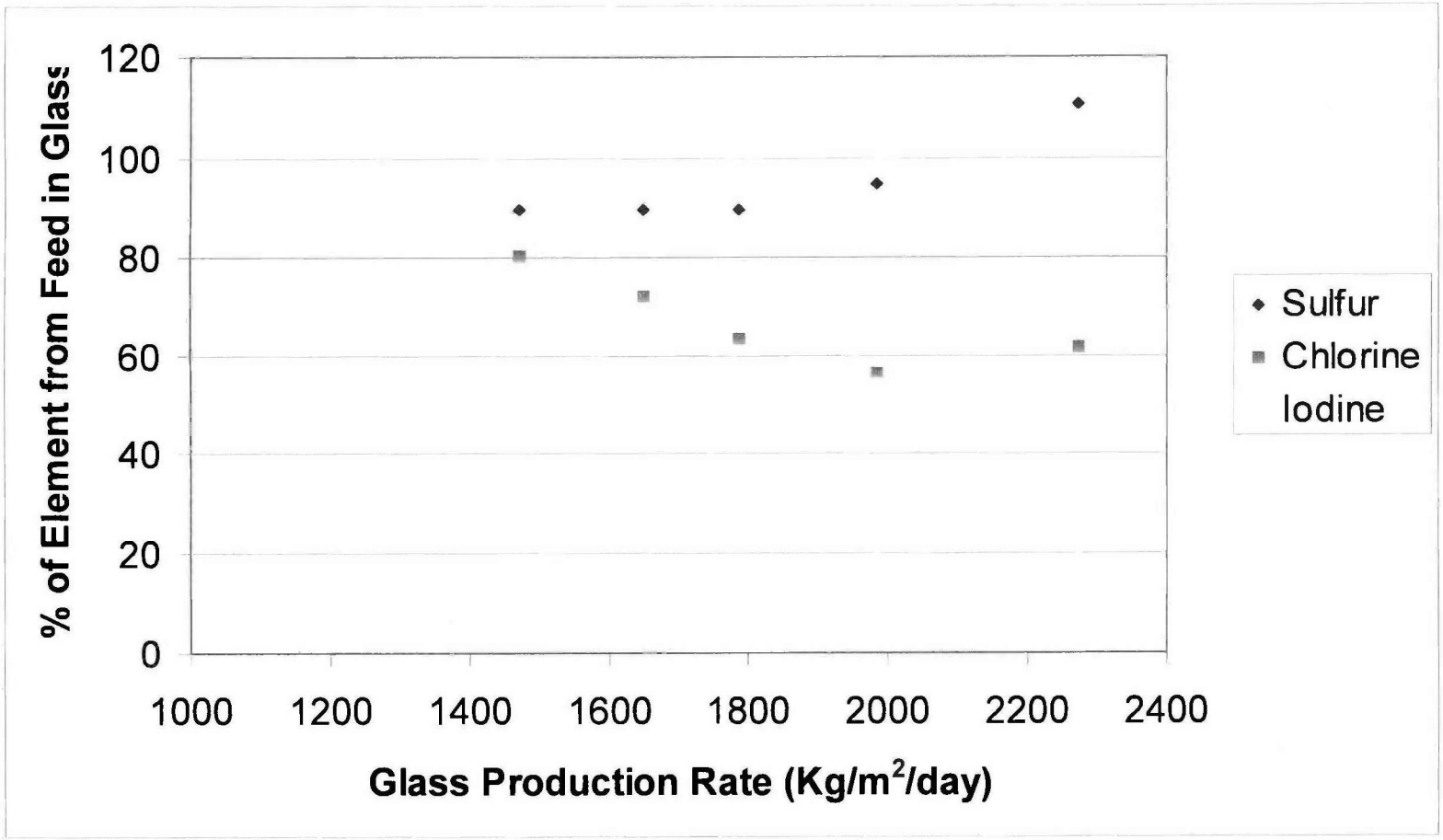


Figure 3.2-6 Melter Organic Offgas Emissions per Test Report

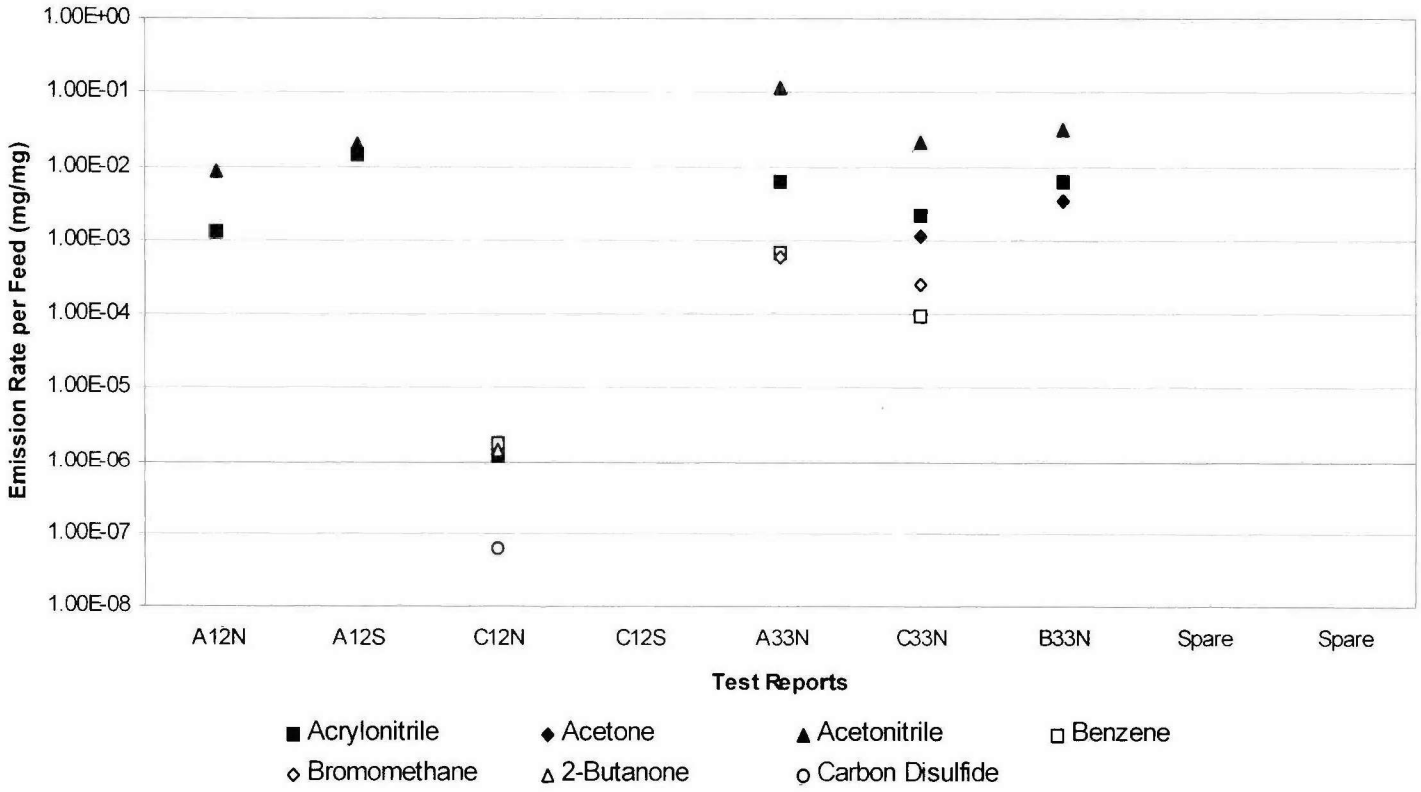


Figure 3.2-7 Melter Chlorinated Organic Offgas Emissions per Test Report

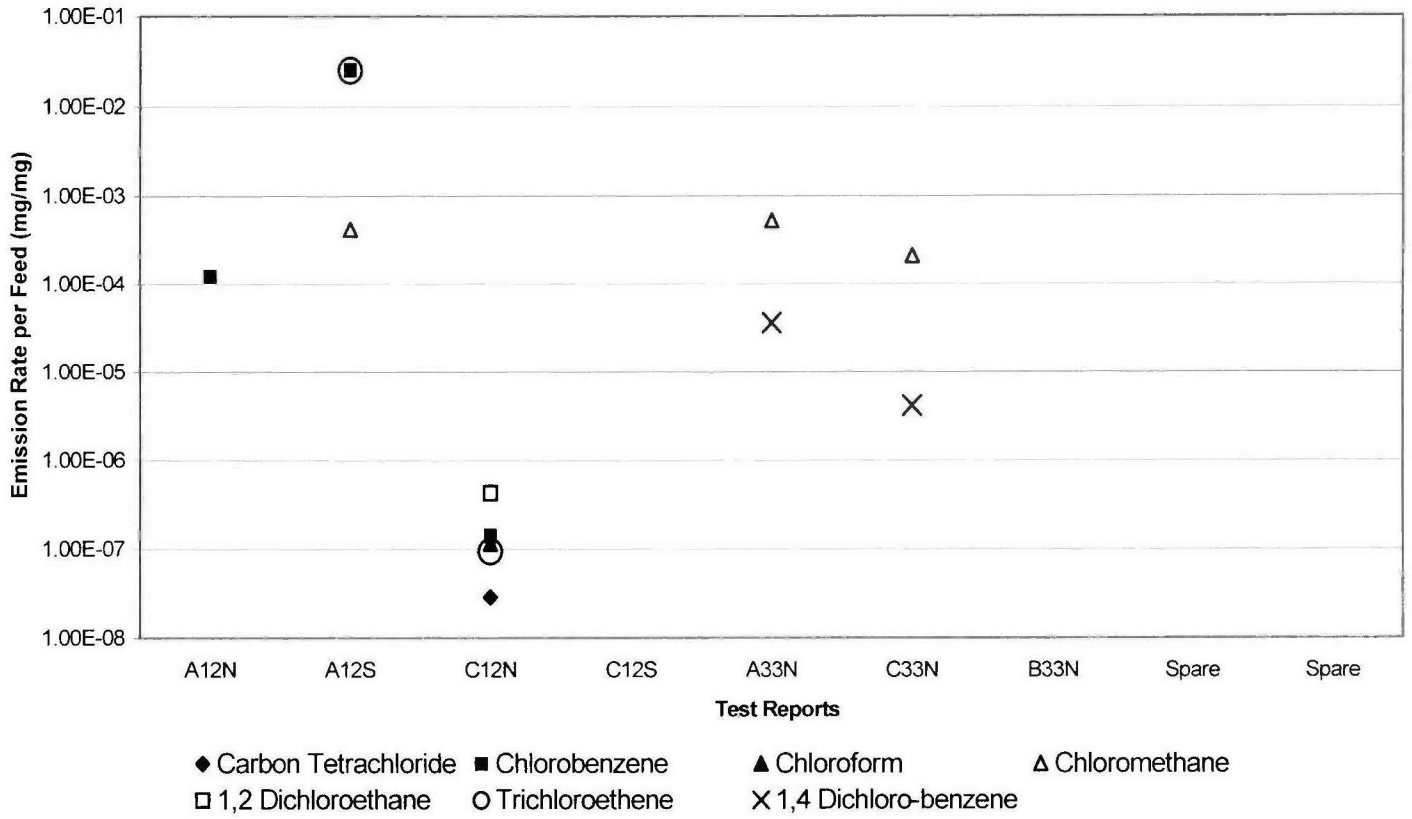


Figure 3.2-8 Melter Organic Offgas Emissions per Test Report

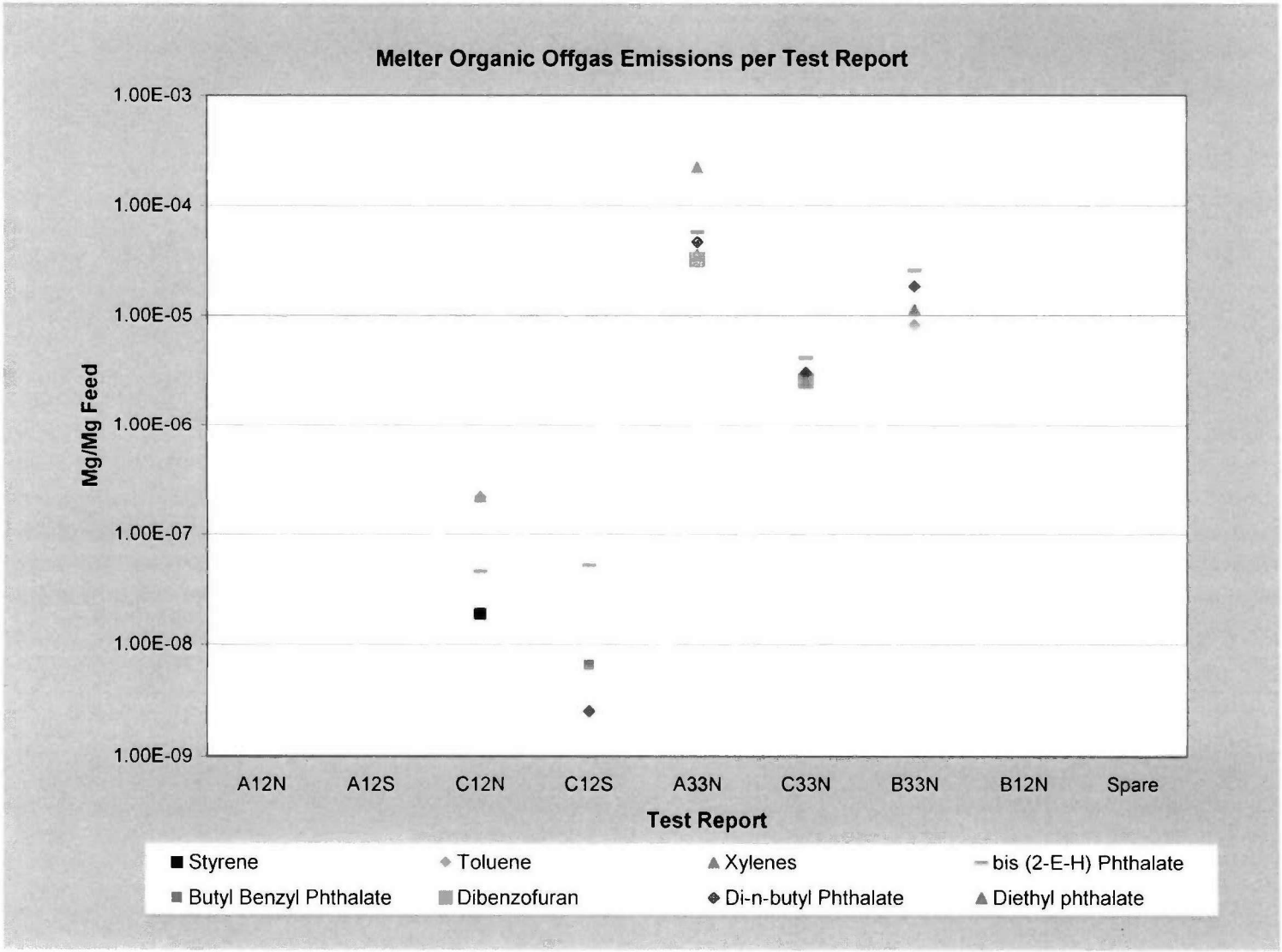


Figure 3.2-9 Melter Organic Offgas Emissions per Test Report (cont.)

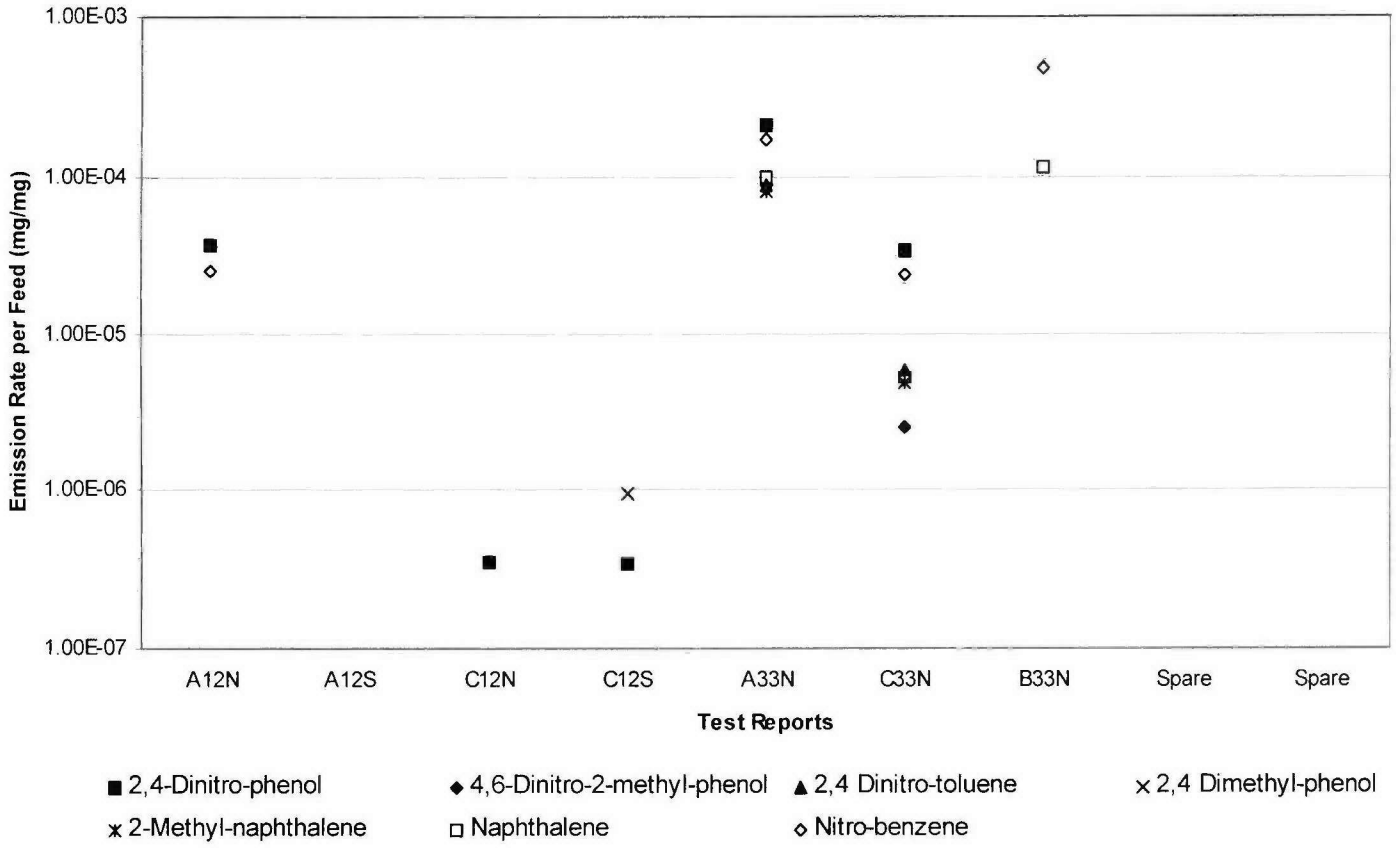


Figure 3.2-10 Melter Organic Offgas Emissions per Test Report (cont.)

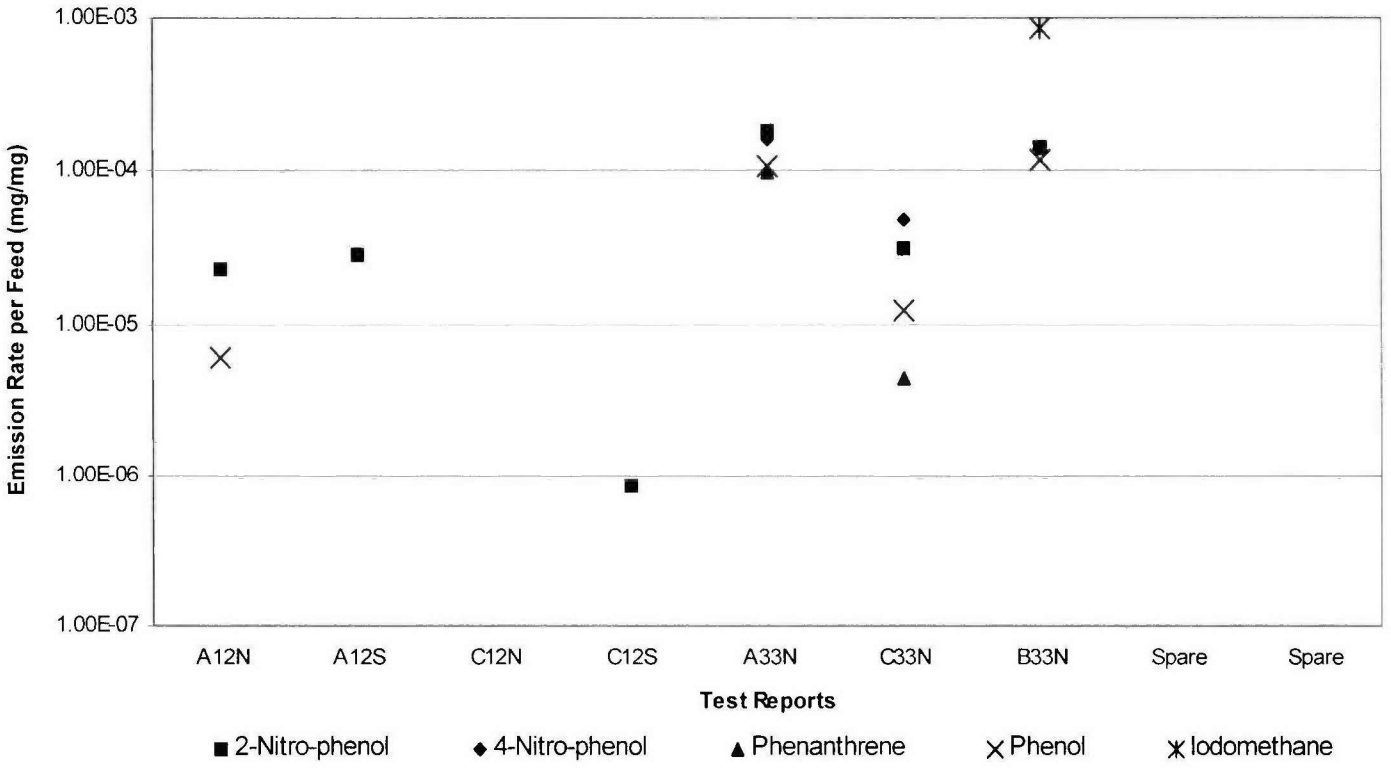


Figure 3.2-11 Melter Dioxin, Furan Emissions

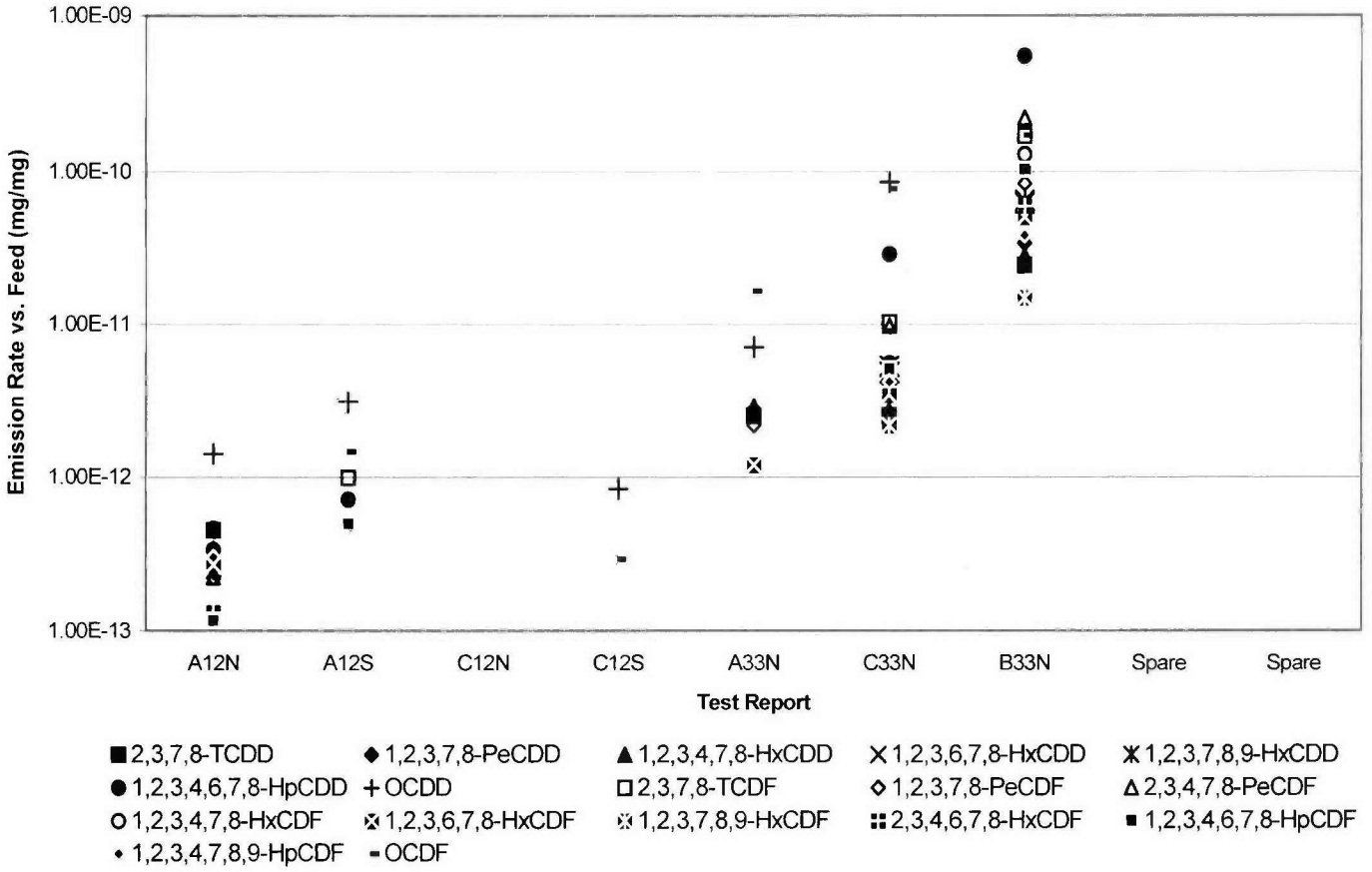


Figure 3.2-12 Melter PCB Emissions

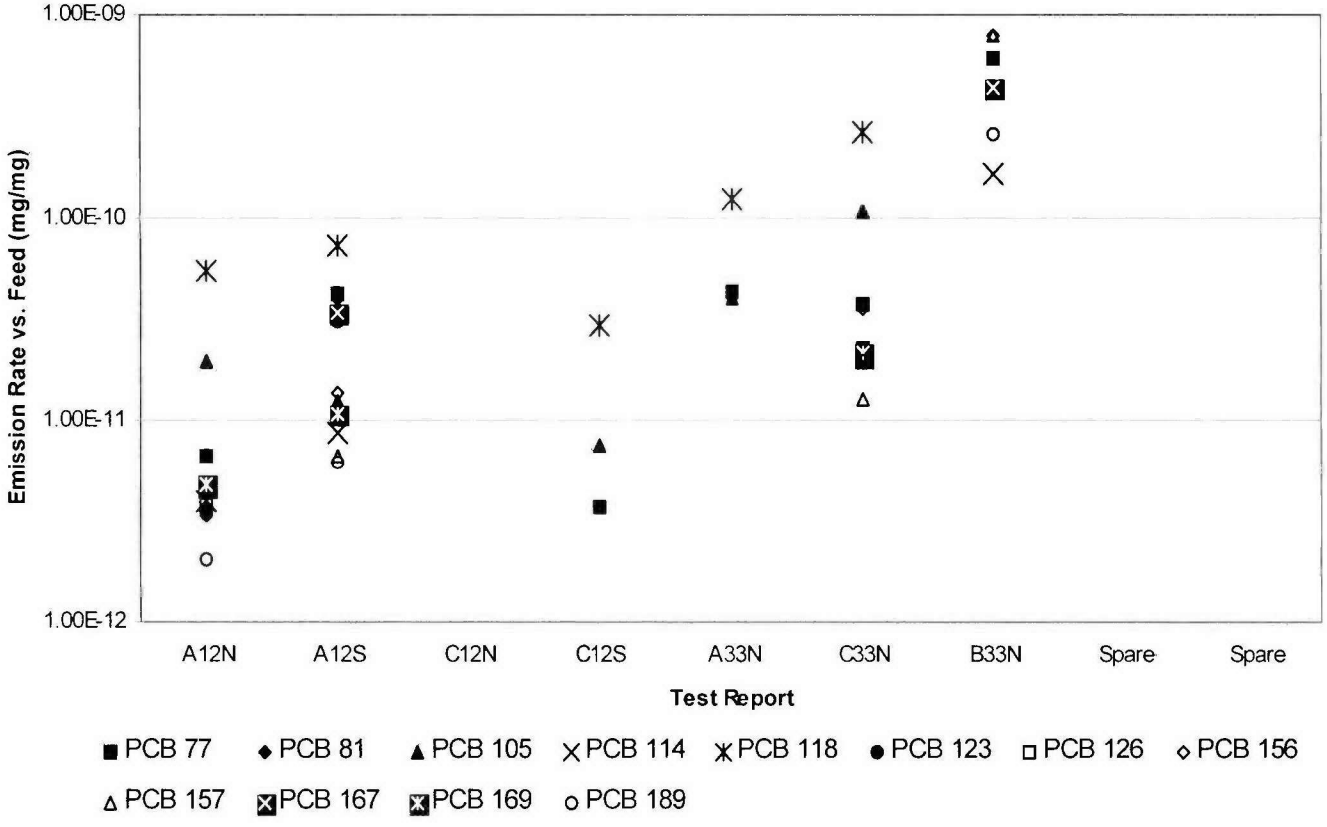


Figure3.2-13 Melter Spike DFs

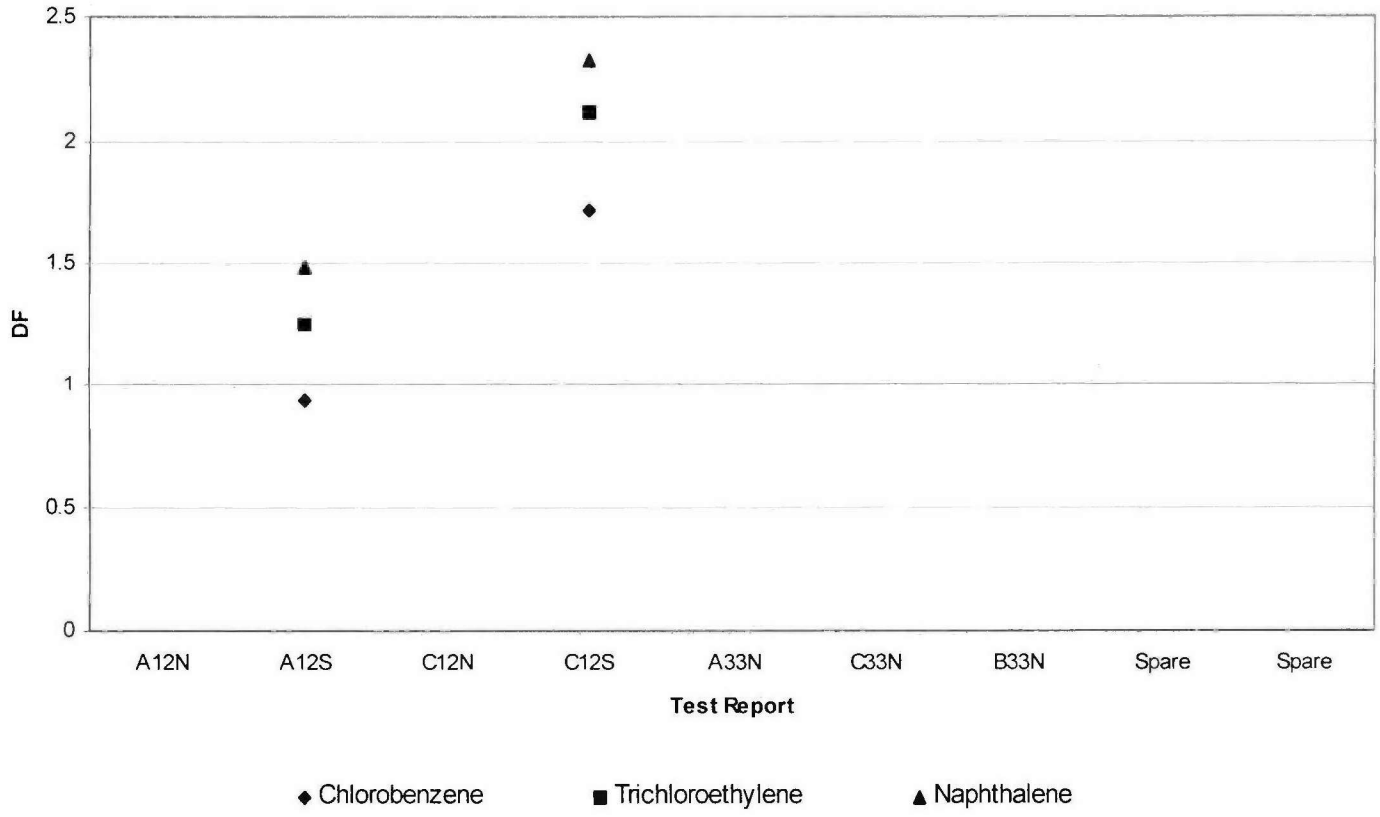


Figure 3.2-14 Miscellaneous Offgas Products

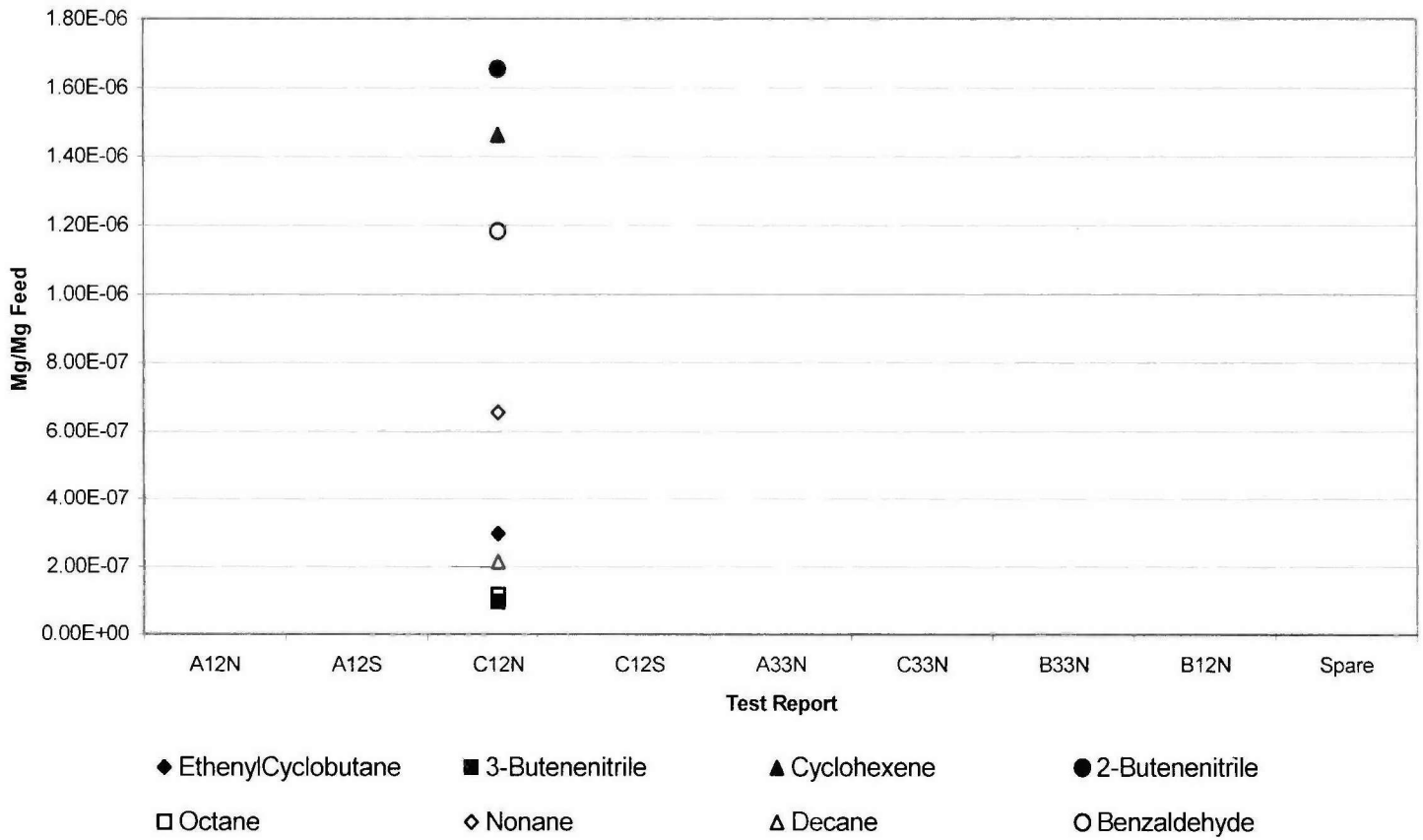


Figure 3.2-15 Miscellaneous Offgas Products (cont.)

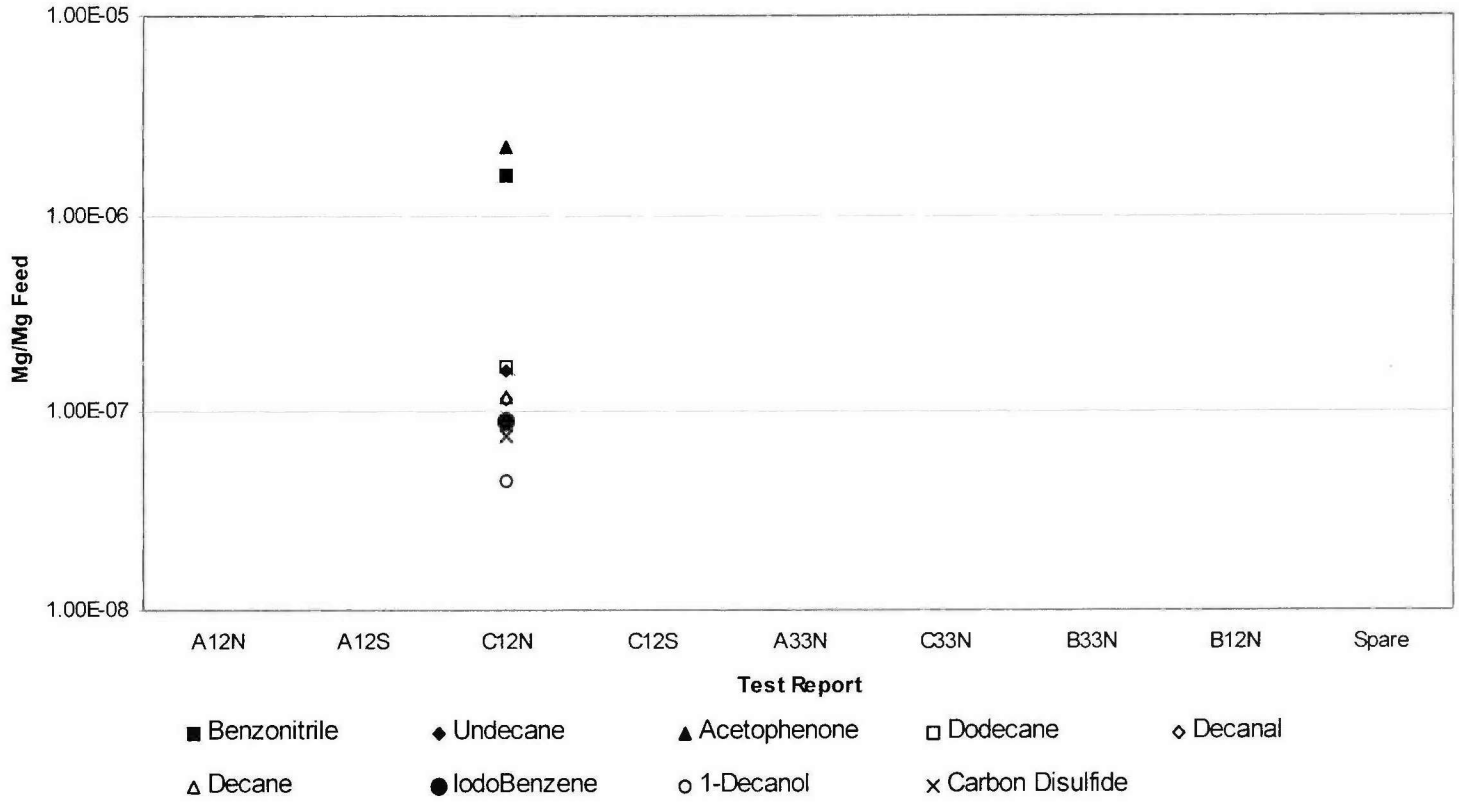


Figure 3.2-16 Comparison of Feed Type to Specific Offgas Generation

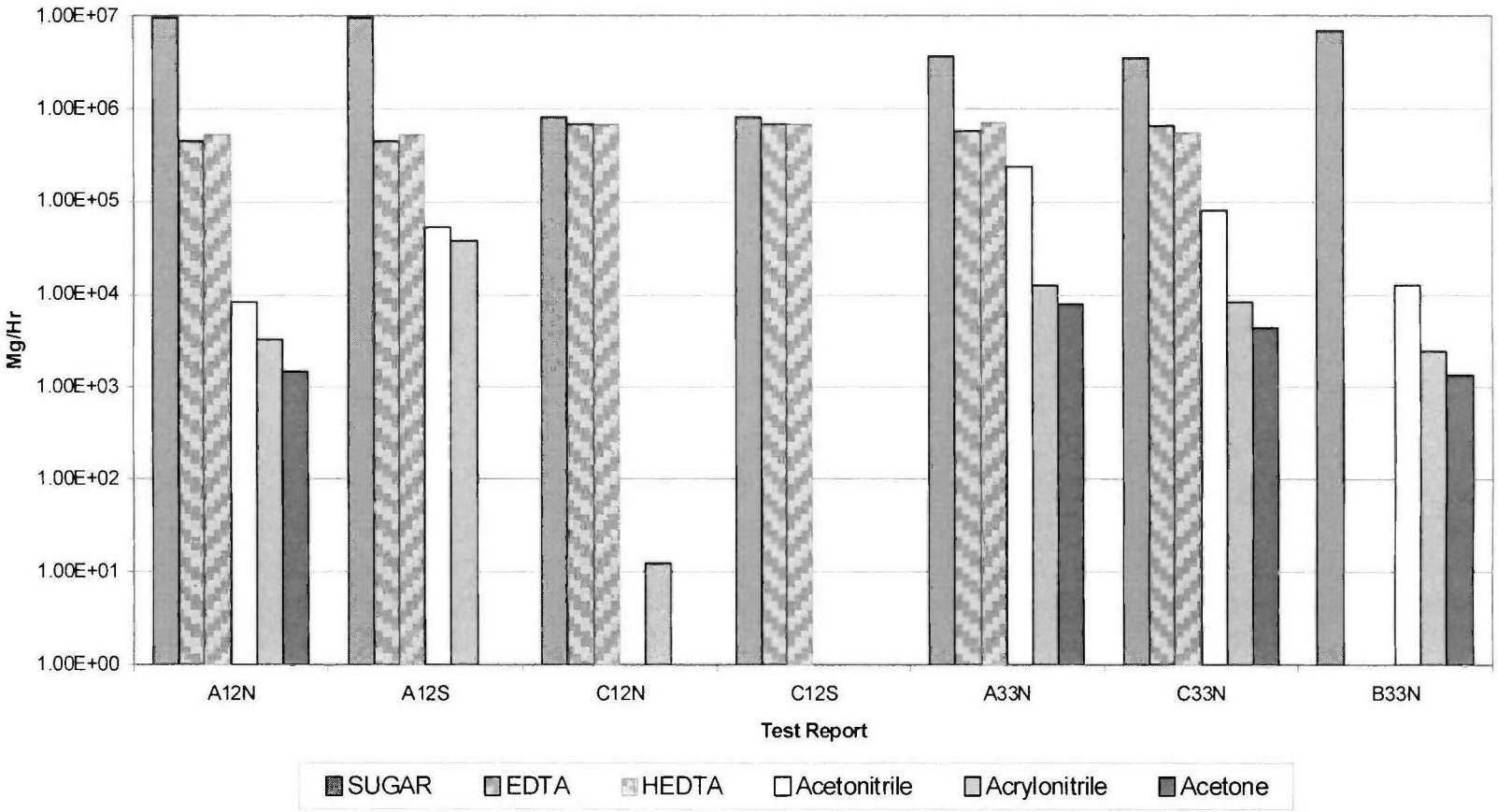


Figure 3.2-17 Comparison of Feed Type vs. Total CDD/CDF/PCB Production

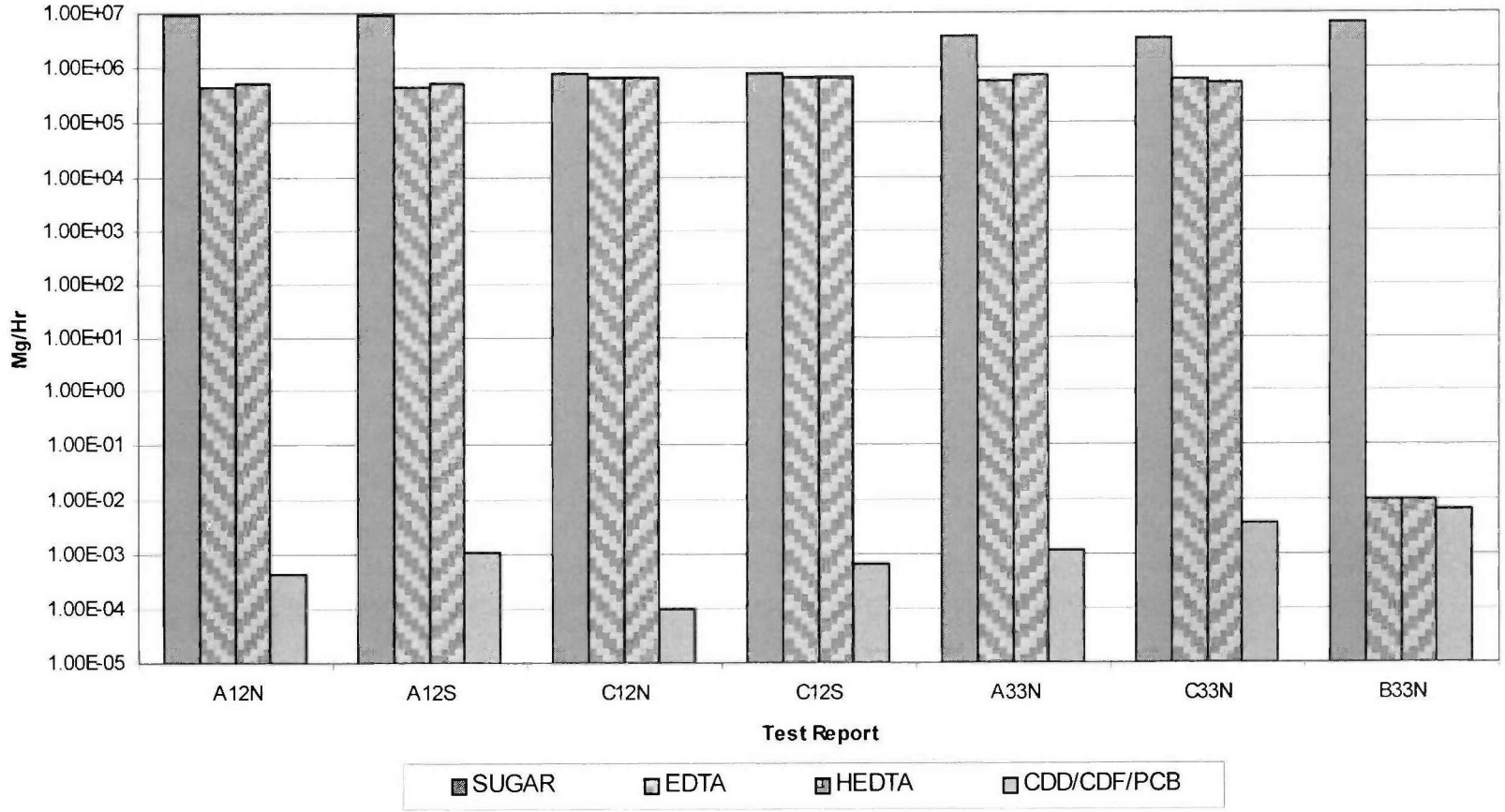


Figure 3.2-18 Comparison of Feed Types to DREs

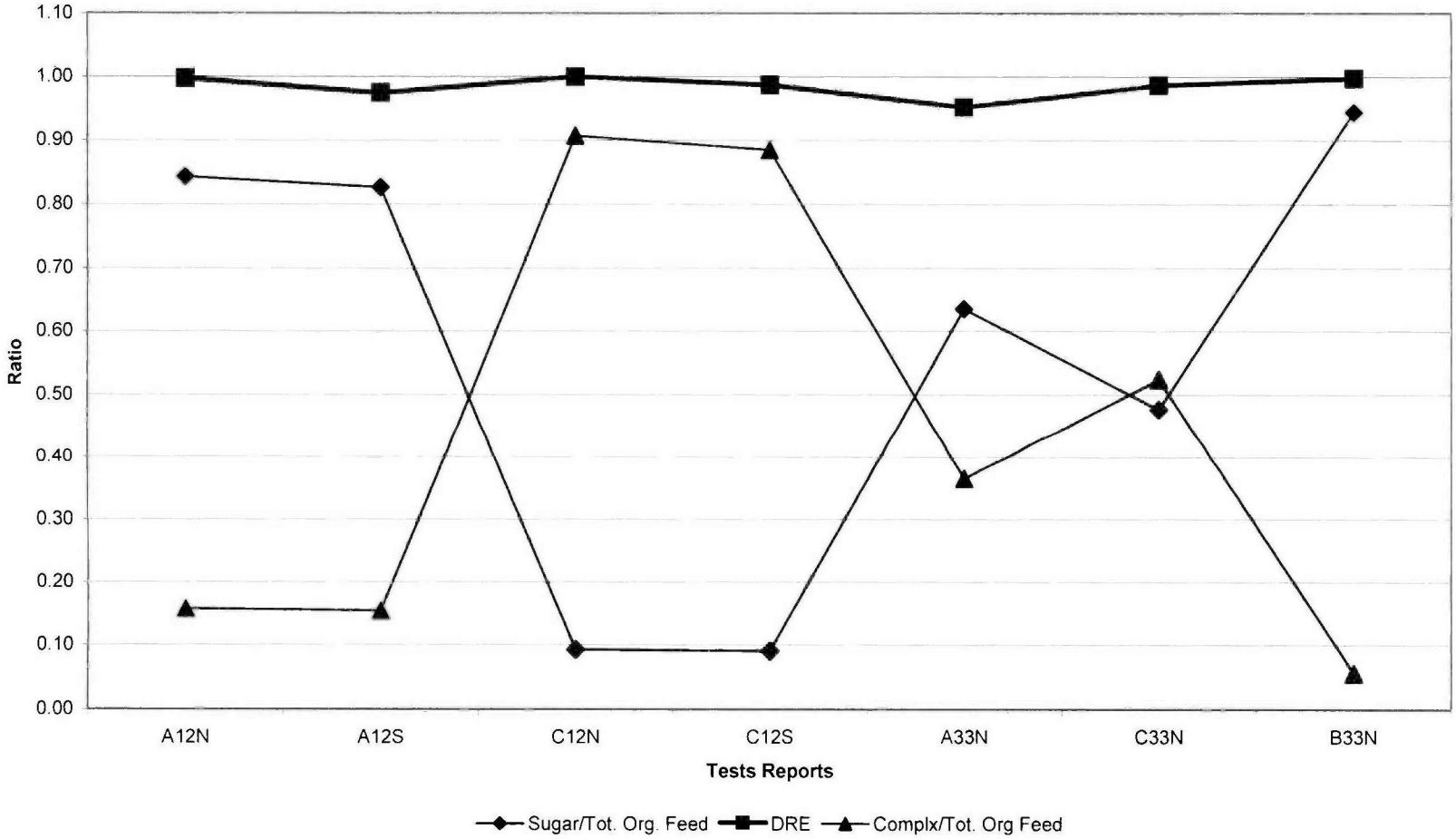


Figure 3.2-19 Relationship Between Feed Constituents and Total Organic Offgas Generation

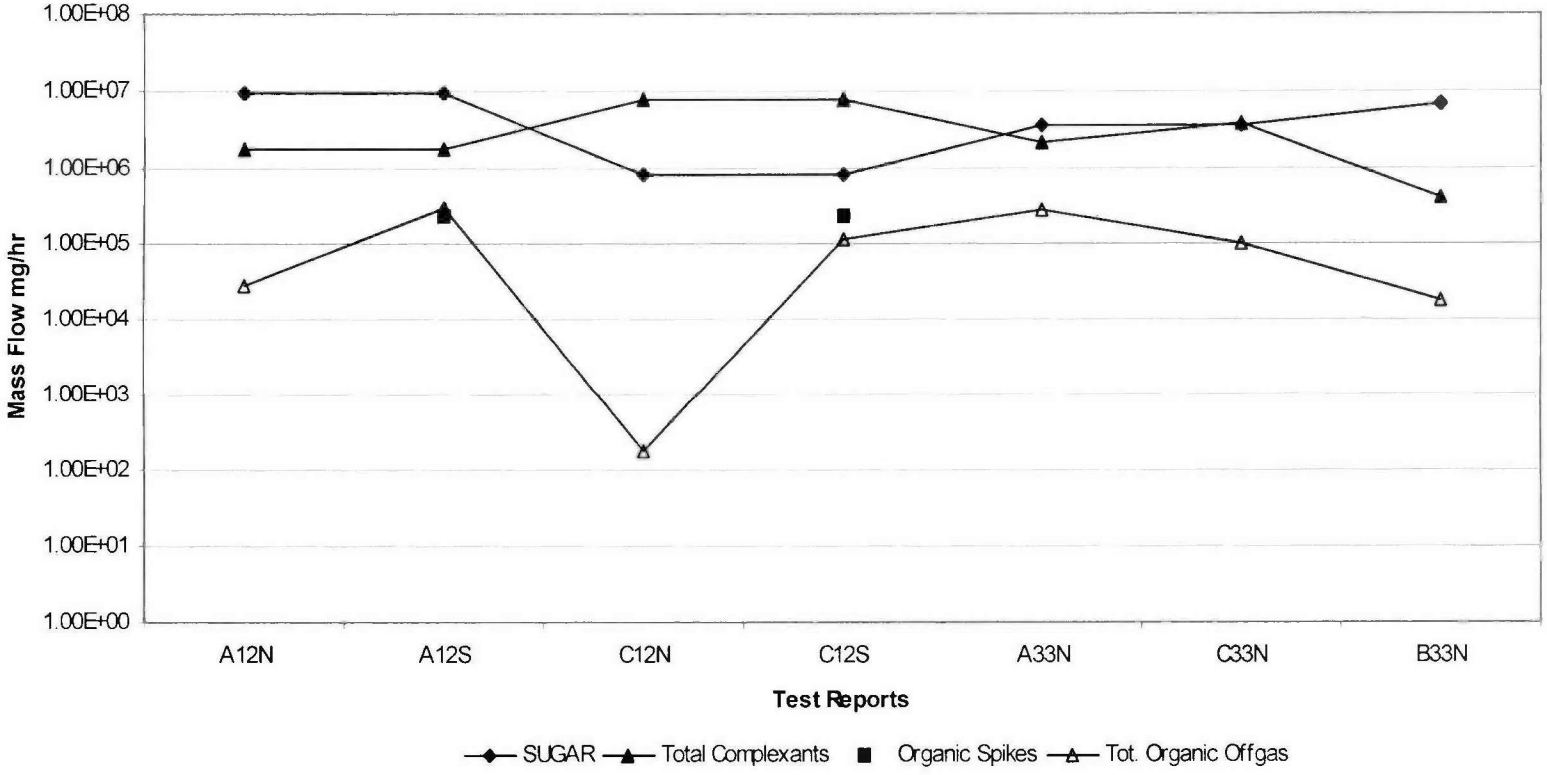


Figure 3.2-20 Relationship Between Feed Constituents and Priority Offgas Generation

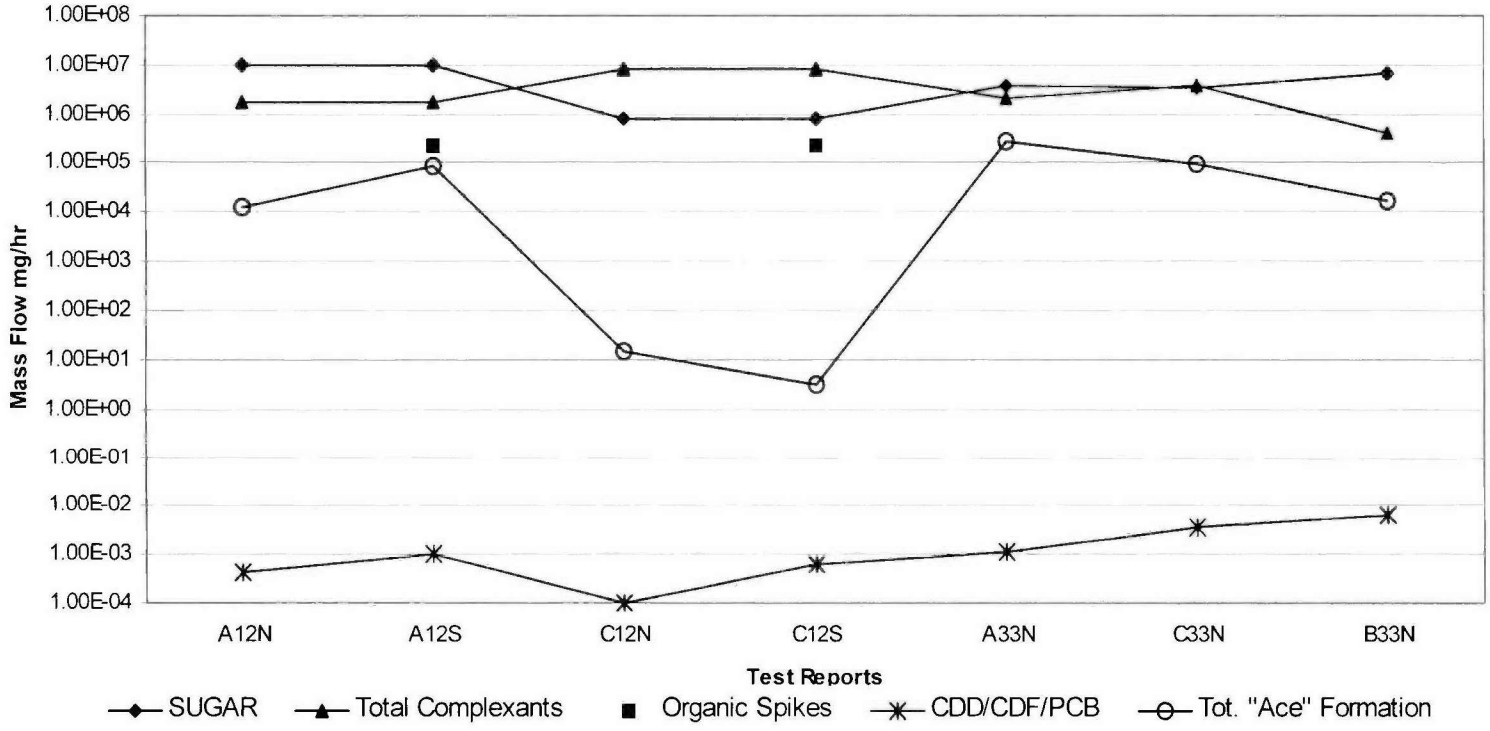
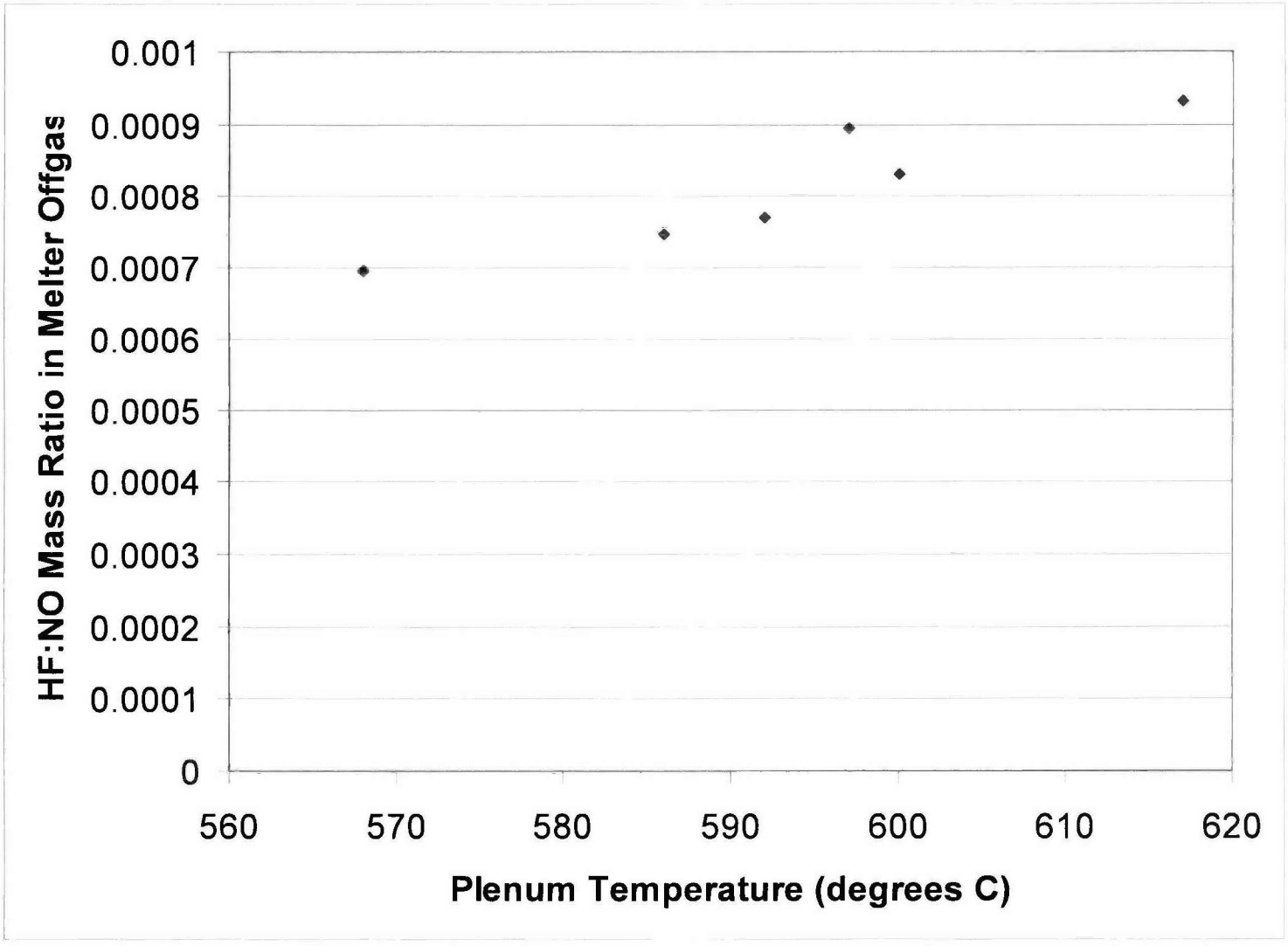


Figure 3.2-21 Element Retention in A1 Glass as a Function of Glass Production Rate in DM100 Melter



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3.3 System LOP/LVP: LAW Primary Offgas and Secondary Offgas Process

3.3.1 Function and Requirements

The function of the low-activity waste (LAW) primary offgas process system (LOP) and the secondary offgas/vessel vent process system (LVP) is to treat gases generated by the LAW Facility melters. Treatment of these gases results in meeting air discharge permit limits. Required treatment of the gas before release consists of cooling, removing larger particulates and aerosols (> 1 μm), high-efficiency removal of submicron particulates and aerosols including radionuclides, removal of mercury, control of nitrogen oxides and carbon monoxide emissions, organic destruction, and removal of acid gases.

Safety-related functions identified for these systems include:

- Preventing melter pressurization, thus avoiding release of radioactive contamination and hazardous gases to potentially occupied areas
- Protecting the public, environment, and operating staff from radionuclides and hazardous chemical exposure

Stated in the WTP Contract, *Statement of Work* (DE-AC27-01RV14136), Facility Specification, Section C.7 (a) (12):

> *Comply with applicable Federal, State and local requirements, including environmental permits and other regulatory approvals and authorizations. The WTP shall be designed and operated to ensure that exposure to the maximally exposed off site individual (non-acute) is ALARA but not more than 1.5 mrem per year and hazardous organic emissions are ALARA but not more than 0.375 tons per year from compounds regulated under 40 CFR 265 Subpart AA.*

Non-safety related functions are dependent on the performance of each piece of equipment. Descriptions of these functions are in the *System Description for LOP and LVP: LAW Melter Offgas* (24590-LAW-3YD-LOP-00001). Requirements of the system are specified primarily in the *Basis of Design* (24590-WTP-DB-ENG-01-001) and in 24590-LAW-3YD-LOP-00001.

3.3.2 Process Description

Offgas is generated from the vitrification of LAW in two joule-heated ceramic melters. The offgas consists of:

- Gases resulting from decomposition, oxidation, and vaporization of feed material:
  - NO_x from decomposition of metal nitrates and nitrites in the melter feed
  - Chlorine, fluorine, and sulfur as acid gases, elements, and volatile salts
  - Semivolatile radionuclides such as cesium
- Air in-leakage to the melter caused by operating the melter under vacuum (rate of in-leakage depends on the melter condition and the vacuum applied)
- Air from the operation of the bubblers and air purges of equipment
- Entrained particulates from the feed and glass melt

- Carbon dioxide, carbon monoxide, water vapor, and various products of incomplete combustion (PIC) from oxidation or partial decomposition of organics
- Small quantities of volatile and semi-volatile organics
- Mercury

In addition, the LAW melters release small quantities of radioactive gases, including carbon 14, tritium, and iodine 129. The isotopes ^{14}C and ^{3}H are mainly in the form of carbon dioxide and water, respectively; ^{129}I may be elemental, an acid gas, or a volatile halide salt.

Separate systems are provided for the initial treatment of offgas from each melter. This is considered the primary offgas treatment system. Figure 3.3-1 shows a simplified diagram of the LAW primary offgas treatment process. The primary system consists of the following.

LAW Primary Offgas Treatment System Equipment	Purpose
Submerged bed scrubber (SBS) (LOP-SCB-00001, LOP-SCB-00002)	The SBS removes particulates from the melter offgas. It also cools the offgas to a desired temperature by using chilled water. Condensate produced and solids captured in the SBS column are removed periodically. The SBS water purge pump (LOP-PMP-00003A/B, LOP-PMP-00006A/B) for the SBS transfers condensate to the SBS condensate collection vessel (RLD-VSL-00005).
SBS condensate vessel (LOP-VSL-00001, LOP-VSL-00002)	Collects condensate overflow from the SBS, thereby maintaining a constant liquid level in the SBS. Pumps LOP-PMP-00001/4 recirculate cooled condensate back to the SBS.
Wet electrostatic precipitator (WESP) (LOP-WESP-00001, LOP-WESP-00002)	Removes aerosols and micron-sized particulate matter from the offgas stream.

The secondary offgas treatment system, from the high-efficiency particulate air (HEPA) filter preheater to final discharge, removes almost all remaining particulates, Hg, NO_x, CO, volatile organic carbons (VOC), and miscellaneous acid gases. Figure 3.3-2 shows a simplified diagram of the LAW secondary offgas treatment process. The LVP system consists of the following.

LAW Secondary Offgas Treatment System Equipment	Purpose
Vessel ventilation subsystem	Maintains LAW melter feed system vessels, plant wash and condensate vessels, and the C3/C5 effluent vessel under vacuum via a header that feeds into the primary offgas system. This is to control emissions during normal operation and during maintenance.
Offgas HEPA preheaters (LVP-HTR-00001A/B, LVP-HTR-00003A/B)	Heats the offgas to lower the relative humidity of the gas stream in order to prevent condensation in the HEPA filters.

LAW Secondary Offgas Treatment System Equipment	Purpose
HEPA filters (LVP-HEPA-00001A/2A/3A, LVP-HEPA-/00001B/2B)	Provides high-efficiency submicron particulate removal from the offgas.
Activated carbon adsorbers (LVP-ADBR-00001A/B)	Removes mercury, halides, and acid gases, including ^{129}I, in the offgas by adsorption.
Catalyst skid (LVP-SKID-00002)	Removes NO_x, CO, and VOCs to meet the facilities' discharge limit.
Catalytic oxidizer heat recovery exchanger (LVP-HX-00001)	This plate heat exchanger heats the offgas exiting the activated carbon adsorbers with the exhaust from the catalyst beds. This reduces or eliminates the heat input requirements for the electric heater.
Catalytic oxidizer electric heater (LVP-HTR-00002)	Heats the offgas to the operating temperature for the VOC catalyst.
Thermal catalytic oxidizers (LVP-SCO-00001)	Oxidizes volatile organics and carbon monoxide to carbon dioxide and water.
Selective catalytic reducer (SCR) (LVP-SCR-00001)	Reduces NO_x in the offgas stream to nitrogen and water using ammonia.
Caustic collection tank (LVP-TK-00001)	Recirculates scrubbing liquid to the caustic scrubber via recirculation pumps (LVP-PMP-00003A/B).
Caustic scrubber (LVP-SCB-00001)	Removes acid gases such as sulfur oxides (SO_x). It also provides offgas cooling.
Exhausters (LVP-EXHR-00001A/B/C)	Provides the motive force in the system to remove offgas from the melter plenum and vessel vents, maintains the offgas system at a negative pressure through all the abatement processes, and discharges the offgas from the stack.

For a detailed description of this system, refer to 24590-LAW-3YD-LOP-00001.

3.3.3 Basis

3.3.3.1 Submerged Bed Scrubber and Condensate Vessel

After the film cooler (Section 3.2), the offgas enters the SBS (LOP-SCB-00001, LOP-SCB-00002) for further cooling and solids removal. Each melter system has a dedicated SBS and SBS condensate vessel. The SBS is designed for aqueous scrubbing of ammonia, entrained radioactive and nonradioactive particulate from melter offgas, and cooling and condensation of melter vapor emissions, and condensed fluids from SBS flow to SBS condensate vessels (LOP-VSL-00001, LOP-VSL-00002). A cooling jacket on the outside of the SBS and SBS Condensate Collection vessels and cooling coils inside the SBS vessel maintain the scrubbing liquid to a designated temperature. Recirculation of condensate from the SBS condensate vessels also contributes to the SBS column condensate cooling. The cooling medium for both vessels is chilled water. As the offgas cools, water and other condensables increase the liquid inventory.

The liquid overflows into the SBS condensate vessel, thereby maintaining a constant liquid depth in the SBS scrubber section.

Heavier solids captured in the SBS tend to be deposited at the bottom of the SBS vessel. To help suspend these solids, a recirculation pump in the SBS condensate vessel recirculates the condensate to the SBS vessel. Solids in the SBS condensate vessel are also kept in suspension with an eductor (LOP-EDUC-00001 or -00002) powered by a side stream from the recirculation line.

LOP-SCB-00001, LOP-SCB-00002, LOP-VSL-00001, and LOP-VSL-00002 have provisions to add demineralized water. Water is added through these streams for start-up and for make-up water during melter idling, as required.

Design and operating parameters for these units include the following.

3.3.3.1.1 Design Data - SBS and SBS Condensate Vessel

LOP-SCB-00001/00002 (24590-LAW-MKD-LOP-00008, 24590-LAW-M4C-LOP-00001, 24590-QL-POA-MKAS-00001-08-00002)

See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

- Pressure differential: 99 mbar
- For particulate removal, the expected decontamination factors (DF) are in Table 3.3-3 (where the definition of the DF is: mass flow rate of the offgas in / mass flow rate of the offgas out)
- Line pressure drop from the film cooler to the SBS: 5 mbar
- Line pressure drop from the SBS to the WESP: 7 mbar

LOP-VSL-00001/00002 (24590-LAW-MVC-LOP-00002)

See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

3.3.3.1.2 Operating Logic – SBS and SBS Condensate Vessel

LOP-SCB-00001, LOP-SCB-00002 (24590-LAW-3YD-LOP-00001, 24590-LAW-MVC-LOP-00001, 24590-LAW-MPD-LOP-00001)

The submerged bed scrubber (SBS) is a passive vessel designed for removal of particulates and aerosols from melter offgas and further cooling the melter offgas. The film cooler performed the initial cooling. Melter offgas passes bubbles through a packed water bed in the SBS. The packed bed breaks large bubbles into smaller ones. The water scrubs and cools the offgas. As the offgas cools, water vapor condenses and increases the water bath inventory in the SBS. The excess generated bath water overflows into the SBS condensate receipt vessels (LOP-VSL-00001/2) in order to maintain a constant bath level. Both the SBS and SBS condensate receipt vessel have capability to remove heat from the water bed. The bed's scrubbing water is recycled between the SBS and SBS condensate receipt vessels to increase the total quantity of the scrubbing water and, thus, its useful life before its replacement is required. The Condensate Receipt Vessels also allow replacement of the spent scrubbing water without disturbing the operation of the SBS vessels.

- The SBS is kept at its working volume (see Appendix B). Condensate generated by offgas quenching overflows to LOP-VSL-00001.
- The water bed is nominally maintained at 122 °F (50 °C) by using chilled water.
- The condensate receipt vessel recirculates to the SBS at a rate of 80 gpm. An additional 44 gpm is directed back to the eductors in the condensate receipt vessels to help maintain solids suspension in these vessels.
- Even though the bath/scrubbing water is recycled, the batch size and level in the SBS increases. Thus, extra needs to be transferred to the SBS condensate collection vessel. This is done at an approximate rate of 48 gpm. This is anticipated to occur approximately every 24 to 48 hr.

LOP-VSL-00001, LOP-VSL-00002 (24590-LAW-MVC-LOP-00001)

- Inflow liquid from the SBS is 82 gpm (2 gpm due to condensation).
- This vessel constantly recirculates condensate to the SBS at a rate of 80 gpm.
- It has the capacity to hold up to 2 days of condensate at maximum production rates.
- An eductor, powered by a side stream from the recirculation line, suspends the solids in the SBS condensate vessel (as mentioned above).
- When the operating level in condensate receipt vessel is high, a batch transfer is made from the condensate receipt vessel (LOP-VSL-00001/2) to RLD-VSL-00005. Condensate is pumped to vessel RLD-VSL-00005 at 35 gpm to maintain the constant liquid level in the SBS and condensate receipt vessel. Transfer stops when the heel level in the condensate receipt vessel is reached.
- The cooling jacket can help prevent excessive SBS temperatures cooling by cooling the circulating loop if necessary.

3.3.3.1.3 Energy Contributions – SBS and SBS Condensate Receipt Vessel

(24590-LAW-3YD-LOP-00001, 24590-LAW-MVP-LOP-00001)

- These units cool the offgas to 122 °F by using chilled water (in the cooling jackets and cooling coils). The exiting offgas and the condensate are at thermal equilibrium.
- The cooling jacket of the condensate receipt vessel (LOP-VSL-00001/2) can help prevent excessive SBS temperatures by cooling the circulating loop if necessary.
- Energy contributions from the mechanical pumps are considered negligible.

3.3.3.1.4 Services – SBS and SBS Condensate Receipt Vessel

(24590-LAW-3YD-LOP-00001, 24590-LAW-MVP-LOP-00001)

- Demineralized water is used during startup to fill the vessels and during vessel washings.
- Chilled water is used for the SBS cooling jacket and coils and SBS condensate receipt vessel cooling jacket.
- Electrical power is supplied to the recirculation and transfer pumps for operation.

3.3.3.1.5 Chemistry - SBS

(24590-101-TSA-W000-0009-53-01, 24590-101-TSA-W000-0009-98-06, 24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-111-02, 24590-101-TSA-W000-0009-143-01, Pourbaix 1974, Kotz and Treichel 1996)

Various acid/base neutralization reactions are expected to occur in the SBS. Commercially available thermodynamic chemistry software (Environmental Simulation Program [ESP] from OLI Systems, Inc.) calculates the most stable products for the AES flowsheet. The most important anticipated reactions that are common to aqueous solutions are noted herein. These reactions represent the most common or most likely reactions unless otherwise stated. Note that any reactions with CO_2 also apply to ^{14}C as it is considered to be in the form of CO_2. These reactions are as follows.

Gases

$H_2O(g) \rightarrow H_2O(l)$
$H^+(l) + OH^-(l) \rightarrow H_2O(l)$
$CO_2(g) \rightarrow CO_2(l)$
$CO_2(l) + H_2O(l) \rightarrow H_2CO_3(l)$
$H_2CO_3(l) \rightarrow HCO_3^-(l) + H^+(l)$
$HCO_3^-(l) \rightarrow CO_3^-(l) + H^+(l)$
$HCl(g) \rightarrow H^+(l) + Cl^-(l)$
$HF(g) \rightarrow H^+(l) + F^-(l)$
$NH_3(g) \rightarrow NH_3(l)$
$NH_3(l) + H_2O(l) \rightarrow NH_4^+(l) + OH^-(l)$
$P_2O_5(g) + 3H_2O(l) \rightarrow 6H^+(l) + 0.5PO_4^{-3}(l) + 1.5PO_4^{-3}(s)$

Sulfur and SO_x Reactions:

$SO_3(g) + H_2O(l) \rightarrow 2H^+(l) + SO_4^{-2}(l)$
$SO_2(g) + H_2O(l) \rightarrow 2H^+(l) + SO_3^{-2}(l)$

Even though sulfites are produced, they are reported as sulfates in Research and Technology (R&T) documents. Likewise, sulfur generation from the melter is reported as SO_2, so the following reaction best represents sulfur gas reaction in the flowsheet.

SO_x reactions represented as: $SO_2(g) + H_2O(l) + \frac{1}{2}O_2(g) \rightarrow 2H^+(l) + SO_4^{-2}(l)$

NO_x Reactions:

With enough O_2 and time present	$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
In cold water:	$NO_2(g) + aH_2O(l) \rightarrow 2aH^+(l) + bNO_2^-(l) + cNO_3^-(g)$ (where a, b, and c are variables.)
In hot water:	$3NO_2(g) + H_2O(l) \rightarrow 2H^+(l) + 2NO_3^-(l) + NO(g)$

NO_x reactions are complex. R&T reports show that both nitrates and nitrites are formed in the SBS fluid; which one is dominant varies. Therefore, both the "hot" and "cold"

reactions shown above appear to take place. Other forms of NO_x are possible (i.e., N_2O_3 and N_2O_5). To keep the modeling from becoming too complex, the following convention is used:

NO_x reactions represented as: $2NO(g) + H_2O(l) + 1½O_2(g) \rightarrow 2H^+(l) + 2NO_3^-(l)$
$3NO_2(g) + H_2O(l) \rightarrow 2H^+(l) + 2NO_3^-(l) + NO(g)$

Solids Carryover Reactions

$2Na^+(s) + O^{-2}(s) + H_2O(l) \rightarrow 2Na^+(l,s) + 2OH^-(l,s)$ Conversion factor (CF) = 1

Cl^- and F^- are represented as reacting with Na^+ (the most abundant cation); therefore, the above Na^+(s) reaction needs to be shortened by mole amounts of Cl^- and F^- in the first two reactions shown below:

$Na^+(s) + Cl^-(s) \rightarrow Na^+(l) + Cl^-(l)$
$Na^+(s) + F^-(s) \rightarrow Na^+(l) + F^-(l)$
$2Li^+(s) + O^{-2}(s) + H_2O(l) \rightarrow 2Li^+(l) + 2OH\text{-}(l)$ CF = 1
$2K^+(s) + O^{-2}(s) + H_2O(l) \rightarrow 2K^+(l,s) + 2OH\text{-}(l,s)$ CF = 1
$Ca^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Ca^{+2}(l) + 2OH^-(l)$ CF = 0.3
$Mg^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Mg^{+2}(l,s) + 2OH^-(l,s)$
$Sr^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Sr^{+2}(l) + 2OH^-(l)$ CF = 0.5 (also applies to ^{90}Sr)
$Zn^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Zn^{+2}(l,s) + 2OH^-(l,s)$
$Cd^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Cd^{+2}(l,s) + 2OH^-(l,s)$
$Pb^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Pb^{+2}(l,s) + 2OH^-(l,s)$
$2Al^{+3}(s) + 3O^{-2}(s) + 3H_2O(l) \rightarrow 2Al^{+3}(l,s) + 6OH^-(l,s)$
$S^{+6}(s) + 3O^{-2}(s) + H_2O(l) \rightarrow 2H^+(l) + SO_4^-(l)$ CF = 1

Other

The gaseous mercury from the melters is converted to soluble $HgCl_2$ gas or elemental mercury (Hg^0) in the melters' plenum. The fraction of Hg converted to $HgCl_2$ will be determined by the molar ratio of [Hg/Cl] in the melter feed. If the ratio of [Hg/Cl] is 0.1 or less, all mercury in the offgas will be converted to $HgCl_2$; if the [Hg/Cl] ratio is between 0.1 and 0.5, a portion of the mercury will be converted to $HgCl_2$; finally, if the ratio of Hg:Cl is greater than 0.5, the majority of mercury will be converted to Hg^0. $HgCl_2$, is soluble and is readily absorbed in the submerged bed scrubbers, while elemental mercury is insoluble and readily passes through the scrubbers (24590-101-TSA-W000-0004-125-00004, *WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant*). The absorption of $HgCl_2$ into the scrubber solution will be represented by the simplified reaction.

$HgCl_2$ (g) $\rightarrow$ $HgCl_2$ (l) CF = 1

Whether elemental mercury is in the liquid or gaseous state will be determined by operating conditions within the offgas system.

All other constituents are split between liquid and gas phases according to their DFs, as shown in Table 3.3-3.

Table 3.3-3 shows the LOP system DF for individual species. When available, these DF values are based on reconciliation of data collected from integrated offgas system tests on the pilot melter processing specific simulants. If pilot test data are not available, values in the table are based on empirical data. When empirical data are not available, estimates are based on the relative volatility of the species. Non-volatile species are assigned values equal to the average of the DFs of Al, Fe, and Zr. When anion data are lacking, the anions are assumed to be associated with sodium (as it is the most abundant cation and is the most likely cation to be associated with an anion), and the DF of the anion will be assigned the sodium DF.

3.3.3.2 Wet Electrostatic Precipitator

After removing larger particulates and aerosols in the SBS, the cooled offgas is routed to the WESP (LOP-WESP-00001, LOP-WESP-00002) for high efficiency removal of sub-micron particulates and aerosols. Each melter system has a dedicated WESP.

To aid in flushing the tubes and increased efficiency, the inlet to the WESP is provided with a demineralized water spray. The collected liquid gravity drains into the C3/C5 drains/sump collection vessel RLD-VSL-00004 (24590-LAW-3YD-LOP-00001). Heated process air is introduced into the electrode housing to keep the conductors clean and dry. This additional air is vented to the main offgas line.

Design and operating parameters for this unit include the following.

3.3.3.2.1 Design Data - WESP

(24590-LAW-3YD-LOP-00001, 24590-LAW-MVC-LOP-00001, 24590-CM-POA-MEE0-00003-04-00002, 24590-QL-POA-MKE0-00001-06-33)

- The expected DFs in this unit for offgas components are in Table 3.3-3.
- Pressure drop: 6 mbar
- Line pressure drop from the WESP to the vessel vent header: 13 mbar
- 350 acfm heated air purge required at 1 psig and at least 5 °F above the offgas inlet temperature

3.3.3.2.2 Operating Logic - WESP

(24590-LAW-3YD-LOP-00001, 24590-QL-POA-MKE0-00001-06-33, 24590-LAW-MVC-LOP-00001, 24590-CM-POA-MEE0-00003-04-00002)

- Power is supplied to the WESP to provide particle charging.
- The unit is rinsed in the upper section of the electrodes at 100 gpm (nominal) for 5 min every few days or as required. The minimum rinse frequency is assumed to be the same as in the HLW Melter Offgas Treatment Process System (HOP): 24 hr or until the rinse frequency can be better established through operational experience.
- The unit is misted with demineralized water continuously at 0.36 gpm (21.6 gal/hr) per WESP (total for both WESPs is 0.72 gpm).
- A constant air addition of 350 acfm at 1 psig and at least 5 °F above offgas inlet temperature is supplied to keep the electrode housings dry.

3.3.3.2.3 Energy Contributions - WESP

(24590-WTP-MKC-50-00003, 24590-QL-POA-MKE0-00001-06-33)

- Power to the electrodes is the main source of energy in this unit. Twelve kilowatts (nominal) of electrical power is supplied to the unit to provide particle charging. This power input will cause a slight increase in the offgas temperature. The WESP offgas and condensate are at thermal equilibrium.
- Power requirement for the WESP air purge heaters: enough power is provided to heat the purge air to 5 °F above the WESP offgas inlet temperature.

3.3.3.2.4 Services - WESP

(24590-LAW-3YD-LOP-00001, 24590-QL-POA-MKE0-00001-06-33)

- Heated process air addition through the electrical bus housing is necessary to maintain a dry atmosphere in the electrical insulation.
- Demineralized water is used to wash solids from the tube walls and for misting.

Anticipated common reactions associated with the WESP are identified below and account for the expected acidity of the bottoms stream per pilot plant data.

Gases

$H^+(l) + OH^-(l) \rightarrow H_2O(l)$
$2NO(g) + H_2O(l) + 1½O_2(g) \rightarrow 2H^+(l) + 2NO_3^-(l)$
$2NO_2(g) + H_2O(l) + ½O_2(g) \rightarrow 2H^+(l) + 2NO_3^-(l)$
$SO_2(g) + H_2O(l) + ½O_2(g) \rightarrow 2H^+(l) + SO_4^{-2}(l)$
$CO_2(g) + H_2O(l) \rightarrow 2H^+(l) + CO_3^{-2}(l)$
$HCl(g) \rightarrow H^+(l) + Cl^-(l)$
$HF(g) \rightarrow H^+(l) + F^-(l)$
$I(g) \rightarrow I(l)$
$NH_3(g) + H_2O(l) \rightarrow NH_4^+(l) + OH^-(l)$
$P_2O_5(g) + 3H_2O(l) \rightarrow 6H^+(l) + 2PO_4^{-3}(l)$
$HNO_3(l) \rightarrow H^+(l) + NO_3^-(l)$

Solids

All solids captured by the WESP become dissolved species because the WESP fluid has a very low pH. Pilot plant testing has shown pH levels of approximately 1 or less. Example reactions are:

$Na^{+}(s) + 0.5O^{-2}(s) + 0.5H_2O(l) \rightarrow Na^{+}(l) + OH^{-}(l)$
$Fe^{+3}(s) + O^{-2}(s) + H_2O\ (l) \rightarrow Fe^{+3}(l) + 3OH^{-}(l)$,
$K^{+}(s) + 0.5O^{-2}(s) + 0.5\ H_2O\ (l) \rightarrow K^{+}(l) + OH^{-}(l)$
$Na^{+}(s) + Cl^{-}(s) \rightarrow Na^{+}(l) + Cl^{-}(l)$
$Na^{+}(s) + F^{-}(s) \rightarrow Na^{+}(l) + F^{-}(l)$

3.3.3.3 Vessel Ventilation

The vessel ventilation collects offgas from LAW melter feed system vessels, plant wash and condensate vessels, and the C3/C5 effluent vessel in a header that feeds into the offgas system. This offgas consists primarily of air, water vapor, and minor amounts of aerosols generated by the agitation or movement of vessel contents (24590-LAW-3YD-LOP-00001). Hydrogen may be generated in vessels and equipment by thermolysis or radiolysis and is vented through the vessel ventilation system. The equations and methodology to determine the generated hydrogen component are located in Section 2.13.3.2.

The vessel ventilation header joins the combined WESP outlet offgas streams, which are routed to the LVP system. If solids build up in this header, the header can be flushed with demineralized water. Flush water drains to the C3/C5 drains/sump collection vessel, RLD-VSL-00004 (24590-LAW-M6-LVP-00003).

Design and operating parameters for the vessel ventilation system include the following.

3.3.3.3.1 Design Data - Vessel Ventilation

(24590-LAW-3YD-LOP-00001, 24590-LAW-MVC-LFP-00001, 24590-WTP-DB-ENG-01-001, 24590-LAW-M6C-LVP-00004, and 24590-LAW-M4C-LOP-00001)

- Stream temperature is approximately 86 °F
- Pressure in the vessels is maintained around 3 in. WG
- Standard cubic feet per minute of the vessel ventilation offgas generated for the collected vessel vents are shown below
- Line pressure drop from the vessel vent header junction with the main offgas system to the HEPA pre-heaters: 7 mbar

Vessel Name	Vessel Number	Retention Factor	Offgas Generated (scfm)
LAW concentrate receipt vessel	LCP-VSL-00001	1.0E-08	9
LAW concentrate receipt vessel	LCP-VSL-00002	1.0E-08	9
Melter 2 feed preparation vessel	LFP-VSL-00003	1.0E-08	9
Melter 2 feed vessel	LFP-VSL-00004	1.0E-08	9
Melter 1 feed preparation vessel	LFP-VSL-00001	1.0E-08	9
Melter 1 feed vessel	LFP-VSL-00002	1.0E-08	9
C3/C5 drains/sump collection vessel	RLD-VSL-00004	1.0E-08	5

Vessel Name	Vessel Number	Retention Factor	Offgas Generated (scfm)
Plant wash vessel	RLD-VSL-00003	1.0E-08	8
SBS condensate collection vessel	RLD-VSL-00005	1.0E-08	6

3.3.3.3.2 Operating Logic - Vessel Ventilation

(24590-LAW-3YD-LOP-00001)

- Collect vents from each vessel into one common header for facility offgas treatment.
- The system continuously maintains the LAW vitrification vessels at a slight vacuum to prevent contamination releases to the air. The system is in constant operation as long as the LAW exhausters are operational.

3.3.3.3.3 Energy Contributions - Vessel Ventilation

There are no external energy sources applied to this system. Mixing of the vessel vent header and the main offgas line will cause a slight temperature decrease in the mixed stream due to the differences in temperatures within the streams.

3.3.3.3.4 Services - Vessel Ventilation

Demineralized water is used to flush the header to mitigate solids buildup when necessary.

3.3.3.3.5 Chemistry - Vessel Ventilation

None

3.3.3.4 HEPA Preheater

After the offgas exits the WESP and is combined with the vessel vents, it is heated to lower the relative stream humidity, thereby preventing condensation in the HEPA filters. Two electric heaters (LVP-HTR-00001A/3A), operating in parallel, are provided. Each preheater has the capacity to heat the offgas to required temperature, but both prehearters are operated at 50 % capacity to supply the heat required. LVP-HTR-00001B/3B is melter offgas HEPA safety preheaters and are connected to battery backup power. The backup power requirement has a design value of 13 KW (24590-LAW-MEC-LVP-00005). The safety preheater design is in-progress and the backup power requirement and operation philosophies are subject to change.

Pertinent design and operating parameters for this unit include the following.

3.3.3.4.1 Design Data - HEPA Preheater

(24590-LAW-M4C-LOP-00001)

- ΔT across the heaters: 20 °C
- Pressure drop across the heaters: 8 mbar
- Line pressure drop from the heaters to the HEPAs: 7 mbar

3.3.3.4.2 Operating Logic - HEPA Preheater

(24590-LAW-MEC-LVP-00004)

Heaters are in continuous operation while the system is functional. Redundancy is provided. Both heaters are operated at less than 50% capacity. If one fails, then the preheater has the capability to raise the offgas temperature by 20 °C.

3.3.3.4.3 Energy Contributions - HEPA Preheater

(24590-LAW-MEC-LVP-00004)

The only energy source is the electrical power supplied to the heater. Enough power is added in the heaters to raise the offgas temperature by at least 20 °C.

3.3.3.4.4 Services - HEPA Preheater

Electrical power: enough power is added in the heaters to raise the offgas temperature by at least 20 °C.

3.3.3.4.5 Chemistry - HEPA Preheater

None.

3.3.3.5 HEPA Filters

The HEPA filters (LVP-HEPA-00001A/2A/3A and LVP-HEPA-00001B/2B) remove particulate contamination in order to comply with environmental release limits and to allow downstream equipment to be contact maintained.

The heated offgas passes through one of two HEPA filter trains–one train is primary and the other train is a backup. Both trains have primary and secondary filtration. Normal flow is through the primary train only. The backup train is to provide temporary filtration while maintenance is being performed on the main train.

The main train contains more primary filters to increase time between filter replacements. Eight HEPA filters in two quad-filter enclosures (LVP-HEPA-00002A and -00001A) are operated in parallel, followed by Secondary filtration, which consists of one quad-filter enclosure..

The backup train (LVP-HEPA-00001B, followed by -00002B) contains one primary quad-filter enclosure followed by one secondary quad-filter enclosure.

Each HEPA filter has a rated capacity of 2000 ACFM for a total of 8000 ACFM for the main and backup trains. Even though the main train has eight primary filters it is limited by the flow through the four secondary filters.

Pertinent design and operating parameters for this unit include the following.

3.3.3.5.1 Design Data - HEPA Filters

(24590-LAW-3YD-LOP-00001, 24590-WTP-MKC-50-00002)

- DFs for the HEPAs (shown in Table 3.3-4):
  - First stage: 3333
  - Second stage: 500
- Pressure differential across the HEPA filters: 5 mbar
- Line pressure drop from the HEPA filters to the activated carbon adsorbers: 8 mbar

3.3.3.5.2 Operating Logic - HEPA Filters

(24590-LAW-3YD-LOP-00001)

Two trains HEPA filter trains are installed, one train is for normal operation and the other is a backup to provide temporary filtration while maintenance is being performed on the main train. An excessively high or low pressure drop in one HEPA filter bank alerts the operator to change to the other HEPA filter bank.

3.3.3.5.3 Energy Contributions - HEPA Filters

None.

3.3.3.5.4 Services - HEPA Filters

None.

3.3.3.5.5 Chemistry - HEPA Filters

None.

3.3.3.6 Activated Carbon Absorbers

The activated carbon adsorbers (LVP-ADBR-00001A/B) for mercury, acid gas, and halide (including iodine) removal are placed after HEPA filters. These beds are housed in the mercury mitigation equipment for the LAW offgas system (LVP-SKID-00001). Mercury and acid gas removal is necessary to protect the catalyst from poisons. The carbon adsorbers are normally operated in series, but the system may be operated on with a single adsorber if needed for maintenance. This unit also serves as the abatement unit for ^{129}I.

Assumption 1.1. Heavy organics, such as PCBs, are commonly removed from gas streams with activated carbon. These molecules compete with other contaminants for active

sites in the carbon beds, which may increase the carbon changeout frequency. No credit is assumed for removal of these organics within the carbon beds, nor are competing contaminants considered in the models. This presents a more challenging case for the offgas systems and provides a bounding emissions estimate.

Sulfur-impregnated activated carbon will be used for mercury removal (24590-WTP-RPT-PR-02-003). The beds will have a proprietary guard bed for acid gas and halide abatement. Removal efficiencies will be updated per vendor data.

Pertinent design and operating parameters for this unit include:

LVP-ADBR-00001A/B

3.3.3.6.1 Design Data - Activated Carbon Adsorbers

(24590-LAW-MVD-LVP-00003)

- Maximum mercury concentration at the stack: 45 µg/dscm
- Iodine adsorption efficiency: 99 %, DF = 100
- Acid gas (HCl, HF) removal efficiency: 97 % (DF = 33.3)
- Operating temperature: 180 to 200 °F
- Pressure differential: 48 mbar
- Carbon changeout: every 2 years
- Line pressure drop from the adsorbers to the heat exchanger: 7 mbar

3.3.3.6.2 Operating Logic - Activated Carbon Adsorbers

This is a passive unit that is in constant operation while the system is online. Loss of efficiency will eventually require shutdown and bed changeout. The adsorbers can operate in the following configurations, although lead/lag is the normal operation:

1. Adsorber #1 as lead and adsorber #2 as lag
2. Adsorber #1 offline (for carbon bed replacement due to breakthrough) and adsorber #2 online
3. Adsorber #2 as lead and adsorber #1 as lag
4. Adsorber #2 offline (for carbon bed replacement due to breakthrough) and adsorber #1 online

3.3.3.6.3 Energy Contributions - Activated Carbon Adsorbers

Heat is generated by the absorption of the mercury, water, NO_x, and organic compounds onto the activated carbon, thereby causing a slight temperature increase in the offgas outlet. This is a passive unit and requires no energy input from WTP.

3.3.3.6.4 Services - Activated Carbon Adsorbers

None.

3.3.3.6.5 Chemistry - Activated Carbon Adsorbers

(24590-WTP-RPT-PR-01-011)

$Hg(g) + S(s) \rightarrow HgS(s)$

3.3.3.7 Catalytic Oxidizer Heat Recovery

As the gas enters the catalyst skid unit, it passes through the heat recovery unit (LVP-HX-00001), which is a plate heat exchanger. The heating medium used is the exhaust from the SCR beds.

Pertinent design and operating parameters for this unit include the following.

3.3.3.7.1 Design Data - Catalytic Oxidizer Heat Recovery

- Thermal transfer efficiency: 75 % maximum, ($\varepsilon = q_{cold}/q_{max}$. where ε= heat exchanger effectiveness, q = heat transfer rate)
- Duty: 4,500,000 BTU/hr (max)
- Pressure differential: cold side (2.5 mbar) and hot side (2.5 mbar)
- Line pressure drop from the heat exchanger to the heater (cold side): 2 mbar
- Line pressure drop from the heat exchanger to the caustic scrubber (hot side): 7 mbar

3.3.3.7.2 Operating Logic - Catalytic Oxidizer Heat Recovery

The heat exchanger is a passive unit that is continuously in operation. Under the conditions of a runaway reaction due to high concentration of NO_x in the feed, a bypass valve can be opened ahead of the hot stream inlet to help control the extreme offgas temperature.

3.3.3.7.3 Energy Contributions - Catalytic Oxidizer Heat Recovery

This is a recuperative heat exchanger. There is no direct energy input from facilities. The cold side inlet temperature is the same as the exhauster outlet. The hot side inlet temperature is the same as the one calculated as the exit temperature of the NO_x catalyst beds.

3.3.3.7.4 Services - Catalytic Oxidizer Heat Recovery

None

3.3.3.7.5 Chemistry - Catalytic Oxidizer Heat Recovery

None

3.3.3.8 Catalytic Oxidizer Electric Heater

After the heat recovery unit, the offgas passes through an electric heater (LVP-HTR-00002) to increase temperature, as necessary, for proper operation of the VOC and NO_x SCR catalytic equipment.

Pertinent design and operating parameters for this system include the following.

3.3.3.8.1 Design Data - Catalytic Oxidizer Electric Heater

- Provide enough power to raise the offgas temperature to 750 °F
- Pressure differential: 2.5 mbar
- Line pressure drop from the heater to the VOC catalyst: 0.2 mbar

3.3.3.8.2 Operating Logic - Catalytic Oxidizer Electric Heater

The heater is operated as necessary to maintain temperature. The heater load is greatest during startup and when the NO_x feed concentration is low. Exothermic reactions may provide enough heat to reduce or eliminate the need for heating.

3.3.3.8.3 Energy Contributions - Catalytic Oxidizer Electric Heater

Electrical power: enough power is provided to the heater to raise the temperature to the catalyst beds' operating temperature of 750 °F. The amount of power supplied depends on the cold side outlet temperature of the heat exchanger immediately upstream of the heater.

3.3.3.8.4 Services - Catalytic Oxidizer Electric Heater

Electrical power: enough power is provided to the heater to raise the catalyst beds' operating temperature to 750 °F.

3.3.3.8.5 Chemistry - Catalytic Oxidizer Electric Heater

None.

3.3.3.9 Thermal Catalytic Oxidizers

Oxidation of VOC and CO is the next step in the catalytic unit after heating. The thermal catalytic oxidizer (TCO) column (LVP-SCO-00001) is placed at the beginning of the unit. The oxidation is exothermic. Through this catalyst the organics are generally oxidized to carbon dioxide, hydrogen chloride (if chlorinated compounds are present), and water vapor. Trace amounts of fluoride, bromide, and iodide may also be present in the oxidizer exhaust, depending on the organic compound oxidized.

Pertinent design and operating parameters for this unit include the following.

3.3.3.9.1 Design Data - Thermal Catalytic Oxidizers

(24590-LAW-MAC-LVP-00007, 24590-LAW-MKD-LVP-00012)

- Organic removal efficiency: 95 % (DF = 20)
- The expected DFs for each component are in Table 3.3-4
- Required operating inlet temperature: 650 °F (343 °C) minimum
- Pressure drop across the bed: 5 mbar
- Line pressure drop from the bed to the SCR: 3 mbar

3.3.3.9.2 Operating Logic - Thermal Catalytic Oxidizers

This is a passive unit that is in constant operation while the catalytic unit is on line. Loss of efficiency will eventually require shutdown and catalyst changeout.

3.3.3.9.3 Energy Contributions - Thermal Catalytic Oxidizers

The VOC and CO oxidation reactions are exothermic; producing a slight increase in the offgas temperature exiting the unit. There is no external energy input to this unit.

3.3.3.9.4 Services - Thermal Catalytic Oxidizers

None

3.3.3.9.5 Chemistry - Thermal Catalytic Oxidizers

Reactions occurring will depend on the VOCs in the offgas. In general, VOCs are oxidized to carbon dioxide, hydrogen chloride (if chlorinated compounds are present), and water vapor. Also, the following common reactions are anticipated to occur in this unit:

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g)$$
$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightarrow SO_3(s)$$
$$H^+(g) + Cl^-(g) \rightarrow HCl(g)$$

The DFs associated with this unit are used to describe oxidative reactions that are anticipated to occur.

An offline test of the TCO has been performed by The Vitreous State Laboratory of the Catholic University of America (VSL) in Washington, D.C. The test used spikes of benzene, chlorobenzene, and trichloroethylene. The results concluded that when the residence time is 0.3 to 0.4 sec, and the temperature is 380 to 410 °C, the destruction and removal efficiencies (DRE) will be 99+ %. Therefore, the organic removal efficiency listed above (DF = 20) is sufficiently conservative. (24590-101-TSA-W000-0009-87-09)

3.3.3.10 Selective Catalytic Oxidizer (SCO)

After the VOC catalyst, ammonia is injected to aid in NO_x reduction. The offgas then goes through the NO_x catalyst module (LVP-SCO-00001), where ammonia reacts with the NO_x and reduces it to nitrogen and water vapor. NH_3 is added above the stoichiometric ratio to NO_x in order to maintain the bed saturated with NH_3 and allow the desired reduction of NO_x. Pertinent design and operating parameters for this unit include the following.

3.3.3.10.1 Design Data - SCO

(24590-LAW-MKD-LVP-00012)

- Conversion in the bed: 98 % (DF = 50) for NO_x
- The expected DFs for this unit are in Table 3.3-4
- Minimum operating temperature: 307 °C (585 °F)
- Exiting temperature: calculated based on NO_x reduction heat of reactions

- Pressure drop across the catalyst bed: 7 mbar
- Line pressure drop from the SCO to the heat exchanger: 1 mbar

3.3.3.10.2 Operating Logic - SCO

This is a passive unit that is in constant operation while the catalytic unit is online. Loss of efficiency will eventually require shutdown and catalyst changeout.

3.3.3.10.3 Energy Contributions - SCO

Mixing of anhydrous ammonia and the offgas stream will lower the stream temperature due to the streams' temperature differences. NO_x reduction reactions are highly exothermic, and therefore increase the outlet temperature. No external energy input to this unit is provided.

3.3.3.10.4 Services - SCO

Ammonia is added above the stoichiometric ratio to ensure saturation of the catalyst with ammonia.

3.3.3.10.5 Chemistry - SCO

Anticipated NO_x reduction reactions in oxygen-depleted environment

$$6NO(g) + 4NH_3(g) \rightarrow 5N_2(g) + 6H_2O(g)$$
$$6NO_2(g) + 8NH_3(g) \rightarrow 7N_2(g) + 12H_2O(g)$$

Anticipated NO_x reduction reactions in oxygen-rich environment

$$4NO(g) + 4NH_3(g) + O_2 \rightarrow 4N_2(g) + 6H_2O(g)$$
$$2NO_2(g) + 4NH_3(g) + O_2 \rightarrow 3N_2(g) + 6H_2O(g)$$

3.3.3.11 Caustic Scrubber System

The caustic scrubber (LVP-SCB-00001) further treats the offgas by removing the remaining acid gases such as HCl and SO_x. It also serves to quench the hot gases exiting the catalytic units. To neutralize the collected acid gases, a 5 M NaOH solution is added periodically to the recirculation line (LVP-TK-00001) to maintain a pH around 9. The clean offgas is then discharged through a mist eliminator to prevent droplet carryover.

Pertinent design and operating parameters for this unit include the following.

3.3.3.11.1 Design Data - Caustic Scrubber System

LVP-TK-00001 (24590-LAW-MTC-LVP-00002, 24590-LAW-MVC-LVP-00001)

- The expected DFs for offgas components are in Table 3.3-4.
- See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

- Pressure differential: 25 mbar
- Line pressure drop from the scrubber to the exhaust fans: 7 mbar

3.3.3.11.2 Operating Logic - Caustic Scrubber System

(24590-LAW-3YD-LOP-00001, 24590-QL-POA-MKAS-00003-06-00001, 24590-LAW-MKC-LVP-00004)

The offgas is constantly being scrubbed with a caustic solution. The scrub solution drains into a caustic collection tank, which is designed to hold one to two days of accumulated caustic scrub solution. By periodically adding 5 M NaOH, the generated scrubbing solution is maintained at a pH of about 9. Also, the specific gravity is maintained at no more than 1.10 by blow-down and adding process water. The scrubbing solution is recirculated to the caustic scrubber at a rate of 200 gpm. When the specific gravity exceeds 1.10, the caustic collection tank is purged to RLD-VSL-00017A/B (with a two-day holdup capacity) at a discharge rate of 200 gpm.

3.3.3.11.3 Energy Contributions - Caustic Scrubber System

(24590-LAW-3YD-LOP-00001)

The gas is evaporatively cooled once it comes in contact with the scrubbing solution. No external forms of cooling (cooled or chilled water) are used. Heat generated from the recirculation pumps and transfer pumps is considered negligible.

3.3.3.11.4 Services - Caustic Scrubber System

(24590-LAW-3YD-LOP-00001, 24590-LAW-MKC-LVP-00004, 24590-QL-POA-MKAS-00003-06-00001)

- Process water is added periodically to maintain a specific gravity of < 1.10 grams per cubic centimeter.
- Electrical power: power is supplied to the recirculation pumps and transfer pumps for operation.
- 5 M NaOH: added periodically to maintain a pH between 9 and 9.5.

3.3.3.11.5 Chemistry - Caustic Scrubber System

Various acid/base neutralization reactions are expected to occur in the caustic scrubber. Commercially available thermodynamic chemistry software (ESP) calculates the most stable products. The most important anticipated reactions that are common to aqueous solutions are noted herein. These reactions represent the most common or likely reactions unless otherwise stated. Note that any reactions with CO_2 also apply to ^{14}C, as it is considered to be in the form of CO_2. These reactions are:

$CO_2(g) \rightarrow CO_2(l)$	CF = 0.004
$CO_2(g) + H_2O(l) \rightarrow 2H^+(l) + CO_3^{-2}(l)$	CF = 0.107
$^{14}CO_2(g) + H_2O(l) \rightarrow 2H^+(l) + {}^{14}CO_3^{-2}(l)$	CF = 0.107
$NH_3(g) \rightarrow NH_3(l)$	CF = 0.2857
$NH_3(g) + H_2O(l) \rightarrow NH_4^+(l) + OH^-(l)$	CF = 0.9
$HCl(g) \rightarrow H^+(l) + Cl^-(l)$	CF = 0.99

$HF(g) \rightarrow H^+(l) + F^-(l)$	CF = 0.99
$I_2(g) + 6NaOH(l) \rightarrow 5NaI(l) + NaIO_3(l) + 3H_2O(l)$	
$3NO_2(g) + H_2O(l) \rightarrow 2H^+(l) + 2NO_3^-(l) + NO(g)$	CF = about 1.0
$P_2O_5(g) + 3H_2O(l) \rightarrow 6H^+(l) + 2PO_4^{-3}(l)$	CF = 0.5
$SO_3(g) + H_2O(l) \rightarrow 2H^+(l) + SO_4^{-2}(l)$	CF = 0.98
$SO_2(g) + H_2O(l) \rightarrow 2H^+(l) + SO_3^{-2}(l)$	CF = 0.98
$H^+(l) + OH^-(l) \rightarrow H_2O(l)$	CF = 1.0

3.3.3.12 Exhausters

Three variable speed exhausters, the LAW melters offgas exhausters (LVP-EXHR-00001A/B/C), are located downstream of the caustic scrubber, such that all offgas abatement equipment are maintained at a negative pressure relative to the process facility. The exhausters provide the motive force for offgas movement and control melter pressure. Two exhausters will normally be operating at the same time.

Pertinent design and operating parameters for this unit include the following.

3.3.3.12.1 Design Data - Exhausters

(24590-LAW-MAD-LVP-00006)

- Motor power: 115 hp
- Pressure differential across the fans: 327 mbar
- Line pressure drop from exhausters to the offgas discharge stack: 12 mbar

3.3.3.12.2 Operating Logic - Exhausters

(24590-LAW-3YD-LOP-00001)

The exhausters operate continuously to control melter emissions. Exhausters have variable frequency drives to allow adjusting flow rate to compensate for changes in the offgas flow rates.

3.3.3.12.3 Energy Contributions - Exhausters

Electrical power supply to the exhausters is the only energy source provided. The exhausters themselves transfer some of the energy to the gas stream (heat of compression and fan inefficiency), causing a temperature rise in the stream.

3.3.3.12.4 Services - Exhausters

There is limited battery backup to power exhausters for two hours to allow for the melter cold cap to burn off.

3.3.3.12.5 Chemistry - Exhausters

None.

3.3.4 Semivolatiles and Combined Decontamination Factors

The halides (chlorine, fluorine, and iodine), sulfur, and boron are semivolatile elements in the melters. Some of their mass will leave with the molten glass and the remainder will leave with the offgas. However, that which leaves with the offgas leaves in two forms. This makes tracking these semivolatiles more difficult. One form that leaves is solid particulates entrained in the gas. The most common solid compounds are sodium salts (i.e., NaCl and NaF). The other form is gas (i.e., HCl or Cl_2). The most common gaseous compounds for the semivolatiles are HCl, HF, I_2, SO_2, and H_3BO_3 [or $B(OH)_3$]. Consequently, these semivolatiles have two DFs to describe their behavior. The pilot studies performed at VSL provided the two DFs — one for solid particulate and the other for gas.

The following logic combines the two DFs into one. The logic maintains the appropriate total mass partitioning of the semivolatiles in the process equipment using a *combined* DF. The preferred compounds to use in the offgas are the gases HCl, HF, I_2, SO_2 (with minor amounts of SO_3), and simply B^{+3} or B_2O_3 for boron. Note that these gases also contain and represent the mass of the solid particles released at the melters.

Figure 3.3-3 shows the offgas distribution of 100 kg of chlorine or fluorine feed to the LAW melters. These figures will be used to calculate the combined DFs. The individual DFs are listed in the equipment figure blocks. The individual melter DFs come from engineering calculation 24590-WTP-M4C-V37T-00008. The LAW offgas DFs come from VSL pilot studies as documented in:

- Table 6.3 in 24590-101-TSA-W000-0009-111-02
- Table 6.3 in 24590-101-TSA-W000-0009-143-01
- Table 6.3 in 24590-101-TSA-W000-0009-111-01

The results are compiled in Section 3.2.

Figure 3.3-3 through Figure 3.3-5 show the masses of solids particles and gases entering and leaving the process equipment. The amounts were determined using the DFs cited above. The solids particulates and gases were added together to determine the total mass of halide. These values were then used to calculate the combined DFs. For example, the combined fluorine DF of 1.88 for the LAW melter is calculated by dividing the input mass of 100 kg by the output mass 53.2 kg. That 53.2 kg becomes the input value for SBS to determine its DF, and the process continues. The combined DFs for all the concerned volatiles are listed in Table 3.3-5.

Note that the models will track the semivolatiles as gases, but the streams will actually contain solid particles generated at the melters. As a result, some stages (e.g., the first stage of the HEPAs) have a DF value other than 1.0 for these gases. Consequently, the first stage of HEPAs will remove most of the solids, leaving mostly gases to pass through the second stage of HEPA. Therefore, the second stage of HEPAs needs to have a DF 1.0 since the gaseous portion of the semivolatiles will be passing through them.

As a check of these values, a theoretical approach will be used. The check shows that the above method works for calculating the combined DFs. The example below is performed on the LAW melter and LAW SBS. The combined melter DF using the individual DFs is calculated as follows:

Equation 3.3-1

$$DF_{mc} = \frac{In}{Out} = \frac{M_{in}}{\frac{M_{in}}{DF_{mgas}} + \frac{M_{in}}{DFm_{particulate}}} = \frac{1}{\frac{1}{DF_{mgas}} + \frac{1}{DF_{mparticulate}}} = \frac{1}{\frac{1}{5.7} + \frac{1}{2.8}} = 1.877 \text{ or } 1.88$$

where: DF_{mc} is the combined decontamination factor for the melter
M_{in} is the mass of halide into the melter, kg
DF_{mgas} is the melter gas decontamination factor
$DF_{mparticulate}$ is the melter particulate decontamination factor

Calculation of the combined DF for the SBS uses the combined melter DF as follows:

Equation 3.3-2

$$DF_{sc} = \frac{In}{Out} = \frac{M_{in} / DF_{mc}}{\frac{M_{in}}{DF_{mgas} \cdot DF_{sgas}} + \frac{M_{in}}{DF_{mparticulate} \cdot DF_{sparticulate}}} = \frac{1/1.877}{\frac{1}{5.7 \cdot 4.9} + \frac{1}{2.8 \cdot 7.1}} = 6.19$$

where: DF_{sc} is the combined decontamination factor for the SBS
DF_{sgas} is the SBS gas decontamination factor
$DF_{sparticulate}$ is the SBS particulate decontamination factor

The theoretically calculated values check with the previously calculated values. This confirms the method.

The amount of halide that enters the glass is:

Equation 3.3-3

$$M_{HalideGlass} = M_{in}\left(1 - \frac{1}{DF_{mgas}} - \frac{1}{DF_{mparticulate}}\right) = M_{in}\left(1 - \frac{1}{DF_{mc}}\right)$$

Most of the semivolatiles and their mass will combine with sodium, which is one of the most common cations in the offgas. This means the semivolatile compounds are soluble and will dissolve into the liquid phase when captured by the offgas removal equipment (e.g., Table 4.5 in 24590-101-TSA-W000-0009-111-02 shows the semivolatiles as dissolved in SBS blow-downs).

3.3.5 Semivolatile Losses during Melter Downtime

It was observed from pilot melter studies that when the melters are not being fed or start idling that the semivolatile components begin to leave the molten glass pool and enter the offgas at a higher rate. The rate, at which the semivolatiles leave, appears to follow a half-life curve. *Half-life ($t_{1/2}$)* is the time required for a quantity to fall to half its value as measured at the beginning of the time period. In physics, it is typically used to describe a property of radioactive decay, but may be used to describe any quantity which follows an exponential decay. An example is biological or elimination half-life, which is the time

it takes for a substance (drug, radioactive nuclide, or other) to lose half of its pharmacologic, physiologic, or radiological activity. Figure 3.3-6 shows that approximately one-half of the semivolatile, technetium, is lost to the offgas approximately once every three hours when melter feed stops and the cold cap is gone (CCN 254104: Figure from Slide17, *Tc Loss Rate from Molten Glass without Cold Cap*). The curves shown have slightly different half lifes around three hours. The following derivation will use three hours for the half life of technetium.

3.3.5.1 Half-Life Equation

Once feed stops, the melter cold cap recedes and loses of semivolatiles from the molten glass pool increases. One half of the technetium leaves the glass pool in approximately three hours. This is enough information to establish the mathematical relationship. The half-life relationship can be written:

Equation 3.3-4

$X_i = X_o e^{-\lambda_i t}$ where:

X_0 is the initial concentration of the substance that will decay
X is the concentration that still remains and has not yet decayed after time t, hr
i signifies the substance of concern.
λ_i is a positive number called the decay constant for substance i, hr^{-1}

Substituting in the know values for technetium and solving for λ gives:

$0.5 = 1 * e^{-\lambda_{Tc} * 3hr}$

$\lambda_{Tc} = 0.231\ hr^{-1}$

3.3.5.2 Estimating Half-Lifes and Decay Constants for Other Semivolatiles

The discussion below utilizes semivolatile decontamination factors and the concept of exposed glass pool surface to estimate the melter half life for other semivolatile species. According to the Section 3.2 the LAW melter Decontamination Factor (DF) for technetium is 1.6. This calculates to be a retention fraction of 0.375 can be calculated using the equation below:

Equation 3.3-5

Retention fraction = 1 – 1/DF

Table 3.3-1 list below shows DFs from Table 3.2-2 for the semivolatiles of concern. Retention values for each were calculated using the BARD DF values.

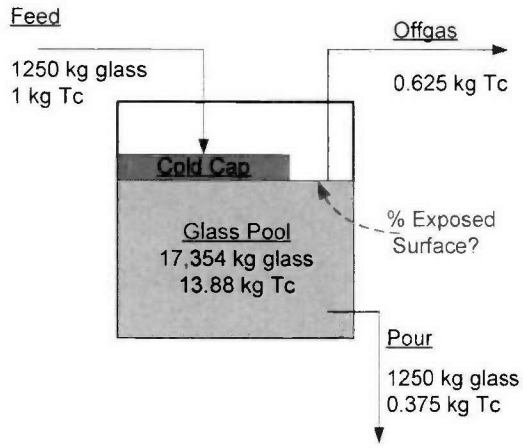
Table 3.3-1 List of Melter Decontamination Factors/Retention Rates for Semivolatiles

Element	LAW Melter DF	LAW Glass Retention Fraction	Loss to Offgas Fraction
Technetium, Tc [a]	1.6	0.375	0.625
Fluorine, F [b]	1.88	0.468085	0.531915
Chlorine, Cl [b]	1.99	0.497487	0.502513
Iodine, I [b]	2.40	0.583333	0.416667

Table 3.3-1 List of Melter Decontamination Factors/Retention Rates for Semivolatiles			
Element	**LAW Melter DF**	**LAW Glass Retention Fraction**	**Loss to Offgas Fraction**
Chromium, Cr [a]	16	0.9375	0.0625

[a]From Table 3.2-2, *LAW Melter Decontamination Factors by Component.*
[b]From Table 3.2-10, *Semivolatiles' Combined Solids and Gas Decontamination Factors*

The cold cap suppresses volatiles from escaping by covering the molten glass surface. However, some volatiles do escape. This derivation calculates the percentage of the molten glass that is exposed (not covered by the cold cap) by using technetium values. This exposed surface becomes the pathway for substances to escape. Half lives are then back calculated to equal the rate they are emitted from the exposed surface. The following shows an estimate of normally exposed melter surface with the feed containing a basis of 1 kg technetium.



Conditions do not change much during a melter pour to the LAW container because the glass pool only drops approximately 1.5 inches, which is only a 5% drop in depth. The BARD Section 3.2 states that drop results in a melter pour (discharge) of about 141 gallons. The mass of the pour is:

Pour Mass = (141 gal/pour)(3.7854 L/gal)(2.45 g/cm^3)(1000 cm^3/L)(kg/1000 g) = 1308 kg/pour

The melter is essentially full most of the time with molten glass called the *glass pool*. The glass pool is approximately 30 inches deep and 269 ft^3 (7617 liters) of molten glass with a density of 2.45 g/cm^3@ 1150 °C. The mass of the glass pool can be calculated:

Glass Pool mass before pour = (7617 liters)(2.45 g/cm^3)(kg/1000 g)(1000 cm^3/liter) = 18,662 kg. Note that this value includes the mass of the cold cap shown in the diagram above.

Glass Pool mass = 18,662 kg – 1308 kg = 17,354 kg

1 kg technetium is used as a basis to help make calculations for developing relationships easy and is not reflective of what is expected in the waste.

Most of the pilot runs for determination of the decontamination factors, etc., were run with equivalent WTP LAW melt rates of 15 metric tons glass per day. Using this rate, the average time between pours from the melter to the LAW container is:

Pour rate = (15 MT/day)(day/24 hr)(1000 kg/MT)(pour/1308 kg) = 0.478 pour/hr.

This gives the following pour cycle:

Pour Cycle = 1 hr/0.478 pour = 2.09 hr between pours.

The amount of technetium partitioned to the glass and offgas is according to *retention fraction* given in above list. The amount of technetium in the glass pool is:

Technetium mass in pool = (17,354 kg/1250 kg)(0.375 kg Tc) = 13.88 kg

3.3.5.2.1 Technetium Loss and Pool Exposure

Technetium retained in the glass pool can be related to the half life equation by assuming the same mechanisms are in play during normal loss of technetium while feeding the melter. Per Equation 3.3-4 with technetium calculated factors applied:

$$X_i = X_o e^{-0.251t}$$

The glass pool regenerates with each pour cycle. Therefore, the time, t = the Pour Cycle or 2.09 hr.

The technetium loss to the offgas and assuming to cold cap impact is simply the difference left:

Equation 3.3-6

$$\text{Full Loss} = X_{i,0}(1 - e^{-0.231t})$$

However, the above does not happen because the cold cap prevents much of evaporation from taking place. What does become airborne can be thought of evaporation in breaks of the cold cap where the molten glass is exposed. The fraction or percentage of the molten glass that is involved is called *exposed*. So, the actual amount lost to the offgas can be written:

Equation 3.3-7

$$\text{Loss}_{Tc} = \text{Exposed} * X_{i,0}(1 - e^{-0.231t})$$

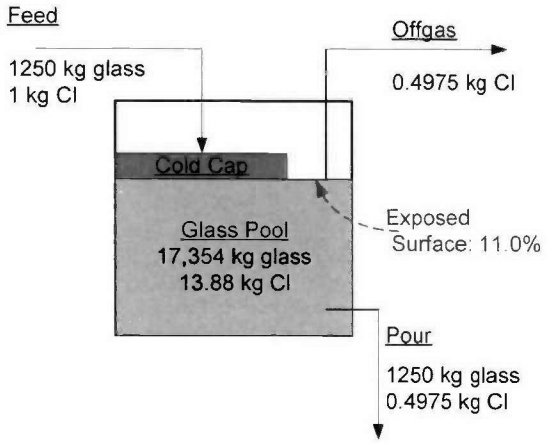
Rewriting to solve for the *Exposed* term gives:

$$\text{Exposed} = \frac{\text{Loss}_{Tc}}{X_{i,0}(1 - e^{-0.231t})}$$

Loss_{TC} from Table 1 is 0.625 kg. Putting in the values gives:

$$\text{Exposed} = \frac{0.625\ \text{kg}}{13.88\ \text{kg} + 1\ \text{kg})(1 - e^{-0.231 \cdot 2.09})} = 0.110 \text{ or } 11.0\%$$

3.3.5.2.2 Half Life and Decay Constants for Other Semivolatiles



Incorporated the calculated *Exposed* term into Equation 3.3-7 and solving for loss gives the following equation that can be used for calculating the decay constant, λ, for chlorine.

Equation 3.3-8

$$Loss_i = 0.110\ X_{i,0}(1 - e^{-\lambda t})$$

$$\lambda_i t = LN\left(\frac{Loss_i}{0.110 X_{0,i}}\right)$$

Equation 3.3-9

$$\lambda_{Cl} = \frac{-LN\left(1 - \frac{0.5025\ kg}{0.110(13.88\ kg + 1\ kg)}\right)}{2.09} = 0.175\ hr^{-1}$$

The results of the calculation for the rest of the semivolatiles are included in the list below and shown in Figure 3.3-7.

Table 3.3-2 List of LAW Melter Decontamination Factors/Retention Rate for Semivolatiles by Method 1 – Molten Glass Surface Exposure

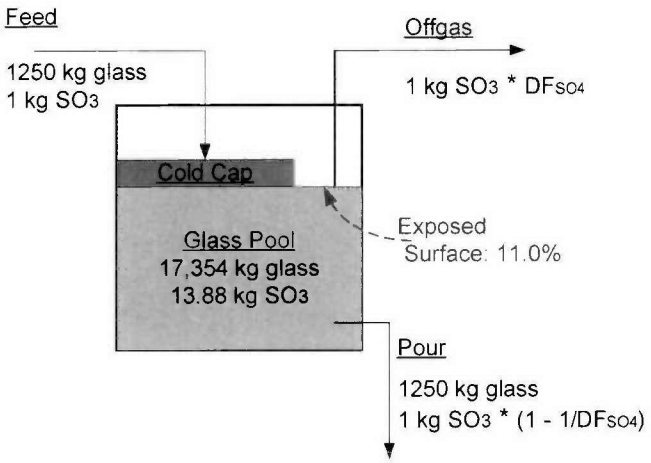
Element	LAW Melter DF	LAW Melter Retention Fraction	Semivolatile λ, hr^{-1}	Semivolatile $t_{½}$, hr
Technetium, Tc [a]	1.6	0.375	0.2310	3
Fluorine, F [b]	1.88	0.468085	0.1880	3.69
Chlorine, Cl [b]	1.99	0.497487	0.1755	3.95
Iodine, I [b]	2.40	0.583333	0.1406	4.93

Table 3.3-2 List of LAW Melter Decontamination Factors/Retention Rate for Semivolatiles by Method 1 – Molten Glass Surface Exposure

Element	LAW Melter DF	LAW Melter Retention Fraction	Semivolatile λ, hr^{-1}	Semivolatile $t_{½}$, hr
Chromium, Cr [a]	16	0.9375	0.0186	37.27

[a]From Table 3.2-2, *LAW Melter Decontamination Factors by Component*, of the BARD
[b]From Table 3.2-10, *Semivolatiles' Combined Solids and Gas Decontamination Factors*, of the BARD

3.3.5.2.3 Estimate Half-life and Decay Constant for Sulfate



The sulfate decontamination factor (DF_{SO4}) is calculated as a function of sulfate and sodium concentrations in the glass (see Section 3.1.3.5.4). Equation 3.3-9 can be modified to incorporate the variable sulfate DF and make it useful for calculating sulfate loss (as SO_3) as well during down time of the LAW or 2nd LAW melters. The schematic at the left shows how the variable DF for sulfate is used to determine the sulfate outputs. Incorporating these terms into Equation 3.3-9 gives Equation 3.3-10, which is to be used for calculating sulfate loses while a LAW or 2nd LAW melter is down or idle.

Equation 3.3-10

$$\lambda_{SO3} = \frac{-LN\left(1 - \frac{1\,kg \cdot \left(\frac{1}{DF_{SO3}}\right)}{0.110(13.88\,kg + 1\,kg)}\right)}{2.09}$$

Simplified:

$$\lambda_{SO3} = \frac{-LN\left(1 - \frac{0.611}{DF_{SO3}}\right)}{2.09}$$

The sulfate half life is:

Equation 3.3-11

$$t_{½\text{-}SO3} = -LN(0.5)/\lambda_{SO3}$$

3.3.5.2.4 Importance and Use of Semivolatile Half-life Relationships

Glass waste loading and production rate are sensitive to the concentration of semivolatiles, halides and sulfate in the melter feed. The offgas system captures most of the semivolatiles and recycles them back to the front end of the WTP process. The recycled semivolatiles can hamper the waste loading and production rate for near-future batches feeding the melter. Frequent and long downtimes could have significant impact on glass production.

3.3.6 References

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Table 3.3-3 LAW Primary Offgas System Decontamination Factors

Components	LAW SBS Envelope A	Source	LAW SBS Envelope B	Source	LAW SBS Envelope C	Source	Revised DF LAW SBS Envelopes A/B/C	Source	LAW WESP Nominal Operational	Source
Al3+	93.9	1	118	2	107	3	105	14	4.8	16
Ag+	NA		NA		NA		50	9	1000	9
Am3+	73	5	91.6	5	93.3	5	85	14	1000	9
As5+	NA		NA		NA		20	9	1000	9
B3+	See Table 3.3-3									
Ba2+	NA		NA		NA		350	9	1000	9
Be2+	73	5	91.6	5	93.3	5	85	14	1000	9
Bi3+	NA		NA		NA		50	9	1000	9
Ca2+	31	1	87.7	2	42.9	3	44.8	14	7	16
Cd2+	5.3	1	NA		NA		5.3	1	27	3
Ce4+	NA		NA		NA		620	9	1000	9
Co2+	NA		NA		NA		9.4	9	1000	9
Cr3+	7.4	1	4.9	2	5.5	3	5.8	14	9	16
Cr6+	7.4	1	4.9	2	5.5	3	5.8	14	9	16
Cr(OH)4-	7.4	1	4.9	2	5.5	3	5.8	14	9	16
Cr(TOTAL)	7.4	1	4.9	2	5.5	3	5.8	14	9	16
Cs+	7.1	1	3.3	2	5.8	3	4.9	14	25	16
Cu2+	NA		NA		NA		140	9	1000	9
Eu3+	73	5	91.6	5	93.3	5	85	14	1000	9
Fe2+	74	1	136	2	170	3	112	14	9	16
Fe3+	74	1	136	2	170	3	112	14	9	16
H+	NA		NA		NA		1000	9	1	9
Hf4+	NA		NA		NA		29	37	1.5	37
Hg2+	NA		NA		NA				1	9
Hg:Cl [1] < 0.1	NA		NA		NA		6	32	1	9
0.1< Hg:Cl<0.5	NA		NA		NA		2.27	32	1	9
Hg:Cl > 0.5	NA		NA		NA		1.4	33	1	9
K+	7.7	1	4.7	2	4.4	3	5.3	14	30	16
La3+	NA		NA		NA		1000	9	1000	9
Li+	NA		12.2	2	6.5	3	8.5	11	20	11
Mg2+	>3.6	1	38.1	2	12.8	3	7.9	14	2.3	11
Mn4+	NA		NA		NA		850	9	1000	9
MnO2	NA		NA		NA		850	9	1000	9
MnO4-	NA		NA		NA		850	9	1000	9
Mo6+	8.7	9	8.7	9	8.7	9	8.7	14	1000	9

Components	LAW SBS Envelope A	Source	LAW SBS Envelope B	Source	LAW SBS Envelope C	Source	Revised DF LAW SBS Envelopes A/B/C	Source	LAW WESP Nominal Operational	Source
Na+	9.8	1	9.5	2	6.5	3	8.3	14	27	16
Nd3+	NA		NA		NA		1000	9	1000	9
Ni2+	NA		NA		>4	3	4.0	3	1000	9
Pb2+	NA		NA		7.6	3	7.6	3	15	3
Pd2+	73	5	91.6	5	93.3	5	85	14	1000	9
Pr4+	73	5	91.6	5	93.3	5	85	14	1000	9
Pu4+	73	5	91.6	5	93.3	5	85	14	1000	9
Ra2+	73	5	91.6	5	93.3	5	85	14	1000	9
Rb+	7.1	6	3.3	6	5.8	6	4.9	14	1000	9
Rh3+	7.1	6	3.3	6	5.8	6	4.9	14	1000	9
Ru4+	3.6	7	3.6	7	3.6	7	3.6	7	1000	9
S+6	See Table 3.3-3									
Sb3+	NA		NA		NA		100	9	1000	9
Se4+	8.4	1	NA		NA		8.4	1	1000	9
Si4+	80.7	1	236	2	90.5	3	108	14	9	16
Sr2+	NA		NA		NA		670	9	1000	9
Ta5+	73	5	91.6	5	93.3	5	85	14	1000	9
Tc4+	7.1	6	3.3	6	5.8	6	4.9	14	1000	9
Te4+	NA		NA		NA		20	9	1000	9
Th4+	73	5	91.6	5	93.3	5	85	14	1000	9
Ti4+	>275	1	196	2	538	3	280	14	1.2	2
Tl5+	8.4	8	NA		NA		8.4	8	1000	9
U4+	73	5	91.6	5	93.3	5	85	14	1000	9
U(TOTAL)	73	5	91.6	5	93.3	5	85	14	1000	9
V3+	NA		NA		NA		5.7	9	1000	9
W6+	73	5	91.6	5	93.3	5	85	14	1000	9
Y3+	NA		NA		NA		320	9	1000	9
Zn2+	39.8	1	17.7	2	50.5	3	29.6	14	3.5	16
Zr4+	>16.7	1	59.1	2	>37	3	29	14	1.5	2
Cl-	See Table 3.3-3									
CO32-	9.8	10	9.5	10	6.5	10	8.3	10	27	10
HCO3-	9.8	35	9.5	35	6.5	35	8.3	10	27	10
F-	See Table 3.3-3									
I-	See Table 3.3-3									
CN-	9.8	10	9.5	10	6.5	10	8.3	10	1000	9

Components	LAW SBS Envelope A	Source	LAW SBS Envelope B	Source	LAW SBS Envelope C	Source	Revised DF LAW SBS Envelopes A/B/C	Source	LAW WESP Nominal Operational	Source
NH4+	NA		NA		NA		10	29	1000	9
NO2-	9.8	10	9.5	10	6.5	10	8.3	10	27	10
NO3-	9.8	10	9.5	10	6.5	10	8.3	10	27	10
O2-	NA		NA		NA		NA		757	9
OH-(aq)	9.8	10	9.5	10	6.5	10	8.3	14	1000	9
OH-(s)	9.8	10	9.5	10	6.5	10	8.3	14	1000	9
PO43-	1.8	1	1.7	2	13.1	3	2.5	14	5.9	16
SiO4-4	80.7	1	236	2	90.5	3	108	14	9	16
SO42-	See Table 3.3-3									
acetate	NA		NA		NA		8.3	15	27	15
oxalate	NA		NA		NA		8.3	15	27	15
citrate	NA		NA		NA		8.3	15	27	15
EDTA	NA		NA		NA		8.3	15	27	15
formate	NA		NA		NA		8.3	15	27	15
glycolate	NA		NA		NA		8.3	15	27	15
HEDTA	NA		NA		NA		8.3	15	27	15
IDA	NA		NA		NA		8.3	15	27	15
Sucrose	NA		NA		NA		NA		NA	
PPG	NA		NA		NA		1	38	1	38
PDMS	NA		NA		NA		1	38	1	38
C12H4C16(1)	NA		NA		NA		18.2	36	490	36
C2H3N91)	NA		NA		NA		18.2	36	490	36
C12H4C16(g)	NA		NA		NA		8.6	36	1.1	36
C2H3N(g)	NA		NA		NA		5	36	1	36
H2O	NA		NA		NA		calc.		calc.	
CO	NA		NA		NA		1	9	1	9
CO2	NA		NA		NA		1	9	1	9
HCl	See Table 3.3-3									
HF	See Table 3.3-3									
HI	See Table 3.3-3									
I2	See Table 3.3-3									
N2	NA		NA		NA		1.0	9	1	9
NH3	NA		NA		NA		10	28	1.3	9
NO	1.058	1	NA		NA		1.058	1	1	9
NO2	1.002	1	NA		NA		1.002	1	1.04	9

Components	LAW SBS Envelope A	Source	LAW SBS Envelope B	Source	LAW SBS Envelope C	Source	Revised DF LAW SBS Envelopes A/B/C	Source	LAW WESP Nominal Operational	Source
O2	NA		NA		NA		1.0	9	1	9
P2O5(s)	1.8	30	1.7	30	13.1	30	2.5	14	330	9
SO2	See Table 3.3-3									
3H (1)	follows water		follows water		follows water		follows water		follows water	9
14C(2)	NA		NA		NA		1.0	9	1	9
59Ni	NA		NA		NA		4	3	1000	9
60Co	NA		NA		NA		9.4	9	1000	9
63Ni	NA		NA		NA		4	3	1000	9
79Se	8.4	1	NA		NA		8.4	1	1000	9
90Sr	NA		NA		NA		670	9	1000	9
90Y	NA		NA		NA		320	9	1000	9
93Zr	>16.7	1	59.1	2	>37	3	29	14	1.5	2
93mNb	73	5	91.6	5	93.3	5	85	14	50	17
99Tc	7.1	6	3.3	6	5.8	6	4.9	14	1000	9
103Ru	3.6	7	3.6	7	3.6	7	3.6	7	1000	9
106Ru	3.6	7	3.6	7	3.6	7	3.6	7	1000	9
113mCd	5.3	1	NA		NA		5.3	1	1000	9
125Sb	NA		NA		NA		100	9	1000	9
126Sn	73	5	91.6	5	93.3	5	85	14	1000	9
129I	See Table 3.3-3									
134Cs	7.1	1	3.3	2	5.8	3	4.9	14	25	16
137Cs	7.1	1	3.3	2	5.8	3	4.9	14	25	16
137mBa	7.1	6	3.3	6	5.8	6	4.9	6	25	6
151Sm	73	5	91.6	5	93.3	5	85	14	50	17
152Eu	73	5	91.6	5	93.3	5	85	14	1000	9
154Eu	73	5	91.6	5	93.3	5	85	14	1000	9
155Eu	73	5	91.6	5	93.3	5	85	14	1000	9
226Ra	73	5	91.6	5	93.3	5	85	14	1000	9
227Ac	73	5	91.6	5	93.3	5	85	14	1000	9
228Ra	73	5	91.6	5	93.3	5	85	14	1000	9
229Th	73	5	91.6	5	93.3	5	85	14	1000	9
231Pa	73	5	91.6	5	93.3	5	85	14	50	17
232Th	73	5	91.6	5	93.3	5	85	14	1000	9
232U	73	5	91.6	5	93.3	5	85	14	1000	9
233U	73	5	91.6	5	93.3	5	85	14	1000	9

Components	LAW SBS Envelope A	Source	LAW SBS Envelope B	Source	LAW SBS Envelope C	Source	Revised DF LAW SBS Envelopes A/B/C	Source	LAW WESP Nominal Operational	Source
234U	73	5	91.6	5	93.3	5	85	14	1000	9
235U	73	5	91.6	5	93.3	5	85	14	1000	9
236U	73	5	91.6	5	93.3	5	85	14	1000	9
237Np	73	5	91.6	5	93.3	5	85	14	1000	9
238Pu	73	5	91.6	5	93.3	5	85	14	1000	9
238U	73	5	91.6	5	93.3	5	85	14	1000	9
239Pu	73	5	91.6	5	93.3	5	85	14	1000	9
240Pu	73	5	91.6	5	93.3	5	85	14	1000	9
241Am	73	5	91.6	5	93.3	5	85	14	1000	9
241Pu	73	5	91.6	5	93.3	5	85	14	1000	9
242Cm	73	5	91.6	5	93.3	5	85	14	1000	9
242Pu	73	5	91.6	5	93.3	5	85	14	1000	9
243Am	73	5	91.6	5	93.3	5	85	14	1000	9
243Cm	73	5	91.6	5	93.3	5	85	14	1000	9
244Cm	73	5	91.6	5	93.3	5	85	14	1000	9

NA = DF not available.

Sources:

1. 24590-101-TSA-W000-0009-111-02, Rev 00B, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope A1 Simulants*, Table 6.3.
2. 24590-101-TSA-W000-0009-143-01, Rev 00B, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants*, Table 6.3.
3. 24590-101-TSA-W000-0009-111-01, Rev 0, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sun-Envelope C1 Simulants*, Table 6.3.
4. Not used.
5. Average of Al, Fe, and Zr for the given envelope per 24590-WTP-RPT-ENV-01-014, Rev 0, *Decontamination Factor and Release Fraction Definition for RPP-WTP Offgas Treatment Equipment*, Table 6. Zr4+ DF reported as > 16.7 for Envelope A (source 1) and > 37 for Envelope C (source 3), so DF of 59.1 for Envelope B (source 2) was used for Envelopes A and C.
6. Assumed equal to Cs.
7. Per 24590-101-TSA-W000-0009-144-03, Rev 00B, Table 7.7, Ru DF is the average of runs 4B and 4C.
8. Assumed equal to Se.
9. 24590-WTP-M4C-V11T-00010, Rev 0, *Process Engineering Mass Balance for WTP*, from the CD-ROM of the WEBPPS run.
10. DF for anions set equal to DF for sodium.
11. Source 2 and source 3. The DF value reflects the average of Envelopes B and C.
12. Source 1 and source 2. The DF value reflects the average of Envelopes A and B.
13. The Zr DF for Envelope B was used to calculate the average of the Al, Fe, and Zr DFs for all three envelopes, since the Zr DFs for Envelopes A and C are reported as >16.7 and > 37, respectively.
14. Average of Envelopes A, B, and C.
15. Assumed that the organic ions are bound to sodium, so the sodium DF applies.
16. Source 1, source 2, and source 3. The DF value reflects the average of Envelopes A, B, and C).
17. Per 24590-WTP-M4C-V11T-00010, Rev 0, the average particulate DF is 50.

18. Not used.
19. Not used.
20. Not used.
21. Not used.
22. Not used.
23. Not used.
24. Not used.
25. Not used.
26. Not used.
27. Not used.
28. Assumed based on non-validated ASPEN PLUS/ESP results.
29. DF for NH4+ assumed equal to DF for NH_3.
30. DF for P2O5 assumed equal to DF for PO4-3.
31. Not used.
32. 24590-WTP-RPT-PR-01-011, *Mercury Pathway and Treatment Assessment for the WTP*, Section 7.4.3.3.
33. 24590-101-TSA-W000-0004-125-00004, Rev 00A, *Test Summary: WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant.*
34. Not used.
35. The DF for HCO3- is assumed to be equal to the DF for CO3-2.
36. 24590-WTP-MCR-PO-04-0055, Rev 0.
37. Hafnium is a non-volatile constituent, and is given a DF equal to that of zirconium.
38. PPG and PDMS are semi-volatile organics with flash points below the temperatures in the melter, and negligible amounts are anticipated to pass into the offgas system. The minimum DF of 1 is assumed for these treatment units.

[1] Molar ratio of [Hg/Cl] in melter feed batch determines DF.

Table 3.3-4 LAW Secondary Offgas System Decontamination Factors

Components	DF HEPA (First) Nominal	Source	DF HEPA (Second) Nominal	Source	DF Thermal Oxidizer	Source	DF NOx SCR	Source	DF Caustic Scrubber	Source	DF Mercury Adsorp. Column	Source
Al3+	3333	18	500	18	1	20	1	22	1	9	1	9
Ag+	3333	18	500	18	1	20	1	22	1	9	1	9
Am3+	3333	18	500	18	1	20	1	22	1	9	1	9
As5+	3333	18	500	18	1	20	1	22	1	9	1	9
B3+	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	1	9	1	9
Ba2+	3333	18	500	18	1	20	1	22	1	9	1	9
Be2+	3333	18	500	18	1	20	1	22	1	9	1	9
Bi3+	3333	18	500	18	1	20	1	22	1	9	1	9
Ca2+	3333	18	500	18	1	20	1	22	1	9	1	9
Cd2+	3333	18	500	18	1	20	1	22	1	9	1	9
Ce4+	3333	18	500	18	1	20	1	22	1	9	1	9
Co2+	3333	18	500	18	1	20	1	22	1	9	1	9
Cr3+	3333	18	500	18	1	20	1	22	1	9	1	9
Cr6+	3333	18	500	18	1	20	1	22	1	9	1	9
Cr(OH)4-	3333	18	500	18	1	20	1	22	1	24	1	24
Cr(TOTAL)	3333	18	500	18	1	20	1	22	1	24	1	24
Cs+	3333	18	500	18	1	20	1	22	1	9	1	9
Cu2+	3333	18	500	18	1	20	1	22	1	9	1	9
Eu3+	3333	18	500	18	1	20	1	22	1	9	1	9
Fe2+	3333	18	500	18	1	20	1	22	1	9	1	9
Fe3+	3333	18	500	18	1	20	1	22	1	9	1	9
H+	3333	18	500	18	1	20	1	22	1	9	1	9
Hf4+	3333	29	500	29	1	29	1	29	1	29	1	29
Hg2+	1	18	1	18	1	20	1	22	1	9	241	27
K+	3333	18	500	18	1	20	1	22	1	9	1	9
La3+	3333	18	500	18	1	20	1	22	1	9	1	9
Li+	3333	18	500	18	1	20	1	22	1	9	1	9
Mg2+	3333	18	500	18	1	20	1	22	1	9	1	9
Mn4+	3333	18	500	18	1	20	1	22	1	9	1	9
MnO2	3333	18	500	18	1	20	1	22	1	24	1	24
MnO4-	3333	18	500	18	1	20	1	22	1	24	1	24
Mo6+	3333	18	500	18	1	20	1	22	1	9	1	9
Na+	3333	18	500	18	1	20	1	22	1	9	1	9
Nd3+	3333	18	500	18	1	20	1	22	1	9	1	9
Ni2+	3333	18	500	18	1	20	1	22	1	9	1	9
Pb2+	3333	18	500	18	1	20	1	22	1	9	1	9
Pd2+	3333	18	500	18	1	20	1	22	1	9	1	9

Table 3.3-4 LAW Secondary Offgas System Decontamination Factors

Components	DF HEPA (First) Nominal	Source	DF HEPA (Second) Nominal	Source	DF Thermal Oxidizer	Source	DF NOx SCR	Source	DF Caustic Scrubber	Source	DF Mercury Adsorp. Column	Source
Pr4+	3333	18	500	18	1	20	1	22	1	9	1	9
Pu4+	3333	18	500	18	1	20	1	22	1	9	1	9
Ra2+	3333	18	500	18	1	20	1	22	1	9	1	9
Rb+	3333	18	500	18	1	20	1	22	1	9	1	9
Rh3+	3333	18	500	18	1	20	1	22	1	9	1	9
Ru4+	3333	18	500	18	1	20	1	22	1	9	1	9
S+6	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	33.3	25	1	9
Sb3+	3333	18	500	18	1	20	1	22	1.1	9	1	9
Se4+	3333	18	500	18	1	20	1	22	1	9	1	9
Si4+	3333	18	500	18	1	20	1	22	1	9	1	9
Sr2+	3333	18	500	18	1	20	1	22	1	9	1	9
Ta5+	3333	18	500	18	1	20	1	22	1	9	1	9
Tc4+	3333	18	500	18	1	20	1	22	1	9	1	9
Te4+	3333	18	500	18	1	20	1	22	1	9	1	9
Th4+	3333	18	500	18	1	20	1	22	1	9	1	9
Ti4+	3333	18	500	18	1	20	1	22	1	9	1	9
Tl5+	3333	18	500	18	1	20	1	22	1	9	1	9
U4+	3333	18	500	18	1	20	1	22	1	9	1	9
U(TOTAL)	3333	18	500	18	1	20	1	22	1	24	1	24
V3+	3333	18	500	18	1	20	1	22	1	9	1	9
W6+	3333	18	500	18	1	20	1	22	1	9	1	9
Y3+	3333	18	500	18	1	20	1	22	1	9	1	9
Zn2+	3333	18	500	18	1	20	1	22	1	9	1	9
Zr4+	3333	18	500	18	1	20	1	22	1	9	1	9
Cl-	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	1	9	1	9
CO32-	3333	18	500	18	1	20	1	22	1	9	1	9
HCO3-	3333	18	500	18	1	20	1	22	1	9	1	9
F-	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	1	9	1	9
I-	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	1	9	1	9
CN-	3333	18	500	18	1	20	1	22	1	9	1	9
NH4+	3333	18	500	18	1	20	1	22	1	9	1	9
NO2-	3333	18	500	18	1	20	1	22	1	9	1	9
NO3-	3333	18	500	18	1	20	1	22	1	9	1	9
O2-	NA		NA		NA		NA		NA		NA	
OH-(aq)	3333	18	500	18	1	20	1	22	1	9	1	9
OH-(s)	3333	18	500	18	1	20	1	22	1	9	1	9

Table 3.3-4 LAW Secondary Offgas System Decontamination Factors

Components	DF HEPA (First) Nominal	Source	DF HEPA (Second) Nominal	Source	DF Thermal Oxidizer	Source	DF NOx SCR	Source	DF Caustic Scrubber	Source	DF Mercury Adsorp. Column	Source
PO43-	3333	18	500	18	1	20	1	22	1	9	1	9
SiO4-4	3333	18	500	18	1	20	1	22	1	24	1	24
SO42-	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	1	9	1	9
acetate	3333	19	500	19	20	20	1	22	1	24	1	24
oxalate	3333	19	500	19	20	20	1	22	1	24	1	24
citrate	3333	19	500	19	20	20	1	22	1	24	1	24
EDTA	3333	19	500	19	20	20	1	22	1	24	1	24
formate	3333	19	500	19	20	20	1	22	1	24	1	24
glycolate	3333	19	500	19	20	20	1	22	1	24	1	24
HEDTA	3333	19	500	19	20	20	1	22	1	24	1	24
IDA	3333	19	500	19	20	20	1	22	1	24	1	24
Sucrose	3333	18	500	18	20	20	1	22	1	9	1	9
PPG	3333	30	500	30	20	20	1	22	1	24	1	24
PDMS	3333	30	500	30	20	20	1	22	1	24	1	24
C12H4C16(1)	3333	1	500	1	20	1	1	1	1	1	1	1
C2H3N(1)	3333	1	500	1	20	1	1	1	1	1	1	1
C12H4C16(g)	3333	1	500	1	20	1	1	1	1	1	1	1
C2H3N(g)	3333	1	500	1	20	1	1	1	1	1	1	1
H2O	1	18	1	18	1	20	1 & produced	22	calculated	9	1	9
CO	1	18	1	18	20	20	1	22	1	9	1	9
CO2	1	18	1	18	1	20	1	22	1.02	10	1	9
HCl	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	100	9	33.3	26
HF	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	100	9	33.3	26
HI	Table 3.3-3	--	Table 3.3-3	--	NA		NA		NA		NA	
I2	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	100	9	100	26
N2	1	18	1	18	1	20	1 & produced	22	1	9	1	9
NH3	1	18	1	18	1	20	consumed	22	1.4	28	1	9
NO	1	18	1	18	1	20	50	21	1	9	1	9
NO2	1	18	1	18	1	20	50	21	1.04	10	1	9
O2	1	18	1	18	1	20	1	22	1	9	1	9
P2O5(s)	3333	18	500	18	1	20	1	22	1	9	1	9
SO2	Table 3.3-3	--	Table 3.3-3	--	1.25	20	1	22	33.3	25	1	9

Table 3.3-4 LAW Secondary Offgas System Decontamination Factors

Components	DF HEPA (First) Nominal	Source	DF HEPA (Second) Nominal	Source	DF Thermal Oxidizer	Source	DF NOx SCR	Source	DF Caustic Scrubber	Source	DF Mercury Adsorp. Column	Source
3H (1)	1	18	1	18	1	20	1	22	follows water	9	1	9
14C(2)	1	18	1	18	1	20	1	22	1.1	9	1	9
59Ni	3333	18	500	18	1	20	1	22	1	24	1	24
60Co	3333	18	500	18	1	20	1	22	1	9	1	9
63Ni	3333	18	500	18	1	20	1	22	1	24	1	24
79Se	3333	18	500	18	1	20	1	22	1	24	1	24
90Sr	3333	18	500	18	1	20	1	22	1	9	1	9
90Y	3333	18	500	18	1	20	1	22	1	9	1	9
93Zr	3333	18	500	18	1	20	1	22	1	24	1	24
93mNb	3333	18	500	18	1	20	1	22	1	24	1	24
99Tc	3333	18	500	18	1	20	1	22	1	9	1	9
103Ru	3333	18	500	18	1	20	1	22	1	9	1	9
106Ru	3333	18	500	18	1	20	1	22	1	9	1	9
113mCd	3333	18	500	18	1	20	1	22	1	24	1	24
125Sb	3333	18	500	18	1	20	1	22	1.1	9	1	9
126Sn	3333	18	500	18	1	20	1	22	1	9	1	9
129I	Table 3.3-3	--	Table 3.3-3	--	1	20	1	22	1	9	1	9
134Cs	3333	18	500	18	1	20	1	22	1	9	1	9
137Cs	3333	18	500	18	1	20	1	22	1	9	1	9
137mBa	3333	18	500	18	1	20	1	22	1	9	1	9
151Sm	3333	18	500	18	1	20	1	22	1	24	1	24
152Eu	3333	18	500	18	1	20	1	22	1	9	1	9
154Eu	3333	18	500	18	1	20	1	22	1	9	1	9
155Eu	3333	18	500	18	1	20	1	22	1	9	1	9
226Ra	3333	18	500	18	1	20	1	22	1	24	1	24
227Ac	3333	18	500	18	1	20	1	22	1	24	1	24
228Ra	3333	18	500	18	1	20	1	22	1	24	1	24
229Th	3333	18	500	18	1	20	1	22	1	24	1	24
231Pa	3333	18	500	18	1	20	1	22	1	24	1	24
232Th	3333	18	500	18	1	20	1	22	1	24	1	24
232U	3333	18	500	18	1	20	1	22	1	24	1	24
233U	3333	18	500	18	1	20	1	22	1	9	1	9
234U	3333	18	500	18	1	20	1	22	1	24	1	24
235U	3333	18	500	18	1	20	1	22	1	9	1	9
236U	3333	18	500	18	1	20	1	22	1	24	1	24
237Np	3333	18	500	18	1	20	1	22	1	9	1	9
238Pu	3333	18	500	18	1	20	1	22	1	9	1	9

Table 3.3-4 LAW Secondary Offgas System Decontamination Factors

Components	DF HEPA (First) Nominal	Source	DF HEPA (Second) Nominal	Source	DF Thermal Oxidizer	Source	DF NOx SCR	Source	DF Caustic Scrubber	Source	DF Mercury Adsorp. Column	Source
238U	3333	18	500	18	1	20	1	22	1	9	1	9
239Pu	3333	18	500	18	1	20	1	22	1	9	1	9
240Pu	3333	18	500	18	1	20	1	22	1	9	1	9
241Am	3333	18	500	18	1	20	1	22	1	9	1	9
241Pu	3333	18	500	18	1	20	1	22	1	9	1	9
242Cm	3333	18	500	18	1	20	1	22	1	24	1	24
242Pu	3333	18	500	18	1	20	1	22	1	9	1	9
243Am	3333	18	500	18	1	20	1	22	1	24	1	24
243Cm	3333	18	500	18	1	20	1	22	1	9	1	9
244Cm	3333	18	500	18	1	20	1	22	1	9	1	9

NA = DF not available.

Sources:

1. 24590-WTP-MCR-PO-04-0055, Rev 0.
2. Not used.
3. Not used.
4. Not used.
5. Not used.
6. Not used.
7. Not used.
8. Not used.
9. 24590-WTP-M4C-V11T-00010, Rev 0, *Process Engineering Mass Balance for WTP*, from the CD-ROM of the WEBPPS run.
10. 24590-QL-POA-MKAS-00003-06-00001, Rev 00B, *Calculation - Calculation for LAW Melter Offgas Caustic Scrubber Process.*
11. Not used.
12. Not used.
13. Not used.
14. Not used.
15. Not used.
16. Not used.
17. Not used.
18. Per 24590-WTP-MKC-50-00002, Rev 1, *Process Equipment Decontamination Factor Curves.* Gaseous constituents are not removed by the filters and therefore have a DF of 1.
19. Per 24590-WTP-MKC-50-00002, Rev 1. All tracked organics are below their melting points at the HEPA operating temperatures.
20. Only organics, CO and SO2 are oxidized in the thermal catalytic oxidizer. Data from *LAW Catalytic Oxidizer/Reducer Mechanical Data Sheet* (24590-LAW-MKD-LVP-00012). CO is assumed to oxidize at the same efficiency as the organic constituents.
21. Per 24590-LAW-MKD-LVP-00012, Rev 3.
22. Only NO and NO_2 are reduced in the SCR.
23. Not used.
24. By analogy with 24590-WTP-M4C-V11T-00010, Rev 0, *Process Engineering Mass Balance for WTP.*
25. Per 24590-LAW-MKD-LVP-00011, Rev 1, an SO_2/SO_3 removal efficiency of 97 % is required for the caustic scrubber.
26. Per 24590-LAW-MVD-LVP-00003, Rev 2, an HF and HCl removal efficiency of 97 % (DF=33.3) and an iodine DF of 100 is required for the mercury skid.
27. DF calculated from Attachment 1, Nominal Flowsheet, of 24590-LAW-M4C-LOP-00001, Rev 0, and the requirement that the mercury emissions shall not exceed 45 micrograms per dry standard cubic meter, as stated in 24590-LAW-MVD-LVP-00003, Rev 2.
28. Assumed based on unvalidated ASPEN PLUS/ ESP results.
29. Hafnium is a non-volatile constituent, and is given a DF equal to that of zirconium.
30. PPG and PDMS are below their melting points at the HEPA operating temperatures, and will be removed as particulates.

Table 3.3-5 Combined Solids and Gas Halide Decontamination Factors, DFs

Equipment	Fluorine - LAW	Chlorine - LAW
Melter	1.88	1.99
SBS	6.19	7.08
WESP	1.91	1.30
HEME	n/a	n/a
HEPAs - 1st Stage	1.36	3.28
HEPAs - 2nd Stage	1.00	1.00

Equipment	Iodine - LAW	Boron - LAW
Melter	2.40	94.3
SBS	4.95	390
WESP	1.12	2.30
HEME	n/a	n/a
HEPAs - 1st Stage	1.00	3333
HEPAs - 2nd Stage	1.00	1.00

Equipment	Sulfur Env. A - LAW	Sulfur Env. B - LAW
Melter	Calculated	Calculated
SBS	7.82	22.53
WESP	18.9	6.63
HEME	n/a	n/a
HEPAs - 1st Stage	10.0	1.26
HEPAs - 2nd Stage	1.00	1.00

Sources:

1. 24590-WTP-M4C-V37T-00008, Rev 0, *Reconciliation of HLW and LAW Melter Decontamination Factors.*
2. 24590-101-TSA-W000-0009-111-02, Rev 00B, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope A1 Simulants*, Table 6.3
3. 24590-101-TSA-W000-0009-143-01, Rev 00B, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants*, Table 6.3.
4. 24590-101-TSA-W000-0009-111-01, Rev 0, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sun-Envelope C1 Simulants*, Table 6.3.
5. 24590-WTP-RPT-PT-02-005, Rev 5, *Flowsheet Bases, Assumptions, and Requirement*, Tables 3.3-1 and 3.3-2.
6. Letter Report AEM 068, Reconcile HLW and LAW Secondary Offgas (SBS and WESP) Decontamination Factors. This reconciliation effort included references 1 through 4, and 20 through 22.
7. 24590-101-TSA-W000-0009-98-07, Rev 00C, *DM1200 Tests with C-104/AY-101 HLW Simulants Final Report.*
8. 24590-101-TSA-W000-0009-144-01, Rev 00B, *Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers.*
9. 24590-101-TSA-W000-0009-144-02, Rev 00B, *Integrated DM1200 Melter Testing of HLW AZ-102 Composition Using Bubblers.*
10. 24590-101-TSA-W000-0009-34-03, Rev 00C, *Final Report - Tests on the DuraMelter 1200 HLW Pilot Melter System Using AZ-101 HLW Simulants.*
11. 24590-101-TSA-W000-0009-144-00005, Rev. 00A, *Final Report - DM1200 Tests with AZ-101 HLW Simulants.*
12. 24590-101-TSA-W000-0009-144-00006, Rev 00A, *Final Report - Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification.*
13. 24590-101-TSA-W000-0009-144-00006, Rev 00A, *Final Report - Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification.*
14. 24590-WTP-RPT-PT-02-005, Rev 5, *Flowsheet Bases, Assumptions, and Requirement*, Tables 4.3-1 and 4.3-2.

Figure 3.3-1 LAW Primary Offgas Treatment System

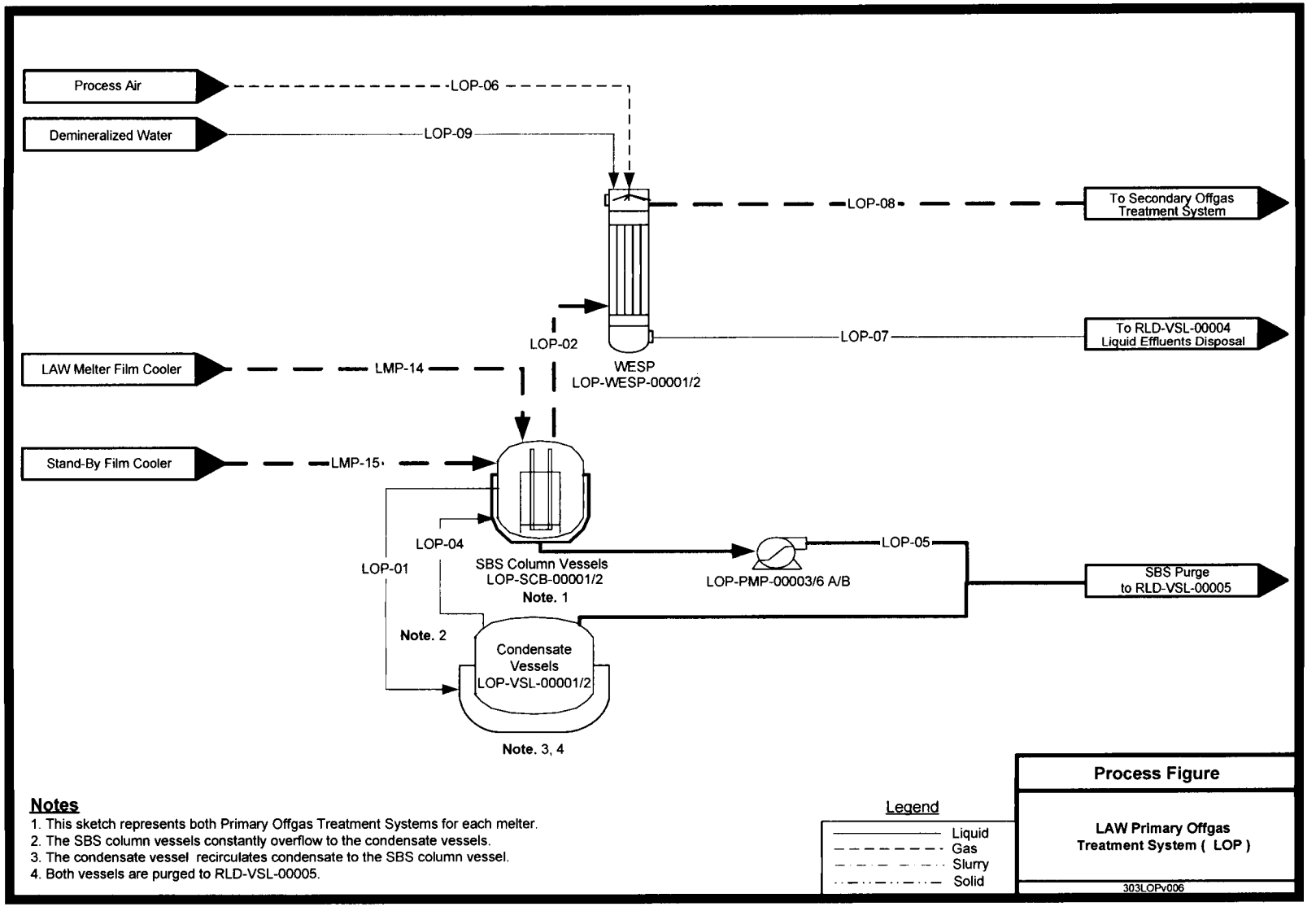


Figure 3.3-2 LAW Secondary Offgas Treatment System

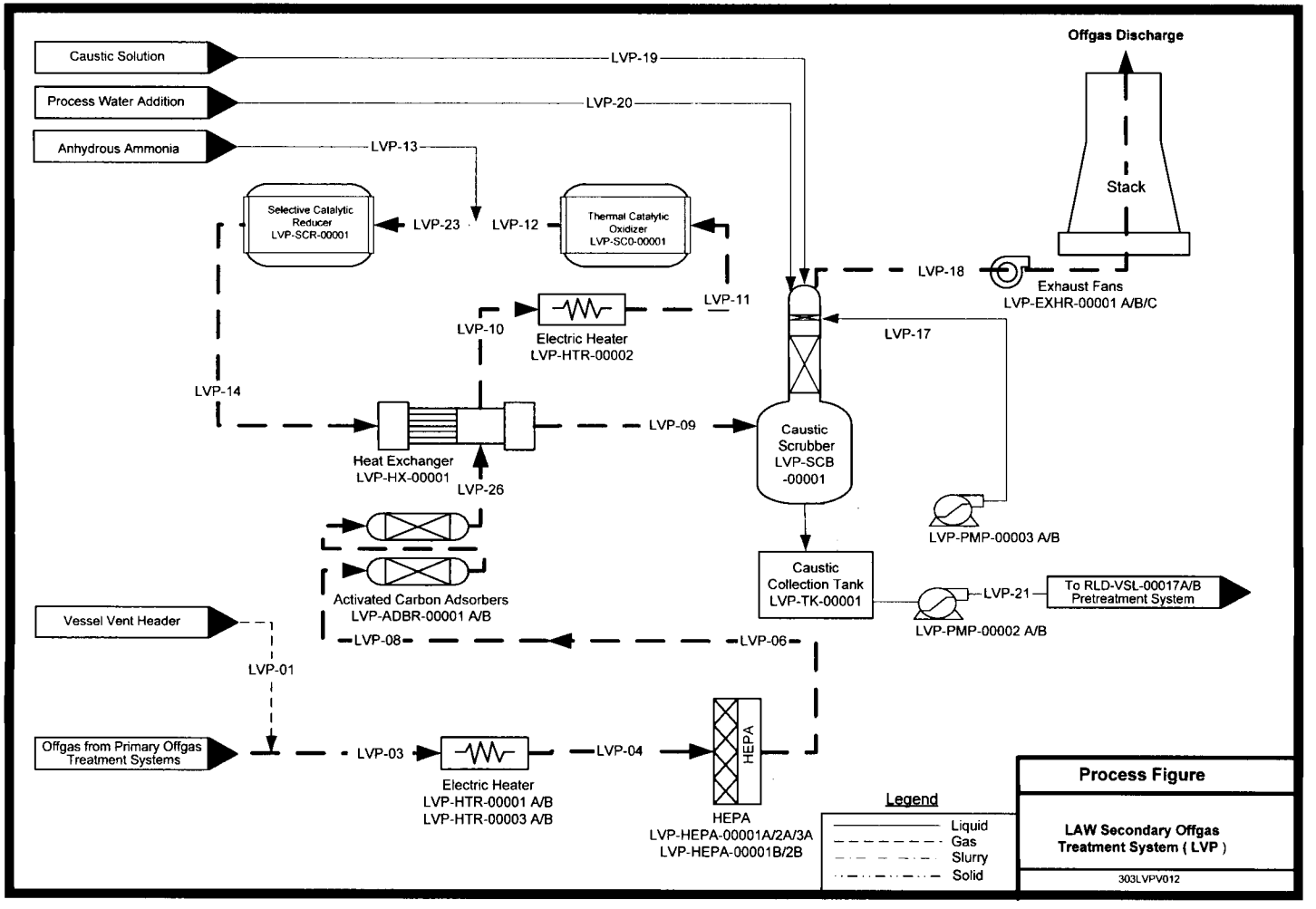


Figure 3.3-3 LAW Partitioning of the Halides

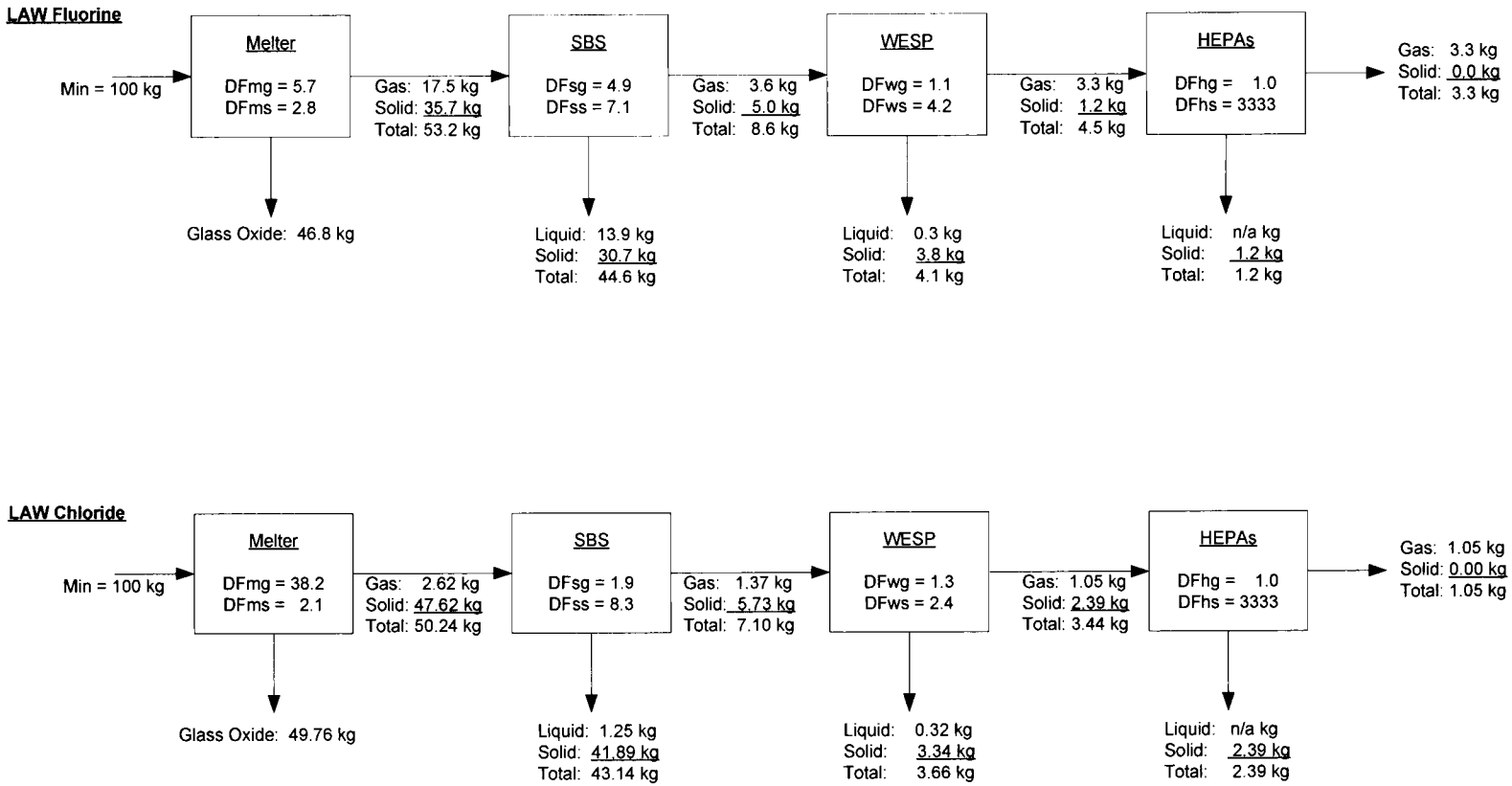
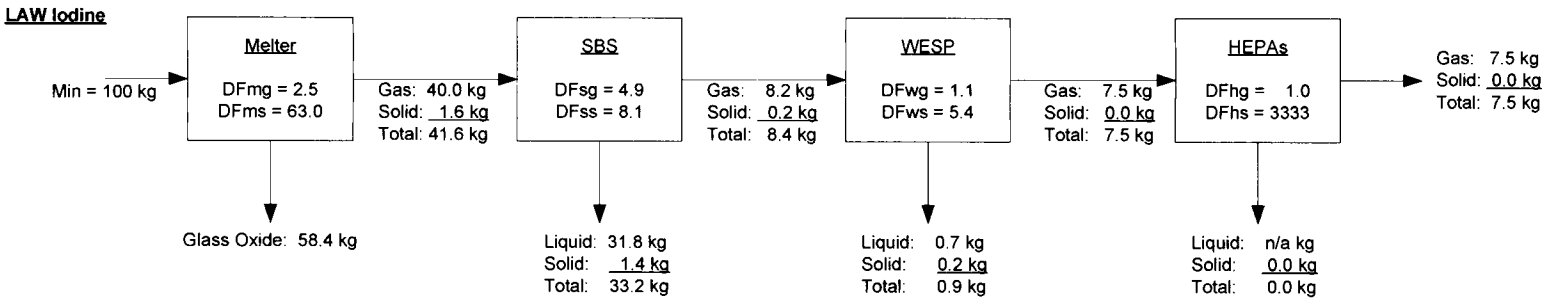


Figure 3.3-4 LAW Partitioning of Iodine and Boron



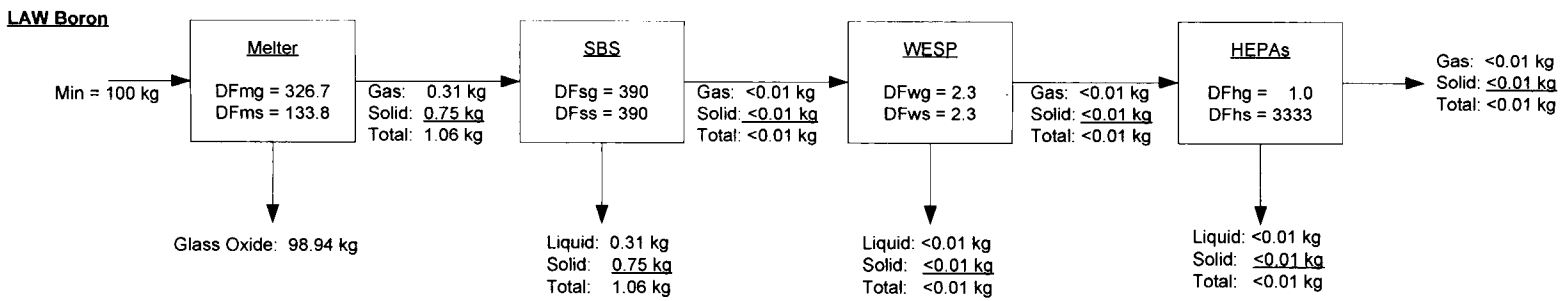


Figure 3.3-5 LAW Partitioning of Sulfur

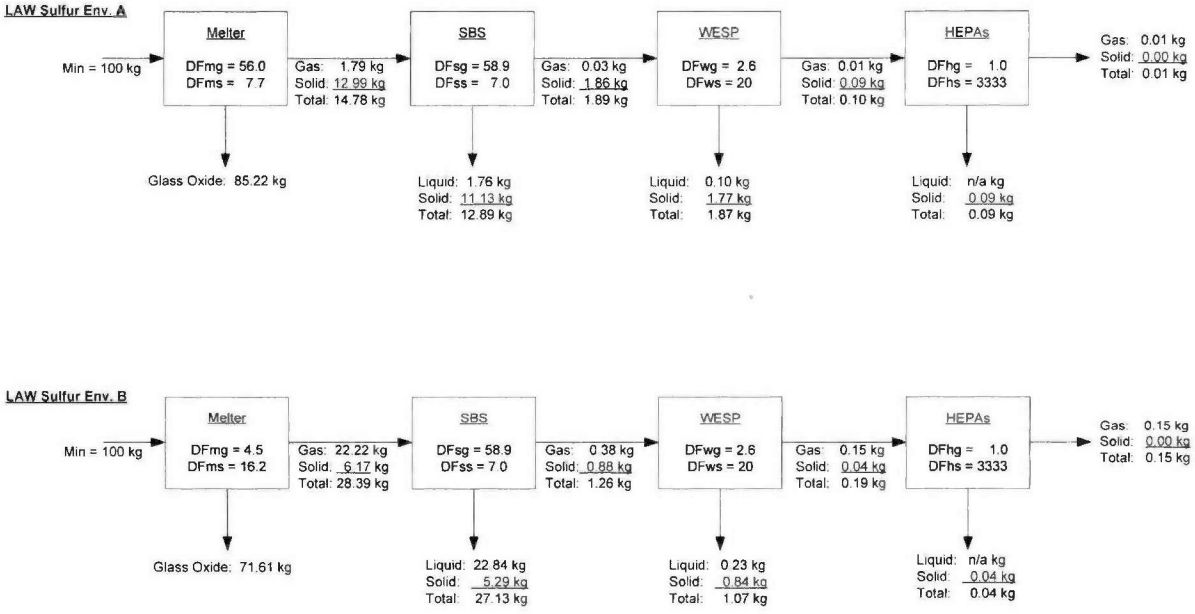


Figure 3.3-6 Tc Loss Rate from Molten Glass without Cold Cap

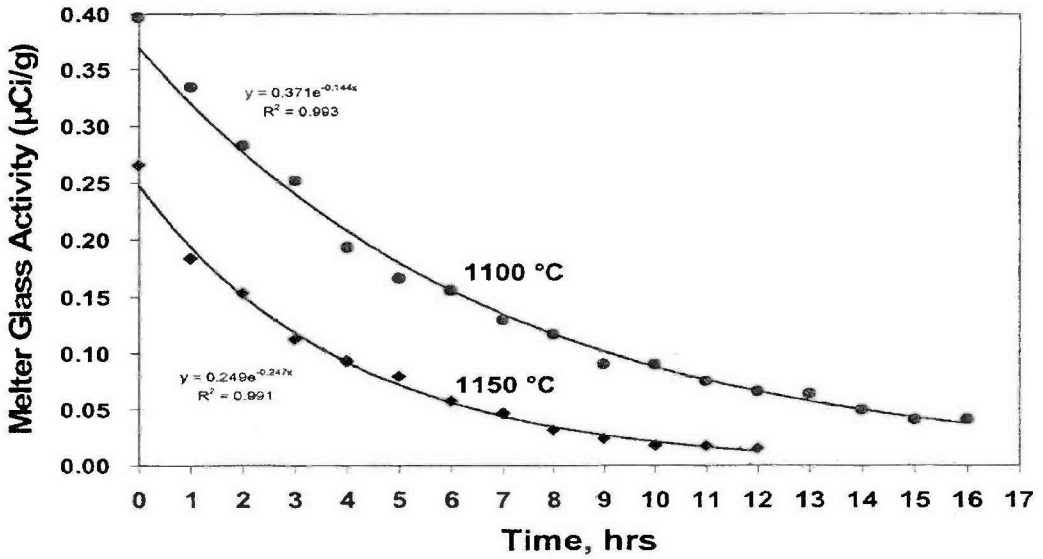
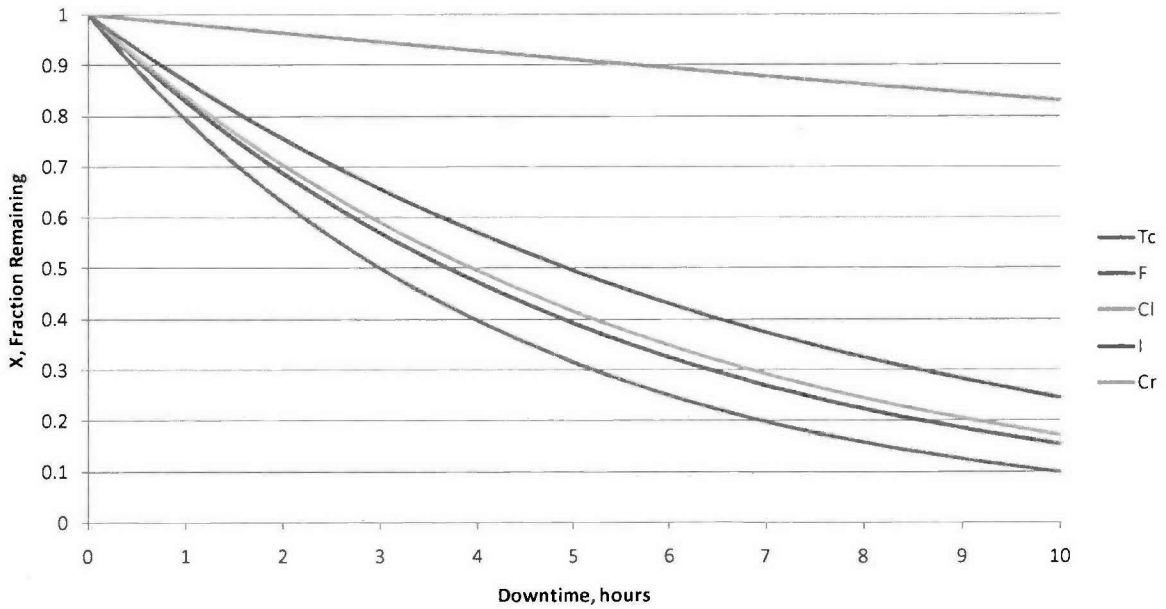


Figure 3.3-7 Melter Glass Decay Curves for Semivolatiles



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3.4 System RLD/NLD: LAW Liquid Waste Disposal Process

3.4.1 Function and Requirements

The effluent collection system consists of two subsystems: the Radioactive Liquid Waste Disposal System (RLD) and the Non-Radioactive Liquid Waste Disposal System (NLD). The RLD system receives vessel washes, vessel vent header drainage from LAW Primary Offgas Process System (LOP), LAW Secondary Offgas/Vessel Vent Process System (LVP), LAW Concentrate Receipt Process System (LCP), LAW Melter Process System (LMP), C3/C5 floor drains, and sump wastes, all of which are expected to have low levels of radioactive contamination. The NLD system receives C1/C2 floor drains and C1V/C2V condensate, which are expected to have little or no contamination. The purpose of the system is to receive effluents for interim storage, sample the effluents as necessary, and, after content has been determined, transfer the effluents to either the Pretreatment (PT) Facility treated LAW evaporator (TLP-VSL-00009A/B), plant wash vessel (PWD-VSL-00044), or the Balance of Facilities (BOF) NLD storage tank (NLD-TK-00001).

The following is stated in the WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7(a)(5):

> *Disposition all secondary wastes in accordance with ICD requirements; secondary wastes are identified in section C.9, Interface Control Documents and Standard 6, Product Qualification, Characterization and Certification.*

ICD 05 - Interface Control Document for Nonradioactive, Nondangerous Liquid Effluents (ICD-05) (24590-WTP-ICD-MG-01-005) has been developed to govern nonradioactive, non-dangerous liquid effluent systems and operations, including transfer to the Tank Farm Contractor.

WTP SOW Facility Specification, Section C.7(d)(1)(vi):

> *Liquid Effluent Treatment: This operation collects the WTP effluent and provides for the discharge to the Hanford Site 200 East Area Effluent Treatment Facility (ETF) or allows for the re-use of liquid effluent as process water with the WTP. Treated effluent will be transferred to the Hanford Site ETF as required.*

3.4.2 Process Description

3.4.2.1 LAW Liquid Effluents

The LAW liquid effluents collection system consists of four vessels that collect, detain, mix, sample, and discharge radioactive and nonradioactive secondary effluents from the LAW Facility. See Figure 3.4-1, LAW liquid effluents disposal process system, which includes system NLD and system RLD.

The NLD system receives firewater and nonradioactive effluents from the C1/C2 floor drains and sumps. These wastes are collected by the C1/C2 drains and sump collection vessel (NLD-VSL-00005), and are stored and sampled. Then, depending on sample results, they are discharged to either the BOF nonradioactive effluent tank (NLD-TK-00001) as stream NLD-01 or to the PT Facility via the plant wash vessel (RLD-VSL-00003). In the event of a fire, floor drains in the C1/C2 areas are directed to the C1/C2 collection vessel. If the vessel volume is exceeded, the firewater overflows to a berm surrounding the C1/C2 collection vessel. A sump pump (NLD-PMP-00022) in the berm can direct the berm contents back to the C1/C2 collection vessel for transfer to PT or BOF. Only effluents meeting Treated Effluent

Disposal Facility (TEDF) limits are sent to the BOF nonradioactive effluent tank. From the BOF nonradioactive effluent tank the nonradioactive effluents pass through an interface point (ICD-05) and are disposed at the TEDF. Contaminated effluents are directed to the LAW plant wash vessel (RLD-VSL-00003) and then to the PT Plant Wash and Disposal System (PWD) for further processing.

Radioactive effluents received from C3/C5 sumps and vessel washes are collected by the plant wash vessel (RLD-VSL-00003), stored until the level setpoint is reached, mixed, sampled as needed, and discharged to PT process system PWD, as discussed in Section 2.15.

The C3/C5 drain/sump collection vessel (RLD-VSL-00004) collects firewater and radioactive effluent from the wet electrostatic precipitator (WESP) drains, overflows from LAW concentrate receipt vessels (LCP-VSL-00001, LCP-VSL-00002), overflows from the LAW melter feed preparation vessels (LFP-VSL-00001, LFP-VSL-00003), vessel vent headers drainage, and C3/C5 area floor drain and sump effluents. These effluents are held, mixed, or sampled as needed, and discharged to either the submerged bed scrubber (SBS) condensate collection vessel (RLD-VSL-00005), or the LAW plant wash vessel (RLD-VSL-00003), depending on their source. The C3/C5 drain/sump collection vessel transfers WESP drainage to the SBS condensate collection vessel, where it is mixed with SBS condensate before discharge to PT system Treated LAW Evaporation Process System (TLP). The C3/C5 drain/sump collection vessel transfers concentrate receipt vessel overflows, vent drainage, and floor drain/sump drainage to the plant wash vessel (RLD-VSL-00003), where it is mixed with other LAW vessel washes before discharge to PT system PWD, discussed in Section 2.15.

SBS condensate purges from the SBS vessels (LOP-SCB-00001, LOP-SCB-00002) and SBS condensate vessels (LOP-VSL-00001, LOP-VSL-00002) are collected by the SBS condensate collection vessel (RLD-VSL-00005). The SBS effluents are held for up to two days, mixed, sampled as needed, and discharged to PT TLP/Treated LAW Concentrate Storage Process System (TCP), as discussed in Section 2.12.

3.4.3 Basis

The two systems, RLD and NLD, are designed to stage, transfer, sample, and mix incidental effluents collected during the operation of the LAW Facility (24590-WTP-3YD-NLD-00001, Rev 1, 24590-LAW-M5-V17T-00014, Rev 5). Holdup is required to allow time for analysis to determine whether the waste meets PT process or BOF acceptance criteria.

3.4.3.1 System RLD

This collection system consists of three vessels that receive unique influent streams: the plant wash vessel (RLD-VSL-00003), the C3/C5 drain/sump collection vessel (RLD-VSL-00004), and the SBS condensate collection vessel (RLD-VSL-00005). Detailed vessel descriptions follow.

3.4.3.1.1 Plant Wash Vessel

The plant wash vessel (RLD-VSL-00003) receives, stores, mixes, samples, and transfers process cell sump and vessel wash effluents, effluent from the C3/C5 drain/sump collection vessel (RLD-VSL-00004), overflow from the SBS condensate collection vessel (RLD-VSL-00005), and can receive C3/C5 sump discharges. It is designed to handle the capacity of the largest LAW vessel (SBS condensate collection vessel, RLD-VSL-00005). The plant wash vessel has a propeller-type mechanical agitator (RLD-AGT-00001) and duplex, as well as in-vessel discharge pumps (RLD-PMP-00001A/B). It is piped and valved to operate in either discharge or recirculation mode. Normal operation is recirculation

mode, except when effluents are being discharged. The vessel discharges to the PWD system vessel PWD-VSL-00044. After transfer, the line is routinely flushed with one line volumes of demineralized water. A sampling system is attached to the recirculation line before discharge back into the vessel. Sampling will be performed during initial startup and intermittently, as required, to control system parameters. There is a requirement that the effluents contain no more than 5 % solids before discharge to pretreatment. The solids content in the vessel is estimated to be between 1 and 2 % (24590-LAW-3YD-RLD-00001, Rev 1). The vessel has level, density, and temperature indicators. It is connected to the vent header. Overflow is transferred to the LAW C3/C5 drain/sump collection vessel RLD-VSL-00004.

3.4.3.1.1.1 Design Data - Plant Wash Vessel

RLD-VSL-00003 (24590-LAW-M6C-RLD-00005, Rev 2)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

RLD-PMP-00001A/B (24590-LAW-M6C-RLD-00007, Rev 0)

- Pump capacity: 130 gpm
- Pump duty: 21.7 bhp

RLD-AGT-00001 (24590-LAW-ESD-RLD-00001, Rev 1)

- Motor rated horsepower: 40 hp

3.4.3.1.1.2 Operating Logic - Plant Wash Vessel

(24590-LAW-3YD-RLD-00001, Rev 2)

- Collects 16,000 gal
- Sample: as needed
- Discharge 16,000 gal at 130 gpm, to PWD-VSL-00044

3.4.3.1.1.3 Energy Contributions - Plant Wash Vessel

- BOF related
  - None: vessel is neither heated nor cooled
- Non-BOF related
  - Pump: 21.7 bhp
  - Agitator: 40 hp

3.4.3.1.1.4 Fluidics - Plant Wash Vessel

Flow rates and quantities are given in vessel Operating Logic, above.

3.4.3.1.1.5 Services - Plant Wash Vessel

- Process service water for vessel washing
- Demineralized water for line flushing

3.4.3.1.1.6 Chemistry - Plant Wash Vessel

None

3.4.3.1.2 C3/C5 Drain/Sump Collection Vessel

The C3/C5 drain/sump collection vessel (RLD-VSL-00004) receives, stores, mixes, samples, and transfers effluent from the WESP drains and vessel vent header drainage and C3/C5 area floor drain and sump effluents. The vessel also receives overflow from the LAW concentrate receipt vessels (LCP-VSL-00001, LCP-VSL-00002), the melter feed preparation vessels (LFP-VSL-00001, LFP-VSL-00003), and the LAW plant wash vessel (RLD-VSL-00003). The C3/C5 drain/sump collection vessel also receives vessel washes. The LAW C3/C5 drain/sump collection vessel has been sized to ensure adequate capacity for the WESPs and HVAC condensates on a high-humidity day. If the volume exceeds the overflow volume, it overflows to the cell and the cell sump pump transfers the contents to the plant wash vessel (RLD-VSL-00003). It has vessel mixing eductors (RLD-EDUC-00001A/B/C) and duplex centrifugal discharge pumps (RLD-PMP-00002A/B). The vessel is piped and valved to operate in either discharge or recirculation mode. Normal operation is recirculation mode, except when effluent is being discharged. The vessel discharges to either the LAW SBS condensate collection vessel (RLD-VSL-00005) or the LAW plant wash vessel (RLD-VSL-00003), depending on the characteristics of the incoming liquid. Effluent from the WESP drains is pumped, daily, to RLD-VSL-00005. Effluent from other sources, such as floor drains and sump wastes, is routinely pumped to RLD-VSL-00003. A sampling system is attached to the recirculation line before discharge back into the vessel. The vessel has redundant level and one temperature indicator. The vessel is connected to the vent header. Overflow is transferred to a sump (RLD-SUMP-00028) in the C3/C5 vessel cell.

3.4.3.1.2.1 Design Data - C3/C5 Drain/Sump Collection Vessel

RLD-VSL-00004 (24590-LAW-M6C-RLD-00001, Rev 2)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

RLD-PMP-00002A/B (24590-LAW-MPC-RLD-00002, Rev 00A)

- Pump capacity: 75 gpm
- Pump duty: 10 hp

3.4.3.1.2.2 Operating Logic - C3/C5 Drain/Sump Collection Vessel

(24590-LAW-3YD-RLD-00001, Rev 2, and 24590-LAW-M6C-RLD-00001, Rev 2)

- Receipt of effluent from the WESPs (LOP-WESP-00001 and LOP-WESP-00002)
- Receipt of drains from the LVP vessel vent header
- Receipt of HVAC condensate drains

- Mixing contents by recirculation through RLD-EDUC-00001A/B/C
- Transfer effluent to RLD-VSL-00005 at 75 gpm
- Cycle repeats every one or two days

3.4.3.1.2.3 Energy Contributions - C3/C5 Drain/Sump Collection Vessel

- BOF related
  - None: vessel is neither heated nor cooled
- Non-BOF related
  - Pump: 10 hp

3.4.3.1.2.4 Services - C3/C5 Drain/Sump Collection Vessel

Provides process service water for vessel washing.

3.4.3.1.2.5 Chemistry - C3/C5 Drain/Sump Collection Vessel

None

3.4.3.1.3 SBS Condensate Collection Vessel

The SBS condensate collection vessel (RLD-VSL-00005) receives, stores, mixes, samples, and transfers waste from the SBS column vessels (LOP-SCB-00001, LOP-SCB-00002) and SBS condensate purge (LOP-VSL-00001, LOP-VSL-00002) located in the LOP system. The vessel has a propeller-type mechanical agitator (RLD-AGT-00002) and duplex, in-tank discharge pumps (RLD-PMP-00003A/B). The vessel is piped and valved to operate in either discharge mode or recirculation (normal) mode. It discharges to PT process (system PWD). After transfer, the line is routinely flushed with two line volumes of demineralized water. One line volume reports to TLP-VSL-00009A/B and the other line volume reports to PWD-VSL-00044. A sampling system is attached to the recirculation line before discharge back into the vessel. The vessel has redundant level and one temperature indicator. The vessel is connected to the vent header. Overflow is directed to plant wash vessel RLD-VSL-00003. The volume of SBS condensate received varies and is dependent upon required additional cooling water and condensate accumulation rate.

Assumption 3.4.2. Assumption resolved. See Appendix C.

3.4.3.1.3.1 Design Data - SBS Condensate Collection Vessel

RLD-VSL-00005 (24590-LAW-M6C-RLD-00006, Rev 2)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

RLD-PMP-00003A/B (24590-LAW-M6C-RLD-00008, Rev 0)

- Pump capacity: 130 gpm
- Pump duty: 18.1 bhp

RLD-AGT-00002 (24590-LAW-ESD-RLD-00002, Rev 1)

- Motor rated horsepower: 40 hp

3.4.3.1.3.2 Operating Logic - SBS Condensate Collection Vessel

(24590-LAW-3YD-RLD-00001, Rev 2, 24590-LAW-M5-V17T-00007/00008, Rev 4, and 24590-LAW-M6C-RLD-00001, Rev 2)

- Receipt of condensate from the SBSs (LOP-SCB-00001 and LOP-SCB-00002)
- Receipt of condensate from the SBS Condensate Vessels (LOP-VSL-00001 and LOP-VSL-00002)
- Receipt of condensate from the WESP (LOP-WESP-00001 and LOP-WESP-00002) drains via the C3/C5 Drains/Sump Collection Vessel (RLD-VSL-00004)
- Mix contents with RLD-AGT-00002
- Transfer contents to LAW SBS Condensate Receipt Vessels (TLP-VSL-00009A/B) at 130 gpm
- Cycle repeats every one or two days

3.4.3.1.3.3 Energy Contributions - SBS Condensate Collection Vessel

- BOF related
  - None: vessel is neither heated nor cooled.
- Non-BOF related
  - Pump: 18.1 bhp
  - Agitator: 40 hp

3.4.3.1.3.4 Services - SBS Condensate Collection Vessel

Provides process service water for vessel washing.

3.4.3.1.3.5 Chemistry - SBS Condensate Collection Vessel

None

3.4.3.2 System NLD

This system consists of one vessel, the C1/C2 drain/sump collection vessel (NLD-VSL-00005). This vessel receives waste from the drains, sumps, and washes in the C1/C2 areas of the LAW Facility (24590-LAW-M5-V17T-00014, Rev 5).

3.4.3.2.1 C1/C2 Drains and Sump Collection Tank

The LAW C1/C2 drain/sump collection vessel (NLD-VSL-00005) receives, stores, mixes, samples, and transfers waste from the floor drains and sumps in the C1/C2 areas of the LAW Facility. The vessel is equipped with mixing eductors (NLD-EDUC-00001A/B/C/D) and duplex centrifugal discharge pumps (NLD-PMP-00003A/B). The vessel is piped and valved to operate in either discharge or recirculation mode. Normal operation is recirculation mode. It discharges to either the LAW plant wash vessel (RLD-VSL-00003) or the BOF nonradioactive liquid effluent tank (NLD-TK-00001). A sampling system

is attached to the recirculation line before discharge back into the vessel. Sampling is performed before discharge to determine the destination of the effluent. Non-active effluent is sent to BOF tank NLD-TK-00001. Suspected active effluent is sent to RLD-VSL-00003. The vessel has level, temperature, density, and radiation indicators. The vessel is vented to the C2 area. Vessel NLD-VSL-00005 overflows to a sump.

3.4.3.2.1.1 Design Data - C1/C2 Drains and Sump Collection Tank

NLD-VSL-00005 (24590-LAW-M6C-NLD-00001, Rev 1)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

NLD-PMP-00003A/B (24590-LAW-MPC-NLD-00001, Rev 1)

- Pump capacity: 100 gpm
- Pump duty: 10 hp

3.4.3.2.1.2 Operating Logic - C1/C2 Drains and Sump Collection Tank

(24590-WTP-3YD-NLD-00001, Rev 1)

- Receives transfer from sumps and continuous flows of condensate through the floor drain headers
- Recirculates and sample condensate
- Transfer effluent to NLD-TK-00001 at 100 gpm

3.4.3.2.1.3 Energy Contributions - C1/C2 Drains and Sump Collection Tank

- BOF related
  - None: vessel is neither heated nor cooled.
- Non-BOF related
  - Pump: 10 hp

3.4.3.2.1.4 Services - C1/C2 Drains and Sump Collection Tank

Process service water for vessel washing

3.4.3.2.1.5 Chemistry - C1/C2 Drains and Sump Collection Tank

None

3.4.4 Ongoing Work and Potential Changes

There are no expected changes for this system at this time.

3.4.5 References

24590-LAW-3YD-RLD-00001, Rev 2, *System Description for LAW Radioactive Liquid Waste Disposal (RLD) System.*

24590-LAW-ESD-RLD- 00001, Rev 1, *RLD-MTR-00001 - Low Voltage Induction Motor.*

24590-LAW-ESD-RLD-00002, Rev 1, *RLD-MTR-00002 - Low Voltage Induction Motor.*

24590-LAW-M5-V17T-00007, Rev 4, *Process Flow Diagram Melter 1 Primary Offgas Treatment System (System LOP).*

24590-LAW-M5-V17T-00008, Rev 4, *Process Flow Diagram Melter 2 Primary Offgas Treatment System (System LOP).*

24590-LAW-M5-V17T-00014, Rev 5, *Process Flow Diagram LAW Liquid Effluent (System RLD).*

24590-LAW-M6C-NLD-00001, Rev 1, *C1/C2 Drains Sump Collection Vessel NLD-VSL-00005.*

24590-LAW-M6C-RLD-00001, Rev 2, *LAW C3/C5 Drains/Sump Collection Vessel RLD-VSL-00004 Sizing.*

24590-LAW-M6C-RLD-00005, Rev 2 *Vessel Sizing Calculation for Plant Wash Vessel RLD-VSL-00003.*

24590-LAW-M6C-RLD-00006, Rev 2, *SBS Condensate Collection Vessel Sizing (RLD-VSL-00005).*

24590-LAW-M6C-RLD-00007, Rev 0, *Sizing of Pump RLD-PMP-00001A and RLD-PMP-00001B.*

24590-LAW-M6C-RLD-00008, Rev 0, *Sizing of Pump RLD-PMP-00003A and RLD-PMP-00003B.*

24590-LAW-MPC-NLD-00001, Rev 1, *Sizing of Pump NLD-PMP-00003A/B & Restricting Orifice.*

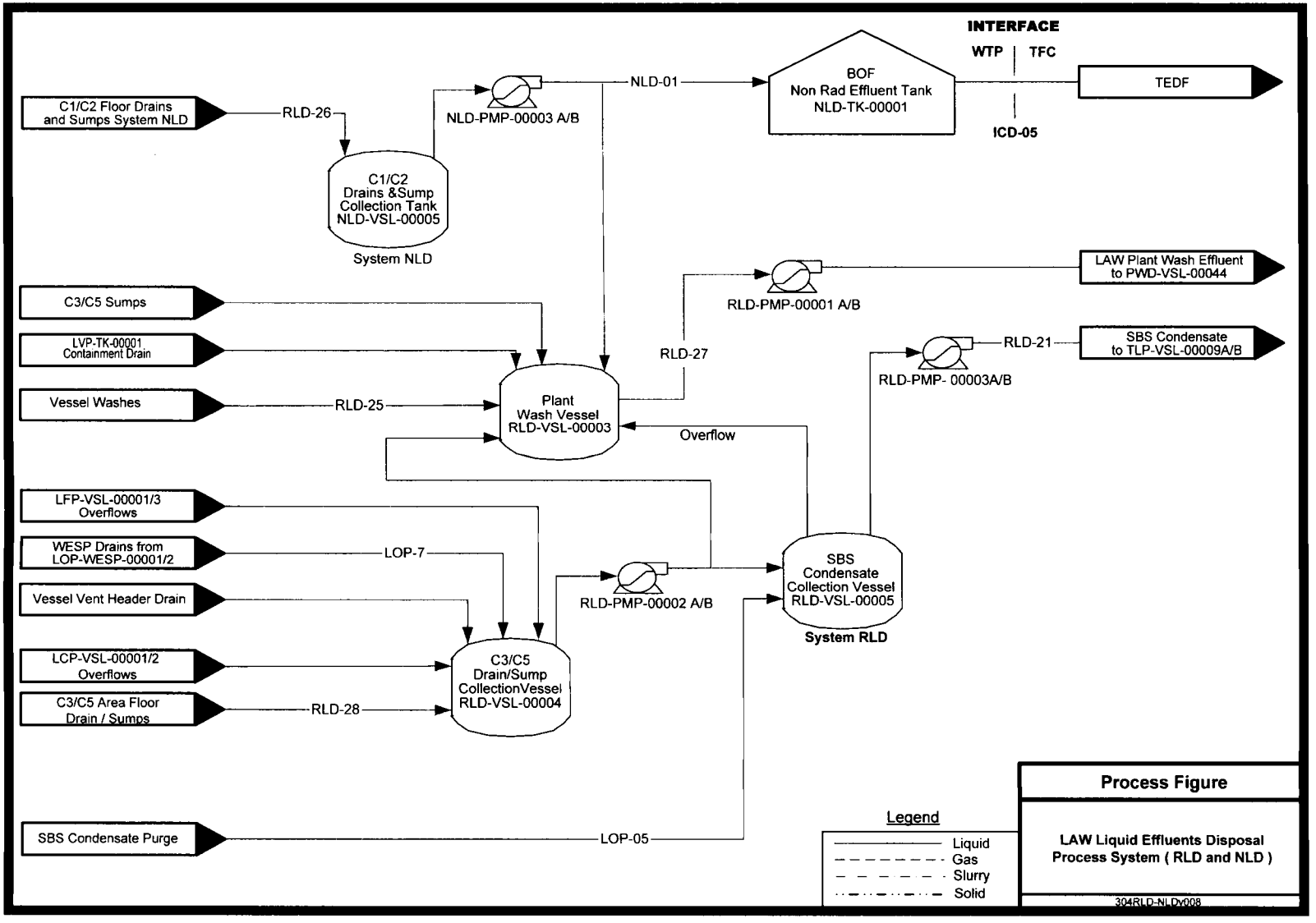
24590-LAW-MPC-RLD-00002, Rev 0, *Sizing of Pump RLD-PMP-00002A and RLD-PMP-00002B.*

24590-WTP-3YD-NLD-00001, Rev 1, *System Description for the Waste Treatment Plant Non-Radioactive Liquid Waste Disposal (NLD) System.*

24590-WTP-ICD-MG-01-005, Rev 4, *ICD-05 - Interface Control Document for Nonradioactive, Nondangerous Liquid Effluents.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

Figure 3.4-1 LAW Liquid Effluents Disposal Process System



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3.5 System CDG: LAW Carbon Dioxide Gas

3.5.1 Function and Requirements

The Low-Activity Waste (LAW) Facility carbon dioxide gas system (CDG) provides the solid CO_2 pellets necessary to decontaminate the filled, sealed immobilized LAW (ILAW) product containers. The CDG system includes the storage vessel for the liquid CO_2 used to produce the pellets. The plant service air system (PSA) provides compressed gas used to drive the solid pellets out of a robotic end-effector. The C5V and LAW container finishing handling (LFH) systems remove the gas effluents and particulates created by the decontamination process. The waste product containers used to store the radioactive glass are constructed of stainless steel and are cylindrical, measuring approximately 7.5 ft high and 4 ft in diameter—part of LFH.

The following is stated in the WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Operational Specification, Section C.8, Specification 2.2.2:

> *Surface Dose Rate Limitations: The dose rate at any point on the external surface of the package shall not exceed 500 mRem/hr.*

WTP SOW Operational Specification, Section C.8, Specification 2.2.2.10:

> *Surface Contamination Limitations: Removable contamination on the external surfaces of the package shall not exceed 367 Bq/m^2 for alpha and 3670 Bq/m^2 for beta-gamma contamination when measured using the method described in 49CFR173.443(a).*

More stringent site design requirements further limit removable contamination to 100 dpm/100 cm^2 for alpha radiation and 1000 dpm/100 cm^2 for beta and gamma radiation (24590-WTP-DB-ENG-01-001, Table 5.2). These limits allow storage of the containers in a C2 area.

WTP SOW Facility Specification, Section C.7(d)(3)(iv) states:

> *Low-Activity Waste Container Closure, Decontamination, and inspection: Container closure, decontamination, and inspection shall be conducted in accordance with Specification 2, Immobilized Low-Activity Waste Product. The ILAW Product container is sealed, decontaminated, and then the container is weighed and checked for dimensionality. The canister is decontaminated using a solid carbon dioxide abrasion process. Temperature and gamma dose rate measurements will be taken on selected containers.*

Section 6, *Basis of Design* (24590-WTP-DB-ENG-01-001, Rev 1 N), states:

> *LAW product handling - The glass will be poured into a container and allowed to cool. The container is sealed and handled through monitoring and decontamination processes prior to delivery to the DOE ORP. Container storage requirements are identified in ICD-15 (24590-WTP-ICD-MG-01-015).*

3.5.2 Process Description

The LAW container decontamination process is shown in *Process Flow Diagram LAW Vitrification Container Decontamination (System CDG)* (24590-LAW-M5-V17T-00013). The LAW CDG system

stores liquid CO_2 to produce solid CO_2 pellets, transports pellets to the nozzles in the decontamination area (LFH system), and removes the effluents generated during decontamination by bombarding the canisters with CO_2 pellets. A more detailed description of this process is provided below.

The major components of the CDG system are the CO_2 storage vessel, four pumps, two pelletizers, four blasters, and four heaters. Liquid CO_2 is stored in a vessel outside of the LAW Facility. From the vessel, the liquid CO_2 is pumped to two separate pelletizers. Part of the liquid CO_2 entering the pelletizing chamber in the pelletizer expands to gaseous CO_2. The remaining liquid freezes into a solid snow-like state. Pellets are produced by injecting liquid CO_2 into the pelletizer extrusion cylinder, where a solid CO_2 is formed. A ram, under hydraulic pressure, presses the solid CO_2 through a die plate to form pellets.

This general decontamination process begins after the LAW container has been cooled and sealed. The container is transported to the decontamination station, where compressed air is used to propel CO_2 pellets against the container to dislodge loose contamination from its surface (24590-LAW-3YD-CDG-00001). When the dry ice pellets hit the container surface they fragment, penetrating the base material and dislodging contaminants from the container. The solid CO_2 pellets instantly sublimate, which adds a lifting force that speeds the removal of the contaminants. The gas expands to nearly 800 times (CCN 193197) the volume of the pellet in a few milliseconds. The blasting system contains two power manipulators, each with four nozzles. One nozzle is for the pellets and one is for heated air. The heated air is applied to the container at the same time as the pellets. This keeps condensation from forming on the vessel when the cold pellets contact the hot container.

This is done in the LFH or C5V system, not the CDG system. The resulting debris is sent through a local high-efficiency particulate air (HEPA) filter using a variable speed fan, thus removing the contaminants entrained in the stream. The fans and HEPA filters are part of the C5 ventilation system and therefore are not discussed further in this section (24590-LAW-DCA-M-03-010). Eventually the gas stream is sent through the facility's HEPA filters, where additional contaminants are removed before the gas stream is discharged through the stack.

The CDG system provides the solid CO_2 pellets necessary to perform container decontamination (24590-LAW-3YD-CDG-00001; 24590-LAW-M6-CDG-00001001, 24590-LAW-M6-CDG-00001002, and 24590-LAW-M6-CDG-00002001, 24590-LAW-M6-CDG-00002002). The simplified diagram of the system is depicted in Figure 3.5-1. For equipment in this system, see Table 3.5-1.

3.5.3 Basis

A study was performed to evaluate several alternatives for the LAW decontamination system (RPT-W375LV-TE00009, Rev 0). The alternatives examined were ultra-high pressure water wash, laser ablation, solid CO_2 pellet blasting, and Ce^{+4} chemical milling. The criteria selected for the assessment of the proposed alternatives included efficiency, reliability, waste minimization, ease of operation, and low maintenance requirements. These criteria were given weighting factors and applied to each of the proposed alternatives.

The solid CO_2 pellet blasting system was chosen as the preferred alternative based on meeting the selection criteria. The pellets are discharged from the blasting gun at high speeds, striking the container. This collision translates the kinetic energy imparted by the blasting gun to energy of deformation plus thermal energy that causes the pellets to shatter, fragment, and instantly sublimate. The solid CO_2 penetrates the base material and dislodges the contaminants from it. The sublimation of the CO_2 also adds a lifting force that speeds the removal of the contaminants and increases the volume of CO_2 by a factor of approximately 800 (CCN 193197). The CO_2-based decontamination process produces no

secondary waste. It is also a relatively simple process with a high degree of reliability and ease of operation.

The LAW decontamination system contains two redundant gaseous effluent flow streams that are mixes of compressed air, CO_2, and whatever contamination or waste is removed from the LAW container surface during the decontamination process. These streams pass through HEPA filters, which remove the particulate contamination or waste. The remaining gas exhausts to the building ventilation system.

3.5.3.1 Liquid CO_2 Storage Vessel (CDG-VSL-00001)

The CO_2 storage vessel stores CO_2 at a pressure of 280 to 300 psig (preliminary data) to maintain the CO_2 in a liquid state. The CO_2 storage vessel's maximum operating volume is 25,286 gal. The CO_2 storage vessel is used to supply liquid CO_2 to both decontamination lines. The vessel is equipped with a refrigeration unit and vaporizer to ensure that the CO_2 is kept in the liquid form. There are level and pressure indicators so the operators can verify the values. The storage vessel is shown in piping and instrumentation diagram (P&ID) 24590-LAW-M6-CDG-00001001.

3.5.3.1.1 Design Data - Liquid CO_2 Storage Vessel (CDG-VSL-00001)

(24590-LAW-MVC-CDG-00001, Rev 0, and 24590-LAW-MVD-CDG-00002, Rev 0)

- Influent flowrate (from vendor tanker): dependent on vendor
- Effluent flowrate (to pelletizer): 8 lb/min

Cryogenic pumps CDG-PMP-00001A/B and CDG-PMP-00002A/B transfer liquid CO_2 from CDG-VSL-00001 to the pelletizers (CDG-PLT-00001/2) on demand during container decontamination activities.

3.5.3.2 Cryogenic Pumps (CDG-PMP-00001A/B and CDG-PMP-00002A/B)

(24590-LAW-MPD-CDG-00001, Rev 2)

Cryogenic pumps CDG-PMP-00001A/B and CDG-PMP-00002A/B transfer liquid CO_2 from CDG-VSL-00001 to the pelletizers (CDG-PLT-00001/2) on demand during container decontamination activities.

3.5.3.3 CO_2 Pelletizers (CDG-PLT-00001/2)

Pellets are produced as needed due to slow deterioration in pellet density and size, if stored. The pelletizer must be kept within 50 ft of the CO_2 gun to ensure high pellet density.

Air is provided to the blaster at a maximum pressure of 105 psig and a maximum flow rate of 200 scfm per nozzle for a total of 800 scfm (24590-CM-POA-MS00-00006-08-00008, Section 5.5).

3.5.3.3.1 Design Data - CO_2 Pelletizers (CDG-PLT-00001/2)

(24590-LAW-MVC-CDG-00001, Rev 0)

- Influent flowrate (from CDG-VSL-00001): 8 lb/min
- Effluent flowrate (to end-effectors): 1320 scfm at 120 psig and 60 °F (24590-LAW-3YD-CDG-00001)
- P&IDs for the CO_2 Pelletizers are 24590-LAW-M6-CDG-00002001 and 24590-LAW-M6-CDG-00002002

3.5.3.4 Liquid CO_2 Pumps (CDG-PMP-00001A/B and 00002A/B)

The liquid carbon dioxide pumps transfer the liquid carbon dioxide at a flow rate of on the order of 146 gpm. The final flow rate value will be confirmed once the vendor design of the CDG system is finalized. The P&ID for the carbon dioxide pump system is shown in 24590-LAW-M6-CDG-00001002.

3.5.3.5 Blast Air Heaters (CDG-HTR-00001/2)

The blast air heaters heat the air stream to 165 °F for normal operations (24590-CM-POA-MS00-00006-05-000011/12).

Air is provided to the heaters at a maximum pressure of 100 psig and a maximum flow rate of 200 scfm per heater for a total of 800 scfm (24590-CM-POA-MS00-00006-08-00008, Section 5.5).

3.5.4 Ongoing Work and Potential Changes

No additional design work in planned for CDG system at this time.

3.5.5 References

24590-CM-POA-MS00-00006-05-00011, Rev 00B, *Mechanical Data Sheet: Heater Skid.*

24590-CM-POA-MS00-00006-05-00012, Rev 00B, *Mechanical Data Sheet: Heater Skid.*

24590-CM-POA-MS00-00006-08-00008, Rev 00B, Manual - CO_2 Blasting - *System Operations Manual.*

24590-LAW-3YD-CDG-00001, Rev 1, *System Description for Low Activity Waste of Carbon Dioxide Gas System (CDG).*

24590-LAW-DCA-M-03-010, Rev 0, *Transfer of CDG Exhaust System from Mechanical Systems to HVAC.*

24590-LAW-M5-V17T-00013, Rev 3, *Process Flow Diagram LAW Vitrification Container Decontamination (System CDG).*

24590-LAW-M6-CDG-00001001, Rev 0, *P&ID-LAW Carbon Dioxide Gas System CDG-VSL-00001.*

24590-LAW-M6-CDG-00001002, Rev 0, *P&ID-LAW Carbon Dioxide Gas System CDG-PMP-00001A/B, -00002 A/B.*

24590-LAW-M6-CDG-00002001, Rev 0, *P&ID-LAW Carbon Dioxide Gas System CDG-SKID-00004A & 00005A.*

24590-LAW-M6-CDG-00002002, Rev 0, *P&ID -LAW Carbon Dioxide Gas System CDG-SKID-00004B &00005B.*

24590-LAW-MPD-CDG-00001, Rev 2, *Mechanical Systems Data Sheet: Carbon Dioxide Pumps.*

24590-LAW-MVC-CDG-00001, Rev 0, *Sizing of the LAW Liquid CO_2 Storage Vessel (CDG-VSL-00001) and Pelletizer (CDG-PLT-00001 and CDG-PLT-00002).*

24590-LAW-MVD-CDG-00002, Rev 0, *LAW CDG Refrigerated Liquid Carbon Dioxide Storage Vessel.*

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

24590-WTP-ICD-MG-01-015, Rev 2, *ICD 15-Interface Control Document for Immobilized Low-Activity Waste.*

CCN 193197, *LAW CDG Pellet Sublimation Expansion Volume.* 14 April 2009.

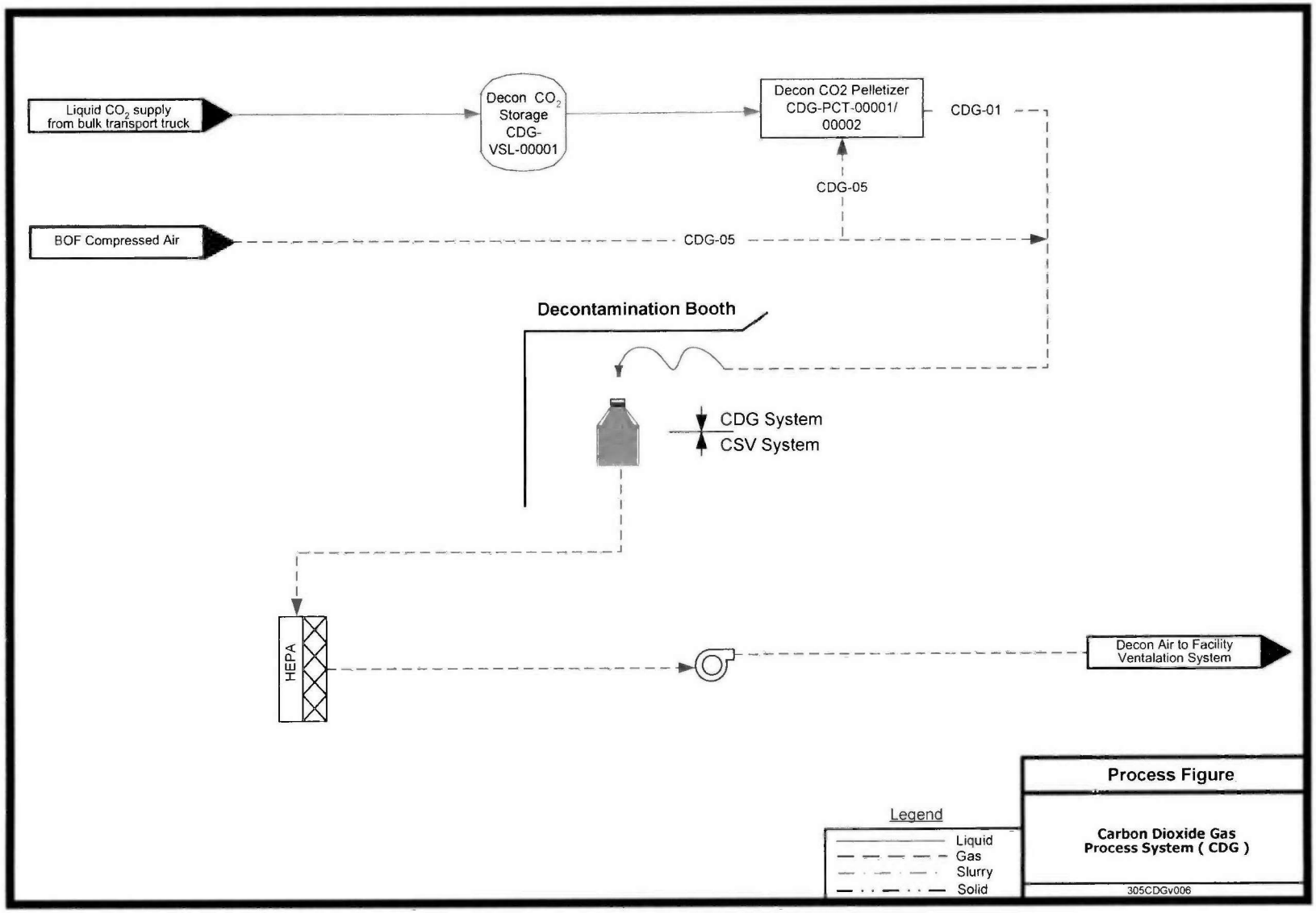
DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, Modification No. M147.

RPT-W375LV-TE00009, Rev 0, *Evaluation of Alternatives for the LAW Container Decontamination System.*

Table 3.5-1 LAW Container Decontamination System Equipment

LAW Container Decontamination System	Purpose
Receipt and storage vessel for liquid CO_2, CDG-VSL-00001	Holds 120 tons of liquid CO_2 at 300 to 350 psig as feed to the pelletizers for CO_2 pellet production (may change with new vendor information).
CO_2 pelletizer, CDG-PLT-00001/00002	CO_2 blasting works because of three primary factors: pellet kinetic energy, the thermal shock effect, and the thermal-kinetic effect. The pelletizer optimizes the blast performance process through the various applications of the above effects and adjusting parameters as indicated below: 1. Compressed air pressure 2. Blast nozzle type (velocity distribution) 3. CO_2 pellet size and density 4. Pellet mass flow rate and flux density (particles per unit area per second) • The kinetic impact force is a product of pellet mass and impact velocity; the pelletizer delivery system achieves the greatest impact force possible from a solid $C0_2$ pellet by propelling the pellets to very high velocities. However, due to the relative softness of the CO_2 pellet and the almost instantaneous phase change upon impact, the process is considered nonabrasive. • The thermal shock effect comes about based on the process of instantaneous sublimation, which takes place as the CO_2 pellet impacts the canister and absorbs maximum heat from the very thin layer of surface coating or contaminant. This very rapid transfer of energy causes relatively large temperature gradients between successive micro-layers within the surface material. Consequently, the high shear stress produced over the very brief expanse of time causes rapid micro-crack propagation between the layers leading to contamination and/or coating final bond failure at the surface of the substrate. The combined impact energy dissipation and extremely rapid heat transfer between the pellet and the canister surface causes an instantaneous sublimation of the solid CO_2 into gas. The gas expands to nearly 800 times the volume of the pellet in a few milliseconds in what effectively is a "micro-explosion" at the point of impact. The CO_2 gas expands outward along the surface and its resulting "explosion shock front" effectively provides an area of high pressure focused between the surface and the thermally fractured coating particles. This results in a very efficient lifting force to carry the particles away from the surface.
Liquid CO_2 pumps (CDG-PMP-0000lA/lB/2A/2B)	The liquid carbon dioxide pumps are required to transfer the liquid CO_2 from the carbon dioxide storage vessel to the pelletizer in a pressurized state.
Blast air heaters (CDG-HTR-00001/2)	The blast air heaters are used to heat the blast air before it is sent to the nozzle.

Figure 3.5-1 Carbon Dioxide Gas Process System



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3.6 LAW Interfaces with WTP Reagents, Ammonia Reagent, and Demineralized Water (SHR, AMR, and DIW)

3.6.1 Introduction

The WTP Reagent System receives, stores, and distributes chemical reagents for use within the WTP. The Balance of Facilities (BOF) Wet Chemical Storage Facility distributes sodium hydroxide (NaOH, designated as SHR) to the Low-Activity Waste (LAW) Facility (24590-WTP-3YD-SHR-00001).

The Demineralized Water System (DIW) is a separate system from the WTP Reagents. The feed water for the DIW system is supplied by the BOF DIW system (24590-WTP-3YD-DIW-00001). The DIW system receives, stores, and distributes reverse osmosis quality of water for use within the LAW. DIW is primarily used for process operations, line flushes, vessel washes, and make-up water for reagent dilutions (24590-WTP-3YD-DIW-00001).

This section describes the chemical reagents used in the LAW Facility along with the LAW DIW system.

3.6.2 Process Description

Chemical reagents are required in the LAW Facility for process operations and equipment/cell cleaning and decontamination (24590-WTP-3YD-SHR-00001). These include anhydrous ammonia, 5 M NaOH, and demineralized water. The overall reagent supply systems must provide adequate reagent storage, feed systems, and control mechanisms to support production of 30 metric tons of glass (MTG) per day: two melters operating at 15 MTG/day per melter. The systems must ensure that the proper concentration and quantity of chemicals are supplied to the process in a controlled manner.

3.6.2.1 Sodium Hydroxide (SHR)

The 5 M NaOH is transferred from the BOF Wet Chemical Storage Facility to SHR-TK-00003 for storage and used in LVP caustic scrubber (LVP-TK-00001) for pH adjustment.

3.6.2.2 Ammonia Reagent (AMR)

The purpose of the Anhydrous Ammonia Reagent System (AMR) is to receive and store liquid anhydrous ammonia, vaporize liquid anhydrous ammonia, and transfer gaseous anhydrous ammonia to the LAW Secondary Offgas/Vessel Vent Process System (LVP) and the HLW Melter Offgas Treatment Process System (HOP) (24590-WTP-3YD-AMR-00001). To perform these functions, the system consists of two 6000-gallon (24590-BOF-M6-AMR-00002002 and 24590-BOF-M6-AMR-00005001) ammonia storage vessels (AMR-VSL-00003/4) and two ammonia vaporization heaters (AMR-VPR-00002/3). The ammonia vaporization heaters have a 50 kW heater duty and a maximum pump rate of 291 lb/hr (24590-BOF-M6-AMR-00003001). Enough liquid ammonia is heated to maintain sufficient ammonia vapor in the vessel for normal demands on the HOP and LVP systems.

3.6.2.3 Demineralized Water (DIW)

The functions of the DIW system are to provide a receiving and interim storage capability for demineralized water and to distribute demineralized water to the LAW vitrification processes. The demineralized water storage tank (DIW-TK-00003) receives demineralized water from the PSW system and supplies demineralized water for LAW Facility needs. Demineralized water is primarily used for

reagent dilutions, process pipeline flushes, sampling pipeline flushes, vessels and bulge rinses, service systems make-up water, pump priming, wet electrostatic precipitator misting, and controls and instrumentation rinses.

3.6.3 Ongoing Work and Potential Changes

Work is ongoing to update the system descriptions for WTP Reagents and also the DIW system.

3.6.4 References

24590-BOF-M6-AMR-00002001, Rev 0, *P&ID - BOF Ammonia Reagent System Truck Unloading Station.*

24590-BOF-M6-AMR-00002002, Rev 0, *P&ID - BOF Ammonia Reagent System Storage Vessel AMR-VSL-00003.*

24590-BOF-M6-AMR-00003001, Rev 0, *P&ID - BOF Anhydrous Ammonia Reagent System Vaporizers and Appurtenances AMR-VPR-00002/3.*

24590-BOF-M6-AMR-00003002, Rev 0, *P&ID - BOF Anhydrous Ammonia Reagent System Safety Shower and Eye Wash Units.*

24590-BOF-M6-AMR-00005001, Rev 0, *P&ID - BOF Ammonia Reagent System Storage Vessel AMR-VSL-00004.*

24590-WTP-3YD-AMR-00001, Rev 2, *System Description for the Ammonia Reagent System (AMR).*

24590-WTP-3YD-DIW-00001, Rev 1, *System Description for the Water Treatment Plant Demineralized Water System (DIW).*

24590-WTP-3YD-SHR-00001, Rev 2, *System Description for WTP Reagents (SHR, NAR, AFR, SPR, STR).*

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3.7 System LRH, LPH, LFH, and LEH: LAW Mechanical Handling

3.7.1 Function and Requirements

The primary functions of low-activity waste (LAW) mechanical handling systems are to provide the ability to bring an empty container into the LAW Facility and move it through the LAW mechanical processing steps. These steps include filling the container with LAW glass and sealing, decontaminating, and exporting it for burial. There are four subsystems that make up the LAW mechanical handling process:

- System LRH: LAW container receipt handling
- System LPH: LAW container pour handling
- System LFH: LAW container finishing handling
- System LEH: LAW container export handling

The WTP *Statement of Work* (DE AC27 01RV14136), Operations Specification, Section C.8, specifies the requirements for the LAW mechanical handling systems with respect to product, handling, inspection, and acceptance.

3.7.1.1 Product Requirements

Specification 2.2.2.1

Package Description: The ILAW product shall be in the form of a package. The constituent parts of each package are a sealed stainless-steel container enclosing a poured glass waste form and an optional filler material of sand or glass. If an optional filler is used, DOE approval on the filler composition is required.

Specification 2.2.2.3

Size and Configuration: The package shall be a 304L stainless-steel right circular cylinder. The height of the package shall be 2.286 m (90"), and the diameter shall be 1.22 m (48"). At the time of acceptance, the ILAW package shall stand without support on a flat, horizontal surface.

Specification 2.2.2.4

Mass: The mass of each package shall not exceed 10,000 kilograms.

Specification 2.2.2.5

Void Space: The void space in the container shall not exceed 10 percent of the total internal volume at the time of filling, excluding void space internal to the glass waste form (e.g., small bubbles in the glass). After cooling, if necessary, the container shall be filled with suitable inert dry filler such that the void space meets the requirements of Dangerous Waste Regulation WAC 173-303-665 (12); i.e., the container shall be at least ninety (90) percent full when placed in the landfill.

Specification 2.2.2.9

Surface Dose Rate Limitations: The dose rate at any point on the external surface of the package shall not exceed 500 mRem/hr.

Specification 2.2.2.10

Surface Contamination Limitations: Removable contamination on the external surfaces of the package shall not exceed 367 Bq/m^2 for alpha and 3670 Bq/m^2 for beta-gamma contamination, when measured using the method described in 49 CFR 173.443(a).

Specification 2.2.2.11

Labeling: Each package shall have an identification number on the shoulder and side of the package as described in the ILAW Product Compliance Plan (Table C.5-1.1, Deliverable 6.3). The lettering on the label shall be at least 5.0 cm high, and characters shall have a width of at least 3.5 cm. The label shall contain a unique identification (e.g., serial number), which shall be assigned to each package and the corresponding documentation. Labels and markings shall have a predicted service life of 50 years, assuming that the packages are stored in a ventilated enclosure at ambient temperatures.

Specification 2.2.2.12

Closure and Sealing: The fully loaded package shall be closed and sealed. The closure system shall be sealed to prevent the dispersal of radioactive material during the most severe conditions encountered during normal use and handling. The closure system shall be designed to ensure that the seal remains intact for a storage period of 50 years in an ambient-temperature, ventilated enclosure.

Specification 2.2.2.13

External Temperature: The temperature of the accessible external surfaces of the package shall not exceed 465 °F (alternating pour) or 550 °F (single pour) when returned to DOE. This temperature constraint shall assume a shaded, still air environment at an ambient temperature of 38 °C.

3.7.1.2 Handling Requirements

Specification 2.2.3.1

Package Handling: The package shall be compatible with crane lifting and movement. The package shall be equipped with lifting and other handling appurtenances designed to allow safe lifting, and movement, when fully loaded. The package shall maintain its integrity during handling, and transportation.

3.7.1.3 Inspection and Acceptance Requirements

Specification 2.4

Inspection and Acceptance: The DOE-approved ILAW Product Compliance Plan (Table C.5-1.1, Deliverable 6.3), described in Standard 6, Product Qualification, Characterization, and Certification, defines the content and delivery of documentation required to demonstrate compliance with the requirements of this specification. Product inspection and acceptance shall be performed in accordance with Specification 13, Waste

Product Inspection and Acceptance, and the required ILAW QA Program. In addition to Specification 13 requirements for ILAW, the Contractor shall conform to the Contractor Certification Program as described in DOE Manual 435.1-1, Chapter IV, Section J.(1).

3.7.2 Process Description

The LAW mechanical handling systems include system LRH, system LPH, system LFH, and system LEH.

System LRH

The function of System LRH is to provide all handling operations, in both remote and local modes, that are required to receive, inspect, and import new empty LAW product containers in the LAW Facility. The container receipt operation can be segregated into the following: product container received from delivery truck, product container received from loading dock, product containers moved on staging conveyors through to import positions, and product containers moved to transport bogie. (24590-LAW-3YD-LRH-00002)

System LPH

The function of System LPH is to provide all handling operations required to import/export new or filled containers through the LAW Facility. The container handling operations can be segregated into several operations. (1) Move containers through the transfer corridor to designated pour caves. (2) Move containers from transfer bogie onto the pour cave turntable. (3) Cycle containers on the turntable to the filling, cooling, and import/export positions. (4) Move containers from the pour cave turntable to the transport bogie. (5) Move containers through the transfer corridor to the buffer store/rework areas. (6) Move the containers from the transport bogie to the export park stand positions.
(24590-LAW-3YD-LPH-00001)

System LFH

The functions of System LFH are to import filled ILAW product containers from System LPH, measure the container's glass fill level and perform volumetric determination, sample waste glass, seal container, decontaminate container surface, swab/smear container surface, and monitor surface does rates. (24590-LAW-3YD-LFH-00001)

System LEH

Provides mechanical handling equipment to export sealed LAW product containers to a DOE storage and/or disposal facility. System LEH equipment removes containers from the LFH and places them on a TFC-supplied combination trailer. (24590-LAW-3YD-LEH-00001)

A simplified diagram of these systems is depicted in Figure 3.7-1, LAW Mechanical Handling, where the equipment in each system is listed separately. More detail can be found in the system descriptions for each of the systems.

3.7.3 Basis

The general process flow through the LAW mechanical handling systems begins with empty containers being transferred by a crane from a truck onto one of two conveyors (each having a capacity of ten containers). The containers are then transferred through an airlock, where a monorail hoist lifts the

container from the conveyor and places it onto one of two transport bogies. Each bogie is capable of transferring containers to and from each of the two LAW melters.

The bogie then transfers the empty container to one of four monorail hoists. Each melter has two pour caves, each with a dedicated monorail hoist. The monorail hoist transfers the empty container to a turntable (with a capacity of three containers) in the pour cave. Each pour cave contains an elevator that transports the containers from the turntable to the melter seal head assembly. Once a container has been filled to a 6 metric ton capacity, it is cooled before being moved to a position beneath the monorail hoist. The monorail hoist lifts the filled container from the turntable and transfers it to one of the two transfer bogies.

The bogie then transfers the filled container to either of two lidding stations, which are located in the north or south finishing lines. If neither of these positions is available, the bogie will transfer the filled container to buffer storage (with a capacity of 18 containers).

At the sampling station, a glass sample is taken, if required. The fill level inside the container is also measured so that the required inert fill can be calculated. Once the fill level has been calculated, the container is transferred to the inert fill station, where it is filled with the calculated amount of inert material. Once filled, a measurement is taken at the sample station to verify the fill height before the container is lidded. The container is transferred to the lidding station, where the lid is placed on the container. The lidding bogie then transports the container into the LFH system decontamination station through the lidding/decontamination shielded door.

Using the decontamination dual-rail hoist, the container is lifted off the lidding bogie and transferred to the decontamination turntable. The lidding bogie is then transferred back into the lidding area. Before decontamination starts, the lidding/decontamination shielded door, the decontamination/swabbing containment door, and the line transfer trap door are closed. The decontamination power manipulator then moves into decontamination position and the decontamination system is activated.

The bottom of the container is decontaminated. The decontamination dual-rail hoist lowers the container onto the decontamination turntable. The mast rotates the power manipulator back into decontamination position and the turntable begins to rotate the container. The decontamination power manipulator follows the profile of the top and sides.

Once the top and sides are decontaminated, the decontamination bogie enters the decontamination station. The dual-rail hoist moves the container from the decontamination turntable to the decontamination bogie. The bogie transports the container into the swabbing station.

The swabbing process uses a power manipulator to maneuver the swabs over the surface. The swabbing power manipulator retrieves a clean swab from the swab-posting machine. The swabbing power manipulator swabs the bottom of the container. The power manipulator places the swab in the swab holder on the swab-posting machine. The operator removes the swab from the swab holder and places it in the monitoring glovebox, where a scanner measures the swab's radioactivity. The swab is then placed in the swab disposal apparatus, where it can be disposed of properly. The operator places a clean swab in the swab holder and posts the swab into the swabbing station. This process continues until the bottom is thoroughly swabbed. Once the container's bottom meets acceptable criteria, the swab turntable bogie moves into the swabbing station and the container is lowered onto it. The top and sides of the container are swabbed following the same procedure.

If the contamination level exceeds the acceptable criteria, the container is transported back into the decontamination station for rework. If the container meets acceptable criteria, the swab turntable bogie moves into the monitoring/export station. As the container is transported into the monitoring/export station from the swabbing station, gamma monitoring measures the surface dose rate of the decontaminated container. The measured dose rate is recorded in the container's records. The container is then exported out of the decontamination area into system LEH.

After entering the LEH system, the export hoist lowers the container into a flask that lies on a flatbed trailer. A lid is then placed on the flask and bolted down before the container and its paperwork are transferred by truck from the export area.

3.7.3.1 System LRH: LAW Container Receipt Handling System

System LRH imports new (empty) containers and makes them available for transfer into the melter pour caves. This system includes the following.

LAW Container Receipt Handling System (LRH)	Purpose
Drive-through truck bay bridge crane (LSH-CRN-00001)	Move a container from the truck in the import truck bay to one of two identical import conveyor trains.
South and north line import conveyor lines (LRH-CNVR-00001 through 00008)	Move a new container from the truck bay import area, through an airlock, to the transfer tunnel area.
South and north line hatch/conveyor (LRH-HTCH-00001/00002)	Provide ventilation, contamination and radiation barriers between the import hatch area and the container transfer corridor.
South and north container import hoist (LRH-HST-00001/00002)	Lower a new container from the import conveyor train to the associated transport bogie in the container transfer corridor.

3.7.3.2 System LPH: LAW Container Pour Handling System

System LPH moves containers into and out of the pour caves, fills the containers with glass, and allows for preliminary container cooling. It also provides bogie transportation and interface to the LRH system, the pour caves, and the LFH system.

Each melter can alternate container fills between its two pour spouts. First, a container will be completely filled under one pour spout, then a container will be filled under the other pour spout in the adjacent pour cave, then the process will begin again at the first pour spout. Each pour cave is capable of sustaining the full production rate for that melter if the other pour cave is down for maintenance. The other container filling method fills two containers in parallel (one under each pour spout), alternating molten glass air lifts between the two containers until both are filled. Either filling scenario is possible, but the first method is preferred. This system includes the following.

LAW Container Pour Handling System (LPH)	Purpose
South and north container transport bogie (LPH-TRLY-00001/00002)	Used to move containers between the container import area, the area outside the pour caves, and the buffer store (directly below the lidding area).
Pour cave monorail hoist (LPH-HST-00001 through 00004)	Used to move containers between the transport bogie, the container park position, and the container turntable (through pour cave shield doors, which remain open except during pour cave maintenance activities).
Container turntable (LPH-TTBL-00001 through 00004)	Located below the melter, rotates containers from the "import/export" position to the "fill" position, then to the "cooling" position, and finally back to the "import/export" position. Two or three containers are in the container turntable at any given time: one being filled, one cooling, and the third being placed in or removed from the turntable. After a container is raised, filled, and lowered back into the turntable "fill" position, the turntable rotates the newly filled container to the "cooling" position, where it cools while the next container is being filled. Once that container is filled, the turntable rotates once again to bring the first container back to the "import/export" position, the next container to the "cooling" position and a third container to the "fill" position.
Container elevator (LPH-ELEV-00001 through 00004)	Lifts an empty container from the turntable "fill" position to engage with the melter glass pour seal head, through which glass is poured. After the container is full, the elevator lowers it back into the turntable "fill" position.
Buffer store crane (LPH-CRN-00002)	Moves full containers from the bogie to the buffer store area or export positions.
Buffer store crane cameras (PTJ-XT-2026/2027)	A camera mounted on the crane that provides visual confirmation of the crane's position for the operator.
In-cave camera assembly (PTJ-XT-2020/2022)	A camera mounted on the pour cave's wall with full pan and tilt freedom, enables personnel to view and identify the hoist container grapple operations in the pour cave.

3.7.3.3 System LFH: LAW Container Finishing Handling System

System LFH consists of two redundant finishing lines. Each finishing line includes a lidding area consisting of a sampling station, an inert fill station, and a lidding station. Each finishing line also includes a decontamination area consisting of a decontamination station, a swabbing station, a line transfer station, and a monitoring/export station. Each decontamination area is directly adjacent to a lidding area and receives a container from that lidding area when lidding has been completed.

One container can be in the lidding area, one in the decontamination station, and one in the swabbing station at any time. When a container has been filled and removed from a pour cave, if neither finishing line is available the container may be moved into buffer storage using the buffer storage crane.

Each finishing line includes the following:

LAW Container Finishing Handling System (LFH)	**Purpose**
North and south lidding monorail hoist (LFH-HST-00008/00009)	Lifts the full container from the transfer bogie through a trap door into the lidding area, and places the container onto the lidding bogie
North and south lidding bogie (LFH-TRLY-00006/00007)	Used to move the container to the various stations in the lidding area and on to the decontamination area
North and south shard pickup assembly (LFH-SMPLR-00001/00008) North and south shard tray (LFH-SMPLR-00005/00003)	Glass samples are obtained and glass level is measured
North and south inert fill hopper (GFR-TK-00026/00027)	Used to "top off" the container level to minimize void space before sealing
Inert fill hopper (LFH-MHAN-00002/00004)	Used to provide inert fill
North and south lidding jib crane (LFH-CRN-00006/00003)	Used to move lids from the lidding magazine to the container and moves the lid press into place for lidding
North and south sealing jib crane (LFH-CRN-00004/00007)	Used with recovery tool to recover container lids not installed correctly
North and south lid press (LFH-LID-00025/00026)	Places and seals the lid on container
North and south lid recovery tool (LFH-LID-00029/00030)	Used for lid recovery operations
North and south decontamination dual-rail hoist (LFH-HST-00005/00010)	Used to transfer a container from the lidding bogie to the decontamination turntable and from decontamination turntable to decontamination bogie
North and south decontamination turntable (LFH-TTBL-00001/00002)	Used to facilitate decontamination by rotating the container
North and south decontamination bogie (LFH-TRLY-00005/00008)	Used to transfer the container from the decontamination station to the swabbing station

LAW Container Finishing Handling System (LFH)	Purpose
North and south decontamination power manipulator (LFH-MANIP-00001/00011) (LFH-MANIP-00008/00012)	Used to direct the CO_2 pellets at the outside of the container wall to decontaminate and remove radioactive contamination from the container Manipulators are in pairs, a higher and a lower manipulator, to provide full container coverage.
North and south swabbing dual-rail hoist (LFH-HST-00006/00011)	Used to transfer the container from the decontamination bogie to the swab turntable bogie
North and south swab turntable/bogie (LFH-TTBL-00005/00006) (LFH-TRLY-00001/00015)	Provides access for a swabbing power manipulator to swab the upper portions of the container and transports the container from the swabbing station to the export station
North and south swabbing power manipulator (LFH-MANIP-00002/00009)	Checks the surface of the container for smearable contamination
North and south shard sampling manipulators (LFH-MANIP-00021/00022) (LFH-MANIP-00023/00024)	Operates the vacuum wand to remove shards from the top of filled containers Also places the samples into the glovebox
North and south lid magazines (LFH-LID-00023/00024)	Stores lids that are used during the lidding process
North and south lid magazines B (LFH-LID-00035/00036)	Stores lids that are used during the lidding process
Line transfer monorail hoist (LFH-HST-00001)	Provides capability to move filled containers from one line to the other if equipment failure occurs during processing Also provides consumable import and waste removal capability from the LFH area

3.7.3.4 System LEH: LAW Container Export Handling System

System LEH exports filled, sealed, and decontaminated containers from the LAW Facility. This system includes the following.

LAW Container Export Handling System (LEH)	Purpose
Export crane (LEH-CRN-00003)	Used to move full LAW containers from the swabbing turntable bogie into the shipping flasks
Container grapple (LEH-TOOL-00002)	Grabs, lifts, and sustains a full container during transport
East end truck camera/trolley camera/bride camera (PTJ-XT-2161/2162/2163)	Cameras operate in series each viewing a separate part of the process

3.7.3.5 Mechanical Handling Steps and Times

The mechanical handling steps required to move a container through the LAW mechanical handling process were identified as part of the LAW Facility design. These steps were coupled with the specific cell and equipment configuration to develop step times for each activity as listed in Table 3.7-1, LAW Mechanical Handling Process Steps and Times.

3.7.4 References

24590-LAW-3YD-LEH-00001, Rev 2, *System Description for the LEH LAW Container Export Handling.*

24590-LAW-3YD-LFH-00001, Rev 2, *System Description for the LAW Container Finishing Handling System (LFH).*

24590-LAW-3YD-LPH-00001, Rev 2, *System Description for the LAW Container Pour Handling (LPH) System.*

24590-LAW-3YD-LRH-00002, Rev 2, *System Description for the LAW Container Receipt Handling System (LRH).*

CCN 232087, *LAW Mechanical Handling Step Times for WTP Operations Research Model.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

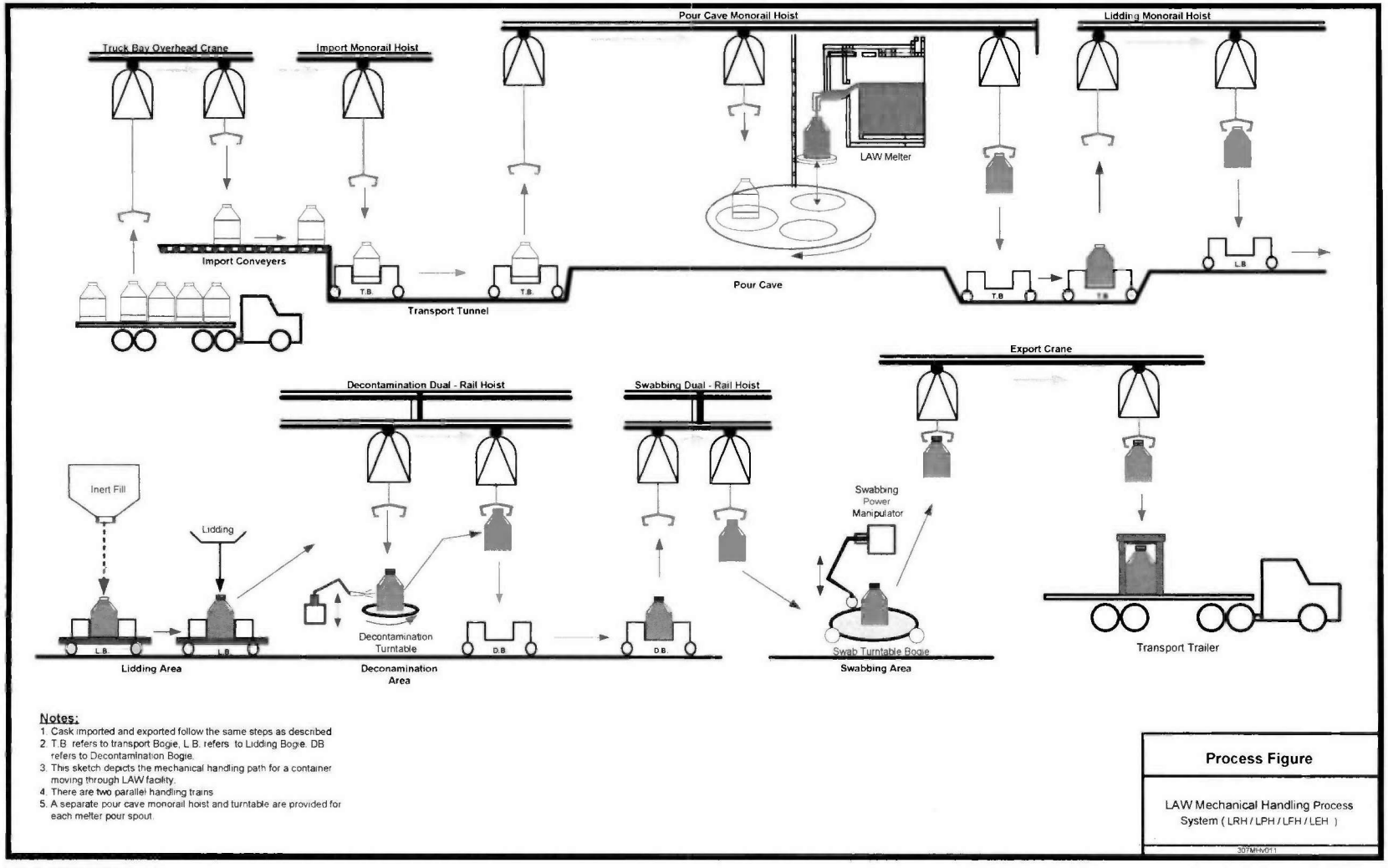
Table 3.7-1 LAW Mechanical Handling Equipment Process Steps and Times

No.	LAW Mechanical Handling Process	Time (min)
LRH		
1	Containers are brought to the WTP by a transport truck. Container unpacked, inspected (QC), and placed onto conveyer by truck bay crane (LSH-CRN-00001)	60
2	Advance containers on conveyor. Time reflects moving each container into the LAW Facility, including open hatch and airlock doors and container movement by one space	20
LPH		
3	Import hoist transfers container to the transport bogie	15
4	Transport bogie transfer to pour cave	6
5	Pour cave monorail hoist transfers the container to the turntable	30
6	The container is lifted to the pour position by the container elevator	10
7	Glass pouring (alternating pour caves)	576
8	Lower container to turntable and rotate to next position	10
9	Repeat steps 7-9 until container reaches load/unload position.	N/A
10	The pour cave monorail lifts container and places it into the transport bogie	30
11	Transport bogie transfers container to lidding monorail hoist	10
12	Time associated with opening and closing of pneumatic lidding trap doors	10
13	Transfer a container to or from Buffer Storage - 15 minutes per pick up or drop off	30
Note	Prior to transporting a filled container to the finishing line, a filled container must cool a minimum of 57.3 hours. This time delay correlates to a container surface temperature of less than 100°C. Administrative control will prevent the container from being transported to the finishing line until the container has cooled sufficiently	
LFH		
14	Lidding monorail hoist transfers container to lidding station	20
15	Take shard sample, measure glass level, dispense inert fill, inspect/clean container flange, and insert container lid	90
16	Time associated with opening and closing of lidding/decon shield door	10
17	Transfer container to decontamination cell using lidding bogie and decontamination hoist. This steps includes advancing the lidding bogie from the lidding station to the decon station. The decon hoist lifts the filled container from the lidding bogie with the decon grapple. The lidding bogie then returns to the lidding station	22
18	Decontaminate bottom of container using lower decon manipulator	45
19	Lower container onto decontamination turntable using decontamination hoist, and decontaminate top and sides of container using both lower decon manipulator and upper decon manipulator. Upon decon completion, the decon hoist lifts the container from the decon turntable, and place the container on the decon bogie (which was brought in from the swabbing station)	123
20	Time associated with opening and closing of decon/swab door	10
21	Transfer container to swab area using bogie and swab hoist	22
22	Move container to swab position using swab hoist	5
23	Swab bottom of container using hoist and swab system and transfer to swab turntable	60
24	Swab container top and sides using swab system	117

Table 3.7-1 LAW Mechanical Handling Equipment Process Steps and Times

No.	LAW Mechanical Handling Process	Time (min)
Note	There is a maximum of one container each at the Lidding, Decon, and Swabbing areas. This means a capacity of three containers possible per line, and a total of six containers per two lines.	
LEH		
25	Time associated with opening and closing of access door	10
26	Transfer container to LAW export area using bogie and export bay crane	22
27	Casks are brought to WTP by a transport truck. Remove cask lid on truck in LEH facility	15
28	Transfer container inside cask on flat bed trailer using crane. Repeat until cask is full	30
29	Put cask on and secure transport trailer (with capacity of five containers)	30
30	Time associated with opening and closing of access door	10
31	Delivery of cask to Tank Farm Contractor	N/A

Figure 3.7-1 LAW Mechanical Handling



4 High-Level Waste Vitrification

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4.1 Systems HCP, GFR, and HFP: HLW Melter Feed Process

4.1.1 Function and Requirements

The purpose of the high-level waste (HLW) melter feed process is to store and sample waste, mix with glass formers, and feed the melter. The HLW melter feed process consists of:

- HLW glass former mixers (GFR - glass former reagent system)
- Melter feed preparation vessels and melter feed vessels (HFP - HLW melter feed process system)

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7(b)(3):

> *The HLW Vitrification Facility shall be designed with two HLW melter systems to support a combined design capacity of 6 MTG/day with the original melters and up to 7.5 MTG/day with replacement melters.*

WTP SOW, Operational Specification, Section C.8, Specification 1.2.2.1.5:

> *Product Loading: Loading of non-volatile components in Envelope D shall be achieved such that the concentration of at least one of the waste components or waste component combinations in Table TS-1.1, Minimum Component Limits in High-Level Waste Glass, exceeds its minimum weight percent in HLW glass as identified in Table TS-1.1 (e.g., for a high-iron waste, the waste product shall incorporate at least 12.5 weight percent [wt%] iron oxide from the waste into the glass). The product loading shall not cause the limits in any other requirement of this specification to be violated. Product waste loading shall be calculated on an average basis for each batch transfer of Waste Envelope D. The waste loading may be adjusted downward if necessary to comply with Universal Treatment Standards leaching requirements.*

The SOW Table TS-1.1, *Minimum Component Limits in High-Level Waste Glass*, is provided in this section as Table 4-1.

The melter feed preparation vessels (MFPV) are required to receive HLW waste concentrate for storage and sampling. The vessel contents must be sampled to determine waste constituents; the concentrations of components in glass are then used in calculating the quantities of glass forming chemicals to be added via the glass former mixers. The vessel size requirements depend on solids content of the HLW feed and the minimum acceptable time to receive, sample, hold, and transfer a batch to the melter feed vessels (MFV).

In the MFPV, the HLW concentrate is received from the PT HLW lag storage and feed blending process system (HLP) feed blend vessel. The waste is sampled, glass formers are received from the glass former mixers, and the waste and glass formers are mixed. The MFPVs are then sampled for process control and for waste form compliance (24590-HLW-PL-RT-07-0001). The melter and feed preparation vessels must be able to hold enough waste to support the glass production requirements.

System requirements are specified primarily in the *Basis of Design* (24590-WTP-DB-ENG-01-001).

4.1.2 Process Description

The HLW melter feed system is depicted in *Process Flow Diagram HLW Receipt & Feed Preparation (System HCP, GFR, & HFP)* (24590-HLW-M5-V17T-00001). The feed to the HLW melter consists of a blended waste slurry (solids from ultrafiltration, strontium/transuranic elements precipitate, cesium concentrate) mixed with glass formers. The HLW melter feed process receives HLW concentrate from the Pretreatment (PT) Facility in the MFPVs, mixes the waste slurry concentrate with glass formers, then pumps the feed slurry to the HLW MFV. The MFVs then meter the feed to the melters at a specified rate. The HLP feed blend vessel provides concentrate to the two feed process trains, which operate independently of each other and are dedicated to a specific melter. Figure 4-1, *HLW Melter Feed Process*, is a simplified depiction of the feed system designed to support two melters.

The HLW glass former mixers, GFR-TK-00025/00031, receive glass formers that are pneumatically transferred by the HLW transporter, GFR-VSL-00008, from the HLW blending silo, GFR-TK-00021, at the Balance of Facilities' (BOF) glass former storage facility. Each glass former mixer holds the blended glass formers required for a batch of melter feed (at 3 metric tons of glass [MTG] per day). The glass formers are mixed with demineralized water in the glass former mixers for dust mitigation, and then discharged via a rotary valve into the melter feed preparation vessels.

The HLW MFPVs, HFP-VSL-00001/00005, receive HLW concentrate from the PT Facility. The process control samples are collected from these vessels and analyzed to determine glass formulation. The MFPVs mix the glass formers from the HLW glass former feed mixers with the HLW concentrate from the HLW feed blend vessels. After adequate mixing of glass formers and feed water, the waste batch is again sampled and analyzed for waste compliance. Each vessel has two mechanical pumps to transfer waste to the associated HLW MFV, with a side stream diverted to an autosampler. The MFPV vessel has a mechanical agitator for mixing.

The HLW MFVs, HFP-VSL-00002/00006, receive the blended melter feed from the associated MFPV and pump the feed to the melter continuously using two air displacement slurry pumps. Each MFV is equipped with a mechanical agitator for mixing. The melter feed preparation batch cycle varies from 25 to 54 hr depending on analytical method and operational turnaround sensitivity.

The HLP feed blend vessel provides concentrate to both of the two feed process trains, which operate independently of each other and are dedicated to a specific melter.

4.1.3 Basis

The basis for operation of the HLW melter feed system is to ensure that adequate feed is provided for both HLW melters, HMP-MLTR-00001/00002. Continuous feed requires the batch transfer and operation of both components within the HLW melter feed system. The feed system contains standardized equipment with all vessels HFP-VSL-00001/2/5/6 sized to hold the same batch capacity under similar process conditions. The MFV sizes are based on a melter feed concentration of 360 g of oxide/L, 3 MTG/day, and 40 to 90 hr per batch cycle (24590-HLW-3YD-HFP-00001). An Operation Research investigation (CCN 028110) demonstrated that the capacities of the HFP system vessels could support feed concentrations that deviate significantly from 360 g of oxide/L.

The MFPVs are the center of the HLW melter feed systems because the concentrate and glass former streams are mixed here, and it is the waste compliance hold point. Hence, the MFPV influences every vessel in the feed systems. Processing of waste concentrate samples to determine the appropriate glass former recipe takes about 11.7 hr, CCN 254099, *Laboratory Sample Turnaround Time*. Processing

samples to determine MFPV constituents including glass formers takes about 25.3 hr, CCN 254099. Estimated cycle time for transfers to the MFPV is based on the melter feed rate (which determines the cycle time for MFV batches) and the cycle time for the MFPV (Section 4.1.3.2). The cycle time for the MFPV varies, depending on total time for receipt of waste concentrate, blending of glass former, sampling, and sample process time. If the time to sample the MFPV is longer than the time to deplete a batch of melter feed, the sample time becomes the limiting factor.

4.1.3.1 HLW Glass Former Mixers

The HLW glass former mixers, GFR-TK-00025/00031, receive blended glass formers from the HLW blending hopper, GFR-TK-00021, via the HLW transporter, GFR-VSL-00008. Constituent volumes for each batch of glass former chemicals are determined by sample analysis of the MFPV contents. The constituents are pneumatically conveyed to GFR-TK-00025/00031, where they are weighed. Weighing ensures proper amounts are added to the MFPVs, thus contributing to waste composition compliance. The glass formers are mixed with demineralized water in the HLW glass former mixers for dust mitigation. The glass former batch is then fed through a screw conveyer and a rotary feeder beneath the hopper. Glass formers are added only after the waste concentrate has been added to the MFPV. The cycle time for the glass former mixers matches that of the MFPV.

- Vessel data: GFR-TK-00025 and GFR-TK-00031 (24590-BOF-3YD-GFR-00001, 24590-CM-POA-MH00-00001-08-00475, and 24590-CM-POA-MH00-00001-07-00001)
  - Batch volume capacity: 320 ft^3
  - Heel volume: 0
  - Influent rate (from blending silo): 320 ft^3/hr
  - Effluent rate (to MFPV): variable, up to 267 ft^3/hr

- Operating logic: GFR-TK-00025 and GFR-TK-00031 (24590-HLW-3YD-HFP-00001)
  - The glass former mixers receive a calculated mass of blended glass formers from GFR-VSL-00008.
  - Batch volumes will vary, depending on required quantities of the recipe generated by sampling (see Section 4.1.3.2).
  - After a verified quantity of HLW waste concentrate has been added to the MFPV, the glass formers are mixed with demineralized water for dust mitigation and then fed to MFPVs.
  - The rotary valve controls flow to the MFPV. Duration of batch addition can be up to 3 hr, depending on feed mixing/agitator performance.
  - The glass formers are mixed with water to prevent dusting (24590-HLW-DCA-PR-03-005). The amount of water added for dusting control is a nominal 5 wt % for all HLW glass former batches (CCN 077705).

4.1.3.2 HLW Melter Feed Preparation Vessel

The HLW MFPVs and HFP-VSL-00001/00005 receive HLW waste concentrate from the PT feed blend vessel HLP-VSL-00028. The MFPV will not process partial batch volumes during normal operating conditions. All volumes of material are continually mechanically mixed to prevent settling of solids. Based on the sample results of the waste concentrate, a glass former batch is made and fed to the MFPV.

MFPV contents are blended for homogeneity and then sampled via two vertical sample/transfer pumps. Sample recycle flowrate is 44 gpm. Eight samples are taken and processed. Immediately after all of the concentrate has been received by an MFPV and before glass formers are added, a sample needs to be taken from the MFPV. The time for this sample to be taken and analyzed is 11.7 hr, CCN 254099.

Immediately after the glass formers are added to the MFPV, another sample is taken and analyzed to confirm that the correct glass formers have been added. The time required for this sample and analysis event is 25.3 hr, CCN 254099. For lower oxide content and solids densities, this cycle time is lower; these data are the limiting factor on vessel cycle time. Transfer of blended melter feed to the associated MFV is driven by batch volume remaining in the MFV. Effluent rate to the MFV is 44 gpm. The set point to enable batch transfer is equal to the heel volume (24590-HLW-M6C-HFP-00001). The MFPVs transfer to their dedicated MFVs.

- Vessel data: HFP-VSL-00001 and HFP-VSL-00005 (24590-HLW-M6C-HFP-00001)
  - Overflow volume: 7650 gal
  - Filled volume: 6940 gal (of which 1280 gal are for glass formers)
  - Batch volume: 5660 gal*
  - Heel volume: 1356 gal
  - Cooling water flowrate: 20 gpm (nominal-will be tuned at startup)
  - Influent flowrate (from VSL-00028): 140 gpm
  - Influent flowrate (from GFR-TK-00025/31): variable, up to 33 gpm
  - Effluent flowrate (to MFV): 44 gpm

- Operating logic: HFP-VSL-00001 and HFP-VSL-00005 (24590-HLW-3YD-HFP-00001)
  - Initial tank fill requires transfer of HLW waste concentrate volume, as determined by sample results, to make the filled volume of 6940 gal; vessel volumes are based on equipment general arrangements and process requirements (24590-HLW-M6C-HFP-00001).
  - The MFPV receives feed via one of two transfer pipelines from the PT feed blend vessel at 140 gpm; this value is the basis for the feed rate. Subsequent batch transfers are of volumes required for a batch volume of 5200 gal. Fill time is approximately 14 to 33 min (24590-HLW-ES-PR-04-0001, p. 6).
  - During all operations the tank is continually agitated to prevent solids from settling.
  - Sampling waste to determine glass formation (12.8 hr).
  - After waste has been received and the volume verified, the glass former batch is added at a controlled rate. Fill time is approximately 1 to 2 hr, as stipulated by feed rate and glass former batch volume.
  - Slurry is sampled through a recirculation pump line. Sampling time is approximately 25.3 hr.
  - Transfer to the MFV occurs when the MFV reaches a point above the heel equivalent to the instrument error or 82.4 gal (1438 gal total volume remaining).
  - Feed is transferred to the MFV via one of two mechanical pumps at 44 gpm.
  - Setpoint for receipt of waste concentrate is 1652 gal.

* 5200 gal will be nominal target. This will leave some room in the tank for glass former shimming if necessary.

  - The transfer line to the MFV is flushed with 9.8 gal of demineralized water following each batch transfer.
  - The HFP MFPV demisters are flushed after each glass former addition for 3 min at 16 gpm (24590-HLW-M4C-30-00003).

- Services
  - Cooling water: removes heat of decay from vessel contents and agitator.
  - Demineralized water: used for line flush and demister flushes following transfer and for vessel wash.

- Energy Contributions
  - Vessel has cooling water jackets to remove energy imparted due to agitator shaft work and decay heat from radionuclides in HLW waste. Cooling water flowrate is 20 gpm at an inlet temperature of about 80 °F.
  - The addition of the glass former boric acid (Section 4.1.3.4.2) to basic HLW concentrate produces an endothermic reaction. The heat of reaction is -4.71 kcal/mol of boric acid.

- Chemistry
  - An expected reaction is (McBride 1994):

$$H_3BO_3 + OH^- \rightarrow B(OH)_4^-$$

The heat of reaction is the heat of formation of the products minus the heat of formation of the reactants. The heat of formation in kcal/mol for the following species came from the *Handbook of Chemistry and Physics* (Lide 1990).

$$(-261.55) + (-54.970) + \Delta h = (-321.23)$$
$$\Delta h = (-321.23) - (-261.55) - (-54.970) = -4.71 \text{ kcal/mol}$$

4.1.3.3 HLW Melter Feed Vessel

The HLW MFVs, HFP-VSL-00002/00006, are the same size as the MFPVs. They supply continual feed to the associated HLW melter for each batch of feed prepared. A mechanical agitator continuously mixes vessel contents to ensure that feed material to the melter is homogeneous and that the final product qualification requirements are met. Feed rate to the melter varies, and rate is determined by the solids content and waste loading of the feed batch (Section 4.1.3.4.3).

- Vessel data: HFP-VSL-00002 and HFP-VSL-00006 (24590-HLW-M6C-HFP-00001)
  - Overflow volume: 7646 gal
  - Filled volume: 7208 gal
  - Batch volume: 5665 gal (nominal target will be 5200 gal.)
  - Heel volume: 1543 gal
  - Cooling water flowrate: 20 gpm

  - Influent flowrate from MFPV: 44 gpm
  - Effluent flowrate to HMP (HLW melter process system):0.4 to 1.8 gpm (variable and depends on waste composition)

- Operating logic: HFP-VSL-00002 and HFP-VSL-00006 (24590-HLW-3YD-HFP-00001)
  - Initial tank fill requires transfer of slurry to the filled volume of 7208 gal.
  - The setpoint for receipt of feed from the MFPV during continual operations is equal to the heel volume plus the instrument uncertainty volume (1625 gal).
  - Feed is received from the MFPV at 44 gpm.
  - Batch volumes are 5200 gal.
  - Sample capability is present but used only if needed.
  - Feed is continually agitated.
  - Total feed rate depends on the oxide density of the melter feed (Section 4.1.3.4.3).
  - The HFP MFV demisters are flushed after every other waste transfer for 3 min at 16 gpm (24590-HLW-M4C-30-00003).
  - The line from the MFV to the melter is flushed with 0.11 gal of demineralized water after each 1 hr of operation, at 0.44 gpm (24590-HLW-M4C-30-00003).

- Services
  - Demineralized water: used for line flushes following transfer and vessel wash.
  - Cooling water: removes heat of decay from vessel contents and agitator.
  - Steam: for steam ejector operation and periodic washdown.

- Energy Contributions
  - Vessel has cooling water jackets to remove energy imparted due to agitator shaft work and decay heat from radionuclides in HLW waste. Cooling water flowrate is 20 gpm at an inlet temperature of 80 °F.

4.1.3.4 Process Technology

4.1.3.4.1 Waste Compliance

Waste compliance samples are taken in the MFPVs. Compliant glass is formulated based on the first sample taken in the MFPV. A second (waste compliance) confirmation sample is taken from the MFPV after glass former addition. In accordance with Section 4.1.1, the waste loading requirements in Table 4-1 must be met. To be a compliant glass, one of the constituents in Table 4-1 must meet or exceed the corresponding weight percent in HLW glass.

The HLW delisting petition (24590-WTP-RPT-ENV-06-001) defines the basis for HLW process control strategy to ensure waste compliance.

4.1.3.4.2 Basis for HLW Glass Formers

Each glass former exerts desirable and undesirable properties on the glass. The mixture of glass formers should compensate for the undesirable properties of the individual glass formers and waste constituents. There are six glass formers normally used in HLW glass formulation:

Borax ($Na_2B_4O_7$ x $10H_20$) or **Boric Acid** (H_3BO_3 or $B(OH)_3$) is mixed with waste slurry as a glass former. Borax is the desired form of boron over boric acid since boric acid is more likely to cause clumping of solids when mixed with the waste slurry. Since borax contains sodium, it can only be used if sodium is also required as a glass former. Boric acid is only used when demand for sodium is negligible.

Hematite (Fe_2O_3) is an inexpensive source of small-grain iron (Muller and others 2001). Iron increases durability, relative to the waste constituents, without decreasing viscosity (Hrma and others 2001). However, iron is associated with foaming in the melter (Bickford and Choi 1991), and many crystals that form in glass contain iron (24590-101-TSA-W000-0010-06-03A).

Kyanite (Al_2SiO_5) is an inexpensive source of aluminum with a high bulk density and diverse availability of particle sizes (Muller and others 2001). Aluminum increases glass durability and decreases viscosity. HLW waste normally has enough aluminum to supply the need for glass formulation. However, kyanite can be used occasionally in HLW glass formulation to adjust viscosity and/or durability for those batches low in aluminum..

Lithium carbonate (Li_2CO_3) is an inexpensive form of lithium with fewer rheology problems than lithium hydroxide (Kot and others 2000). Like sodium, lithium lowers the liquidus temperature of spinel, and decreases viscosity of the melt and decreases glass durability (Hrma and others 2001). However, lithium can exert the desirable properties with less mass than is needed with sodium. Lithium improves sulfate incorporation (Kot and others 2000).

Silica (SiO_2) is the primary glass forming constituent. Silica increases durability but decreases viscosity (Hrma and others 2001). Most commonly used form of silica is quartz sand.

Sodium carbonate (Na_2CO_3) is an inexpensive source of sodium for the glass (Kot and others 2000). Sodium lowers the liquidus temperature of spinel, and decreases viscosity of the melt; however, it decreases durability of the glass (Hrma and others 2001).

The following glass formers are intended for LAW but they are available for HLW use if necessary:

Fosterite olivine (Mg_2SiO_4-Fe_2SiO_4) is an inexpensive source of magnesium, which, unlike magnesium carbonate, does not promote foaming in the melter (Muller and others 2001). Fosterite has a major iron impurity (Muller and others 2001). Magnesium increases glass durability (Hrma and others 2001).

Rutile (TiO_2) is an inexpensive source of titanium (Muller and others 2001). Titanium improves the glass resistance to acid such as in the toxicity characteristic leaching procedure (TCLP) test and improves the glass meltability (Langowski 1996).

Wollastonite ($CaSiO_3$) is an inexpensive source of calcium that, unlike calcium carbonate, does not promote foaming in the melter (Muller and others 2001). Calcium increases glass durability (Hrma and others 2001) and sulfate incorporation (Kot and others 2000).

Zinc oxide (ZnO) is an inexpensive, pure form of zinc (Kot and others 2000). Zinc can increase the durability of glass (McKeown and others 2000) and reduces melter corrosion (24590-101-TSA-W000-0010-06-02). It reduces corrosion by forming spinels on the surface of the melter refractory. HLW glass normally forms enough spinels without zinc oxide to be protective of the melter refractory.

Zircon ($ZrSiO_4$) is an inexpensive source of zirconium (Muller and others 2001). Zirconium improves glass durability (Hrma and others 2001). Zircon contains trace quantities of uranium and thorium impurities (Muller and others 2001).

4.1.3.4.2.1 Impurities in Glass Former Minerals

Minerals, an inexpensive source of glass formers, are preferred over pure chemicals to treat the waste. Some impurities in the minerals are significant and need to be tracked. Table 4-3 shows each mineral and the expected impurities it contains. This table is a compilation of Research and Technology (R&T) data documented in SCT-M0SRLE60-00-175-01, *Characterization of HLW and LAW Glass Formers*. The quantities in the table are shown in two different formats. Perhaps the most important one is the last format. Here, quantities are based on a request for 1 kg (or 1 lb) of the glass former oxides.

For example, a glass recipe calls for 1 kg of the glass former MgO. The table shows that a little less than 1 kg of MgO will be received because of impurities. Actually, 0.98482 kg MgO is supplied along with 0.00390 kg Al_2O_3, 0.00041 kg CaO, 0.00267 kg Cr_2O_3, 0.00021 kg K_2O, 0.00041 kg Na_2O, and 0.00759 kg NiO as impurities for a total of 1 kg. Looking at the table again shows that MgO comes from the mineral olivine, which also contains SiO_2 and Fe_2O_3. Therefore, a total of 2.05128 kg of olivine needs to be received for the 1 kg of MgO (and its impurities) and 0.89374 kg SiO_2 and 0.15754 kg of Fe_2O_3. This amount of SiO_2 and Fe_2O_3 needs to be subtracted from the SiO_2 and Fe_2O_3 glass former additive requirement, respectively. This routine is done for each glass additive oxide in the recipe with SiO_2 and Fe_2O_3 calculated last. Then the SiO_2 and Fe_2O_3 supplied by the other minerals are subtracted from the silica and hematite requirements, respectively.

Some of the minerals contain carbonate or hydrate that will be lost at the melter to the offgas. This needs to be accounted for in determining the glass former amounts.

Note: Boric acid and sugar do not normally contain molecular water, and that sugar, sodium carbonate, and lithium carbonate do actually contain molecular carbon dioxide. They are tracked as having water and carbon dioxide in them because they can be broken down into mass units that have the same stoichiometry as water and carbon dioxide.

4.1.3.4.2.2 Determine Amounts of Borax and Boric Acid Used in HLW

Borax is the preferred mineral to use for HLW. It also supplies Na_2O. Therefore, borax cannot be used if no Na_2O is needed as a glass former. Likewise, borax can only be used up to the amount of the Na_2O needed. The following equations establish the amounts of borax and boric acids used.

IF $2 * A_{Na2O} / MW_{Na2O} >= A_{B2O3} / MW_{B2O3}$

where: Ai is the demand for additive i

THEN

Equation 4.1-1

$$MboraxO = A_{B2O3}$$

Equation 4.1-2

$$MboricO = 0.0$$

where: MboraxO is the mass of B_2O_3 that comes from borax

MboricO is the mass of B_2O_3 that comes from boric acid

ELSE

Equation 4.1-3

$$MboraxO = A_{Na2O} (MW_{B2O3} / MW_{Na2O})$$

Equation 4.1-4

$$MboricO = A_{B2O3} - MboraxO$$

4.1.3.4.3 HLW Glass Shell

Efforts are being made to increase the efficiency and decrease the cost of vitrifying radioactive waste stored in tanks at the DOE Hanford Site. The compositions of acceptable and processable HLW glasses need to be optimized to minimize the waste-form volume and, hence, to reduce cost. A database of glass properties of waste glass and associated simulated waste glasses was collected and documented in PNNL-18501, *Glass Property Data and Models for Estimating High-Level Waste Glass Volume*, and glass property models were curve-fitted to the glass compositions.

A routine, commonly called the *HLW Glass Shell*, was developed that estimates HLW glass volumes using the following glass property models:

- Nepheline
- One-percent crystal temperature ($T_{1\%}$)
- Viscosity (η)
- Product consistency tests (PCT) for boron, sodium, and lithium
- Liquidus temperature (T_L)

The HLW Glass Shell is documented in CCN 18495, *Incorporation of HLW Glass Shell V2.0 into The Flowsheet.* The HLW Glass Shell is summarized in this section of BARD; however, details must be obtained from the CCN and subsequent documents that may modify the shell's logic as more glass formulation and modeling data becomes available. Revisions to the HLW Glass Shell will be noted as *v2.1*, *v2.2*, etc.

In addition to the use of the glass property models, glass composition constraints and rules, as recommended in PNNL-18501 and in other documents (cited in Section 4.1.3.4.4) were incorporated into the HLW Glass Shell. The new version of the HLW Glass Shell should generally estimate higher waste loading in the HLW glass than previous versions.

PNNL-18501 documents other glass property models; namely: Electrical Conductivity (ε) and Toxicity Characteristic Leaching Procedure (TCLP). These glass models would have little or no impact on calculating the volume of HLW glass. Justification is given in PNNL-18501; the following is a short summary:

- Electrical Conductivity (ε) - Studies show that if the glass viscosity is good, then the electrical conductivity of the glass is also good. Consequently, electrical conductivity is not needed for estimating glass volume.

- Toxicity Characteristic Leaching Procedure - Historically the waste contains so little cadmium (the major TCLP concern) that failure of glass due to high cadmium TCLP values is rare. Consequently, it has little or no impact on estimating WTP mission glass volumes.

Non-spinel rules as given in CCN 184900, *Non-Spinel Phase Rule*, were not incorporated into the HLW Glass Shell because it was felt that the new liquidus temperature model covers the intent of the non-spinel rules dealing with combined glass concentrations of Al_2O_3, ThO_2, and ZrO_2.

4.1.3.4.4 Criteria for the HLW Glass Shell

Three reports were used as the basis for the HLW Glass Shell:

- PNNL-18501, *Glass Property Data and Models for Estimating High-Level Glass Volume*, JD Vienna and others, October 2009.
- 24590-101-TSA-W000-0009-02-00001, *Final Report: Baseline HLW Glass Formulations for Bismuth Phosphate Wastes.*

4.1.3.4.5 Methodology for the HLW Glass Shell

The HLW Glass Shell is designed to provide a reasonable and probable HLW glass composition using a single-pass calculation routine. The major steps in the routine are:

1. Mass of the HLW is estimated by determining the most limiting constituent or combination in the glass.
2. Probable glass formers are chosen to occupy the volume of glass that is not waste. The waste and chosen glass formers constitute the initial glass recipe known as the *PreGlass*.
3. The PreGlass composition is checked against the various glass property models.
4. Changes are made to the PreGlass composition/glass formers as necessary to bring the glass composition into compliance with the various glass properties.
    - Swapping glass formers is tried first to bring the glass composition into compliance because this does not change the waste loading in the glass.
    - If swapping does not work, the PreGlass is blended with another glass (called the *Dilution Glass*) until it becomes compliant. The Dilution Glass is low in the property limiting the PreGlass. The lowest property limiting Dilution Glass possible that meets the other properties as well is used to help limit its impact waste loading.

The PreGlass is systematically checked against the glass property models and changes are made to the glass formers. Each succeeding change in the glass formers will change the PreGlass values for previously checked glass property models, but the changes should be in the positive direction for the previous glass property models. The order of checking by the glass property models is per the list cited above.

4.1.3.4.5.1 Initial Estimate of HLW Glass Quantity (PreGlass)

The preliminary estimate of the HLW glass, or PreGlass, is determined by the most constrained constituent or bounding condition listed in Table 4-2. This is determined by comparing each of the waste constituents to their corresponding limits.

Equation 4.1-5

$$BC_{Max} = MAX\ (M_1 / BC_1, \ldots M_{28} / BC_{24})$$

Only one constituent or combination should meet bounding conditions in the glass. As such, the glass is said to be *constrained* by that condition because the glass is known or considered to be incapable of tolerating any more of that constituent or combination. The glass should contain less than allowed for all the other constituents. The bounding conditions and their values are listed in Table 4-2. The bounding constraints are used in determining a preliminary estimate of the amount of PreGlass that will be made. The PreGlass recipe is tested in various glass models to determine if it will make a good glass. If not, changes will be made to bring the glass in line with glass model constraints.

4.1.3.4.5.2 Glass Formers

Since most of the batches from the Tank Farms contain excess amounts of aluminum, and some amount of leaching will be required, it does not make sense to add aluminum glass former to the recipe unless a glass property model absolutely requires it per a glass property model, or the PreGlass contains so little aluminum it is below the validity levels of the developed glass models, which is 4 wt %*. Other glass formers have low validity levels as well. For example, the minimum amount of silica in the glass allowed by PNNL-18501 is 35 wt %, but the glass shell frequently gives a higher waste loading with a slighter higher minimum (i.e., 41 wt %). The glass formers added by the HLW Glass Shell are:

- Al_2O_3 - Aluminum oxide or alumina
- B_2O_3 - Boron oxide or boria
- Fe_2O_3 - Iron oxide
- Li_2O - Lithium oxide or lithia
- Na_2O - Sodium oxide or sodia
- SiO_2 - Sodium oxide or silica

Zinc oxide is mentioned in PNNL-18501 as a glass former, but the examples in the document were never used because it appears to add little or no benefit. Therefore, it is not used in the HLW Glass Shell. Zinc oxide is used in LAW glass to protect the melter refractory from corrosion/erosion. Around 1 to 2 wt % ZnO is used to form spinels that collect on the surface LAW melter wall refractory. The spinels then protect the refractory from corrosion. However, it is assumed that the HLW glasses themselves naturally produce enough spinels to protect HLW melter wall refractory.

4.1.3.4.5.3 Glass Chemistry Adjustments by Glass Property Models

The glass formers at this stage are only estimated quantities used for evaluation and correction in the property models.

Nepheline Adjustments

The silica must meet two conditions. First, there is a minimum amount of silica required to make a glass. Second, there is a *Nepheline Rule* that applies if there is too much silica present with respect to sodium

* The validity minimum per PNNL-18501 is 0.019 or 1.9 wt % but the glass shell frequently gives a higher waste loading with a slighter higher minimum as shown in table.

and aluminum. If too much silica is present, nepheline (a crystalline mineral) can form. The condition when nepheline can form is expressed by Equation 4.1-6.

Equation 4.1-6

$$N_{Si} = \frac{SiO_2}{Al_2O_3 + Na_2O + SiO_2} \geq 0.62$$

Solving Equation 4.1-6 for SiO_2 gives Equation 4.1-6.

Equation 4.1-7

$$SiO_2 = \frac{0.62}{1 - 0.62}(Al_2O_3 + Na_2O) = \frac{62}{38}(Al_2O_3 + Na_2O)$$

$T_{1\%}$ or Spinel-Limited Glass Adjustment

The liquidus temperature ($T_{1\%}$) model (Equation 4.1-8) often has the biggest impact on the quantity of glass made. Molten glass that cools to 950° C and forms 1 % or less of spinel crystals is desired. The amount of spinel crystals is largely dependent on the type of waste in the glass. The waste oxides that have the biggest impact are listed below. If the glass has a high $T_{1\%}$ value, swapping glass former to bring down the $T_{1\%}$ value will not help much. Swapping glass formers only has merit in fine-tuning the recipe and quickly becomes too tedious for mission studies. Therefore, this routine will adjust $T_{1\%}$ by diluting the PreGlass with a low $T_{1\%}$. If the waste contains a significant amount of aluminum, a Dilution Glass with low amount of aluminum and iron will be used. If the waste contains low amounts of aluminum or iron, a Dilution Glass with moderate amounts of aluminum and iron will be used.

Equation 4.1-8

$$T_{1\%} = \sum_{i=1}^{16} b_i \frac{M_i + GF_i}{M_{Glass}} + b_{17} \frac{M_{othersT1\%}}{M_{Glass}}$$

where: $T_{1\%Glass.p2}$ is the Spinel Temperature ($T_{1\%}$) for PreGlass.

i is the ith component in the following order:

Al_2O_3, Cr_2O_3, Fe_2O_3, K_2O, MgO, MnO, NiO, SrO, ThO_2, ZnO, ZrO_2, noble metals PdO_2 + Rh_2O_3 + RuO_2, B_2O_3, Li_2O, Na_2O, SiO_2

M_i is the Mass of i-th waste component listed above. There are 16 components plus Others.

GF_i is the Mass of the i-th glass former component matching the waste component listed above.

b_i is the component coefficient for i-th component in PNNL-18501.

Glass Viscosity

Viscosity of the PreGlass can be determined by the following model equation, which is a curve fit of numerous glasses with varying compositions.

Equation 4.1-9

$$\ln(\eta_G) = \sum_{i=1}^{19} c_i g_i + c_{20} g_{Na2O} g_{B2O3} + c_{21} g_{Na2O} g_{Al2O3} + c_{22} g_{B2O3}^2 + c_{23} g_{CaO} g_{Al2O3} + c_{24} g_{Li2O}^2$$

where: $\ln(\eta)$ is the natural log of the glass viscosity η. η is in Pascal-seconds (Pa-s).
i is the ith component in the following order:
Al_2O_3, B_2O_3, BaO, CaO, F, K_2O, La_2O_3, Li_2O, MgO, MnO, Na_2O, P_2O_5, PbO, SiO_2, SrO, UO_3, ZnO, ZrO_2, Others, Na_2O x B_2O_3, Na_2O x Al_2O_3, $(B_2O_3)^2$, CaO x Al_2O_3, $(Li_2O)^2$
g_i is the mass fraction of the component in the PreGlass after being adjusted for $T_{1\%}$.
c_i is the coefficient of the ith component as given in PNNL-18501.

The glass viscosity shall be adjusted (if necessary) to be at or between 2 and 4 Pa-s. Fitting to the natural log takes some of the non-linearity out of the programming logic. Therefore, the glass will actually be adjusted to be at or between ln(2 Pa-s) and ln(4 Ps-s).

High Viscosity Adjustment

If the viscosity of the PreGlass (η_G) from Equation 4.1-9 is higher than the desired high viscosity (η_h), then the viscosity of the PreGlass needs to be lowered to the desired high viscosity (η_h). The additive Li_2O will be exchanged for the additive B_2O_3, kilogram for kilogram, until η_G equals η_h. This adjustment is the hardest of all the glass property adjustments to make because some main oxides in Equation 4.1-9 are non-linear and solving unknowns cannot be done directly. The amount of B_2O_3 - LiO_2 to swap is numerically determined using the Newton-Raphson Method*. The answer converges quickly within six iterations of using the Newton-Raphson Method.

No more B_2O_3 can be swapped if the glass Li_2O concentration gets above 6 wt %, which is the maximum allowed in HLW glass. If this happens, then PreGlass will be diluted with a Dilution Glass that has a low viscosity to drop the PreGlass' viscosity further down to the desired high viscosity (η_h).

Low Viscosity Adjustment

The low viscosity adjustment of the PreGlass is similar to the high viscosity adjustment except that SiO_2 is swapped for B_2O_3. This routine will be rarely used, if at all, because most waste oxides increase the viscosity of the glass, not lower the viscosity.

Product Consistency Test

There are three PCTs which the HLW glass must pass. The PCT is a leaching procedure that tests for leached boron, sodium, and lithium in the leachate from the tests. These tests are new to the HLW Glass Shell routine. Most batches of HLW glass as formulated by the HLW Glass Shell routine will pass the three PCT tests. However, a few batches may not. The following routines check for these failed batches and then dilute PreGlass, previously adjusted for viscosity, with a good glass low in PCT values that becomes the final HLW glass.

The PCT routine starts with calculating the PCT values for boron, sodium, and lithium per Equation 4.1-10 and Equation 4.1-11 using values for the PreGlass adjusted for viscosity.

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* Also known as the Newton-Raphson Method, named after Issac Newton and Joseph Raphson. Given the function $f(x)$ and its derivative $f'(x)$, we begin with a first guess or approximation x_0.
A better approximation x_1 is: $x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$.

Equation 4.1-10

$$\ln(PCT) = \sum_{i=1}^{23} d_i g_i + d_{24} g_{Al2O3}^2 + d_{25} g_{Al2O3.p5} g_{ThO2} + d_{26} g_{Al2O3}^3 + c_{27} g_{B2O3}^2 + c_{28} g_{MnO}^2 + c_{29} g_{B2O3} g_{Na2O}$$

Equation 4.1-11

$$PCT = \exp[\ln(PCT))]$$

where: ln(PCT) is the natural log of the PCT value. The PCT values are in g/m^2 of leached boron, sodium, or lithium.

i is the ith component in the following order:

Al_2O_3, B_2O_3, BaO, CaO, CdO, F, Li_2O, MgO, MnO, Na_2O, Nd_2O_3, P_2O_5, SiO_2, SO_3, SrO, +ThO_2, TiO_2, UO_3, ZnO, ZrO_2, Others, $(Al_2O_3)^2$, Al_2O_3 x ThO_2, $(Al_2O_3)^3$, $(MnO)^2$, Na_2O x B_2O_3

g_i is the mass fraction of the component in the PreGlass adjusted for viscosity

d_i is the coefficient of the ith component as given PNNL-18501.

The desired PCT values for boron, sodium, and lithium is 4.0 g/m^2 or less. The PreGlass is adjusted for the highest value of the three over 4.0 g/m^2 as necessary. If none are over 4.0 g/m^2, no adjustment will be made to the PreGlass.

The PreGlass adjusted for PCT is the final HLW Glass to be calculated. Values calculated for this glass are the ones to use for estimating glass quantities for the WTP mission, leaching strategies, feed recipe for the melters, offgas estimates, etc.

Liquidus Temperature, T_L, Model

Zircon can form in HLW glasses and affect glass chemistry. The model for zircon liquidus temperature follows the same format as the $T_{1\%}$. T_L for PreGlass ($M_{Glass.6}$) and should be within limits or close because of all the adjustments made to the glass thus far. However, if adjustment is necessary it is due to high concentrations of Al_2O_3, SrO_2, B_2O_3, and ZrO_2. Consequently, viscosity will be at the high end and PCT, etc. will be at the low end. Therefore, swapping Na_2O for B_2O_3 will be used. Swapping these components should adjust the glass properties values in the positive directions without impacting waste loading.

Equation 4.1-12

$$T_{L.p6} = \sum_{i=1}^{7} d_i \frac{M_i + GF_i}{M_{Glass.p2}} + d_8 \frac{M_{othersTL}}{M_{Glass.p6}}$$

where: $T_{L.p6}$ is the liquidus temperature for PreGlass ($M_{Glass.p6}$).

i is the ith component in the following order: Al_2O_3, B_2O_3, Ln_2O_3, Li_2O, Na_2O, SrO, ZrO_2 and others

M_i is the Mass of i-th waste component listed in PNNL-18501. There are 7 components plus others.

GF_i is the Mass of the i-th glass former component ($GF_{i.p6}$) matching the waste component listed in PNNL-18501.

d_i is the component coefficient for i-th component in PNNL-18501.

4.1.3.4.6 Bridge Between Melters and Glass Chemistry Modules and Compound-Based Flowsheet

The melters and the glass chemistry logic are largely based on a convention known as *glass oxides*. These glass oxides are generally elemental oxides that, when combined together, form more complicated compounds. For example, combining calcium oxide and sulfur oxide forms calcium sulfate:

Equation 4.1-13

$$CaO + SO_3 \rightarrow CaSO_4$$

However, with a compound-based flowsheet, the reverse needs to be done to interface with the glass chemistry and melter modules:

Equation 4.1-14

$$CaSO_4 \rightarrow CaO + SO_3$$

In a similar sub-section, in Section 3.1 (systems LCP, GFR and LFP: LAW Melter Feed Process), the logic in detail is presented for the interface between the compound-based flowsheet and the melter and glass chemistry logic modules.

4.1.3.4.7 Noble Metals

Some noble metals (Rh, Pt, Pd, and Ru) are essentially insoluble in glass (24590-101-TSA-W000-0009-144-03), making it impractical to impose a limit on them in glass formulation. The WTP feeds typically have very low concentrations of these noble metals, so this is not a concern.

4.1.3.4.8 Sugar Addition

It has not been determined whether sugar addition will be required to reduce nitrates and nitrites in HLW.

4.1.3.4.9 Relationship between Waste Loading and System Capacity

The target glass nameplate for each HLW melter is 3 MTG/day. The melter feed is not in the form of glass. Therefore, a mechanism for translating the throughput requirements to the HFP system must be developed. In this section, the glass throughput requirements will be translated to a relationship between batch volume, cycle times, and glass yield for each melter. The WTP glass will be an oxide glass. Therefore, the glass yield (in glass mass made per volume of feed) of the feed is the same as oxide yield of the feed. The feed throughput of the system (liters/day) is equal to the glass production rate (3 MTG/day/melter) divided by the glass yield (mass/L).

Equation 4.1-15

$$\text{Feed throughput (L/day)} = \frac{\text{Glass production (3 MTG / day per melter)}}{\text{Glass yield of feed (mass / L)}}$$

Equation 4.1-15 is the average throughput rate of the system and also the melter feed rate. The glass production rate is straightforward, but glass yield is a complex function of the glass waste loading and feed composition. Glass yield is discussed later in this section (after Equation 4.1-18).

Each melter is fed continuously, so the average throughput rate in Equation 4.1-16 is appropriate for describing the melter feed rate. The MFPVs, however, operate as batch operations, so the instantaneous throughput rate is not the same as the average throughput rate (because the MFPVs are idle most of the time). The average throughput rate in Equation 4.1-15 must equal the volume of feed in an MFPV cycle divided by the time of the cycle.

Equation 4.1-16

$$\text{MFPV throughput} = \frac{\text{Feed volume per cycle}}{\text{cycle time}}$$

where:

Equation 4.1-17

$$\text{Feed volume per cycle} = \frac{\text{glass produced per cycle}}{\text{glass yield}}$$

The MFPV achieves the required throughput when throughput from Equation 4.1-16 ≥ Equation 4.1-15. In a batch-operated vessel, the feed volume in Equation 4.1-16 must equal the batch volume available in the vessel, or:

Equation 4.1-18

$$\text{MFPV throughput} = \frac{\text{Batch volume per cycle}}{\text{cycle time}}$$

A consequence of Equation 4.1-18 is that the cycle time must decrease if the batch volume decreases, but can increase if the batch volume increases. The cycle time of the MFPV includes pumping times and times for glass former batching, but the dominant contributor is sample turnaround time (CCN 028110).

The glass yield is the mass of glass made per volume of melter feed. The glass yield of a melter feed is a function of the glass waste loading and the oxide densities of the HLW concentrate and the glass formers.

Equation 4.1-19

$$\text{Glass Yield} = \frac{(V_c * \rho_{o,c}) + (V_{gf} * \rho_{o,gf})}{\text{Total Volume}}$$

where:

V_{gf} is volume of glass former solids
V_c is volume of HLW concentrate
$\rho_{o,gf}$ is oxide densities of glass former solids
$\rho_{o,c}$ is oxide densities of HLW concentrate

The right side of Equation 4.1-19 is equal to the glass yield (oxide mass/volume) because the volume terms in the numerator are canceled out by the volumes in the density terms. Equation 4.1-19 is related to waste loading (WL) in that:

Equation 4.1-20

$$WL = \frac{(V_c * \rho_{o,c})}{(V_c * \rho_{o,c}) + (V_{gf} * \rho_{o,gf})}$$

The right side of Equation 4.1-20 is equal to WL because all of the volume terms cancel out, the numerator becomes mass of waste oxide, and the denominator becomes total mass of oxide (mass of waste oxide + mass of glass former oxide).

During operation, the WL, waste oxide density, and glass former composition (which defines the oxide density) will be calculated from analytical data (24590-HLW-RPT-RT-02-002). From these data, the volumes transferred to the MFPV will be calculated. The volume fraction of glass formers to waste can be calculated by rearranging Equation 4.1-20, resulting in Equation 4.1-21.

Equation 4.1-21

$$V_{gf}/V_c = \frac{(\rho_{o,c})}{WL(\rho_{o,gf})} - \frac{\rho_{o,c}}{\rho_{o,gf}} \text{ or } = \frac{(\rho_{o,c})}{(\rho_{o,gf})}\left(\frac{1}{WL} - 1\right)$$

The oxide density of glass former solids depends on the composition of the glass formers, which changes for each waste type, and possibly for every batch.

The oxide density of the HLW concentrate ($\rho_{o,c}$) is more complex. Oxide density depends on the waste composition, which depends on the performance of the PT Facility (Section 2). The solids are much denser than the liquids. Consequently, the oxide density is sensitive to the solids-loading of the HLW concentrate. Empirical models have been developed for slurry density and oxide density as a function of solids content of the HLW concentrate (24590-HLW-M4C-50-00001). These models are based on slurry density measurements from tanks AZ-101 and AZ-102 (24590-HLW-M4C-50-00001). Furthermore, evaluation of existing chemical, physical, and rheological empirical data on actual and simulated wastes relevant to the WTP process was performed by Battelle and summarized in 24590-101-TSA-W000-0004-172-001. This review demonstrated that bulk density of pretreated wastes correlate well with concentration parameters such as weight percent total solids and weight percent oxides. These correlations are used for predictive purposes, but in the operating plant the composition of the waste will be measured and the oxide density will be calculated from this measurement (24590-HLW-RPT-RT-02-002). One tank size can accommodate a large variation of feed concentrations by adjusting the waste loading or cycle time (CCN 028110).

4.1.3.4.10 Rheology and Physical Property Data

During operations, the volume and composition of the HLW concentrate is measured (24590-HLW-3YD-HFP-00001). The Operations Research flowsheet basis for predicting the density of pretreated waste slurry as a function of solids content is based on reconciliation of data from Battelle report 24590-101-TSA-W000-0004-172-00001(Figure B2.1 on page B.3), and is shown in Equation 4.1-22.

Equation 4.1-22

$$\text{SlurryDensity}(g/mL) = \frac{-232.74 + \sqrt{54168 - 210(179.18 + \text{wt\%solids})}}{-105}$$

This Battelle report also demonstrated a correlation between density of pretreated wastes and weight percent oxides. This correlation is used to calculate oxide mass fraction of pretreated HLW waste for Operations Research flowsheet, and is shown in Equation 4.1-23.

Equation 4.1-23

$$\text{OxideMassFraction} = \frac{(67.405 * \text{density} - 64.116))}{100}$$

The pumping and mixing of slurries is dependent on factors such as the solids content, solution ionic strength, pH, solids composition, and particle size (Zhou and others. 2001). Figure 4-2 shows the consistency and yield stress of simulated HLW concentrate, which differ only in the source of iron (SCT-M0SRLE60-00-193-02). The two different sources of iron are goethite (FeOOH) and hematite (Fe_2O_3), as shown in Figure 4-2, which shows that the consistency and yield strength of the simulated slurry containing goethite was higher than hematite. Likewise, the simulated slurry with the larger-sized hematite had a higher consistency and yield strength than the smaller-sized hematite. Thus, it is evident that the slurry rheology is dependent on the slurry mineralogy and particle size.

The upper bounding acceptable shear strength and consistency for pretreated HLW waste and HLW melter feeds are shown in Table 4-4. The rheologies of feeds increase with increasing solids content. The addition of glass formers to the feed increases the solids content, and if the waste loading for the glass is small, the quantity of glass formers relative to the quantity of water from the pretreated feed in the melter feed would be large. A recent assessment (CCN 137198) has shown that melter feeds can exceed the upper bounding shear strength and consistency values if care is not taken to ensure the water content is sufficiently high. To protect against that possibility, the assessment recommends that the flowsheet maintain the glass yield of the melter feed below 550 g oxide per liter of feed. This value was chosen because experience at the HLW pilot melter facility at VSL indicates that the melter feed usually has acceptable rheological properties when the glass yield is below 550 g of oxide per liter. The effect of the glass former solids on melter feed rheology is highly feed specific (24590-101-TSA-W000-0004-172-00001), so the WTP operating contractor may choose to optimize this value for given waste types. The flowsheet, however, will use this glass yield limit for all feeds, unless waste specific values are available. When the glass yield limit is exceeded, water will be added to the melter feed preparation vessel to bring the glass yield down to 550 g of oxide per liter. The operating contractor may choose to add this water some other place or may choose to concentrate the HLW pretreated feed to a lower value than 20 wt % instead of adding water to the melter feed preparation vessel. Consequently, this limit will be carried as an assumption.

Assumption 4.4. Resolved, see Appendix C for resolution

Assumption 4.5. The exact quantity of water needed to control melter feed water is waste specific. The assumption will be that melter feeds will have acceptable rheology if the glass yield is below 550 grams of oxide per liter. Water must be added to bring the glass yield below this value and this will be added to the HLW melter feed preparation vessels. The operating contractor may choose to add this water to some other location upstream of the melter feed preparation vessels.

The effects of 1) changes in melter feed waste composition, 2) changes in the amount of glass former added, and 3) the use of different source materials for glass former makeup were studied (24590-101-TSA-W000-0009-180-00002, Rev 00A) in Duratek Melter-100 (DM-100). The

consequences of these changes on molten glass, vitrified glass, and on off-gas emissions were monitored. The HLW vitrification process was tested in DM-100. The quality of the product relevant to the geological disposal of the IHLW was analyzed. During the 700 hours of melter operation, the melter feed was processed with high and low viscosities and high and low concentrations of several major components in the waste. The glass former components, offset by about ±15 wt%, were processed and subsequent changes in melt rate were observed. Different sources of glass former components were employed to evaluate their effect of melt process. The glass composition formulated for HLW C-106/AY-102 waste was used as the baseline feed composition.

The steady-state melter operation produced 900 to 1400 kg/m^2/day of vitrified glass. The production rate was higher when the glass melt viscosity was lower and vice versa. These production rates agreed with those of previous DM-100 operations. High-viscosity glass melt exhibited a tendency to develop foaming. Addition of sugar to the waste batch reduced both the glass-melt viscosity and foaming, and almost doubled the melt rate. Magnesium in the feed was suspected to cause foaming, but these tests indicated that it was not. The glass melt rate was 1000 to 1050 kg/m^2/day, even when the glass former addition was offset by about ±15 wt%. Replacing boric acid and soda ash with borax did not change the glass production rate significantly; no phase separation was observed either in the glass pool or in the solidified glass. Samples of glass produced in DM-100 were analyzed with respect to the properties relevant for IHLW product qualification and were found to be in the acceptable range. Glass samples from sugar-added feed were analyzed for divalent iron concentration to determine the oxidation state of glass. The measured amount of divalent iron was scattered and could not be correlated to the quantity of sugar added. Glass samples from the melter bottom were analyzed for quantification of crystalline phases. Results were inconclusive. Further study was suggested for determining the extent of crystallization at 950 °C. Glass samples with high concentrations of toxic metals were tested for chemical leach rate. The leach rates were within the acceptable limits.

Total particulate carry-over rates from the melter during these tests were within the range previously measured in DM-100, except for three samples that showed above normal levels. This was attributed to the transients in the cold cap. Melter decontamination factors (DF) were determined for many of the elements in the feed. The most volatile species were halides, sulfur, selenium, and thallium and, to a lesser extent, boron, chromium, and arsenic. Gaseous emissions (nitrogen oxides, carbon monoxide, and ammonia) were very low. This was attributed to a lack of nitrates and organic carbon in the feed. Sugar addition to the feed slightly enhanced the emissions of these gaseous products from the molten glass.

A significant observation from these tests was that the high-viscosity melt developed foaming which, in turn, reduced the glass production rate. The addition of sugar also reduced the foaming and increased the glass production rate.

Additional tests were conducted in DM-100 melter (24590-101-TSA-W000-0009-190-00001, Rev 00A) by varying the concentrations of waste feed components. Eleven waste glass formulations were tested by changing the concentrations of major and minor components in the glass, formulated for the HLW in Tank C-106/AY102, designated as HLW98-86 glass. Melter feed components that were varied, on oxide basis, were Al_2O_3 (at 13 %), B_2O_3 (at 15 % max and 4.3 % min), Na_2O (20 %), MnO (8 %), SiO_2 (53.1 % max and 33 % min), SrO (9.27 %), ZrO_2 (10.65 %), LiO_2 (0 %) and others, a combination of several minor components, with HLW98-86, as the base case. The glass formulation, which was generated by algorithm and is different from HLW98-86, was used to determine the maximum tolerable SrO and ZrO_2 concentrations in the melter feed without causing any processing problems. The results of strontium and zirconium tests were therefore not directly comparable to those tested using HLW98-86. The effect of variations in melter feed composition on melt rate, off-gas characteristics, foaming, cold cap stability, and so forth were monitored.

The steady-state glass production rate ranged between 450 to 2150 kg/m^2/day. These melt rates were comparable to those of other WTP HLW waste streams processed in DM-100, considering the spread of maximum and minimum percentages by weight of some of the components tested. The measured melt rates were higher for formulations with higher concentrations of alkali and boron and were lower for higher concentration of silicon, aluminum, manganese, strontium, and zirconium. Melt rate was about 70 % higher for higher concentrations of other minor components (chromium 0.6 %, potassium 2.5 %, lanthanum 1.2 %, titanium 1 %, and zinc 4 %) as oxides, compared to the HLW98-86 base case. The increase in melt rate was attributed primarily to K_2O content in the feed. After the completion of all the tests and idling the melter for 2 days, an extensive secondary sulfate phase was observed on the melt pool surface. Chemical durability was tested using the product consistency procedure (PCT) for boron, silicon, and sodium, and was found to be within the acceptable limits.

Total particulate carry-over from the melter during these tests ranged from 0.63 to 0.96 % in seven out of the eleven tests. In the remaining four tests, the carry-over ranged from 0.38 to 3.86 %. This wide variation in particulate carry-over was attributed to the cold cap instabilities and/or partially covered pool surface areas as in the earlier tests in DM-100.

Formation of secondary sulfate phase on the glass pool surface was further studied by conducting tests in DM-100. Glass formulations HLW98-86 and HLW02-46 were chosen to determine the maximum sulfate concentration in the feed that can be processed without any secondary phase formation. The tests indicated that the maximum concentration of SO_3 in glass that could be processed was 0.37 wt% for HLW98-86 and 0.6 wt% for HLW02-46. Feed formulation for HLW02-46 was processed with three sulfur levels, ranging from 0.1 to 0.75 wt% SO_3 on glass basis without the formation of secondary phase. The WTP flowsheet projects that the majority of the sulfur in Hanford tank waste will be partitioned to the LAW stream. A slight variation in the sulfur content in the LAW waste stream would result in a large change in the levels in the HLW waste stream. It was pointed out in 24590-101-TSA-W000-0009-190-00001 that the effect of sulfur in the waste feed on glass melting is complex, and suggested that more data on the sulfur tolerance level would be required to optimize the HLW melting process with respect to secondary sulfate phase in the melting process.

4.1.4 Ongoing Work

- Work for a revision of the HLW glasses formulation algorithm is in process, which will incorporate expanded qualified glass regions and glass property models. The high aluminum, chromium, etc., glasses calculated by the HLW glass shell are estimated as probable glasses based on glass property curve fits of numerous previously made glasses in the DOE complex and their measured properties (see PNNL-18501). Actual glasses have not been used to simulate the high waste loading of Tank Farm waste. However, tests being conducted through DOE are underway to make such glasses.

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Table 4-1 TS-1.1 Minimum Component Limits in High-Level Waste Glass

Component	Weight Fraction in HLW Glass
Fe_2O_3	0.125
Al_2O_3	0.11
$Na_2O + K_2O$	0.15
ZrO_2	0.10
UO_2	0.08 (0.0811 as U_3O_8)
ThO_2	0.04
CaO	0.07
MgO	0.05
BaO	0.04
CdO	0.03
NiO	0.03
PbO	0.01
TiO_2	0.01
Bi_2O_3	0.02
P_2O_5	0.03
F	0.017
$Al_2O_3 + ZrO_2$	0.14
$Al_2O_3 + ZrO_2 + Fe_2O_3$	0.21
MgO + CaO	0.08
Cr_2O_3	0.005
SO_3	0.005
Ag_2O	0.0025
$Rh_2O_3 + Ru_2O_3 + PdO$	0.0025

Table 4-2 HLW Glass Bounding Conditions, BC

Name	Constituent value or Series	Upper Limit[a], wt%	Rule
BC_1	M_{Al2O3}	20.	Aluminum Validity Region [d]
BC_2	M_{Bi2O3}	3.2	Bismuth Validity Region [d]
BC_3	M_{CaO}	7.	Calcium Validity Region [d]
BC_4	M_{CdO}	1.5	Cadmium Validity Region [d]
BC_5	M_{Cl}[a]	0.5	Chloride Constraint [d]
BC_6	M_{Cr2O3}	1.2	Chromium Validity Region [d]
BC_7	M_F[a]	2.	Fluoride Constraint [d]
BC_8	M_{Fe2O3}	17.4	Iron Validity Region [d]
BC_9	M_{K2O}	6.	Potassium Validity Region [d]
BC_{10}	M_{MgO}	6.	Magnesium Validity Region [d]
BC_{11}	M_{MnO}	7.	Manganese Validity Region [d]
BC_{12}	M_{Na2O}	21.4	Sodium Validity Region [d]
BC_{13}	M_{NiO}	3.	Nickel Validity Region [d]
BC_{14}	$M_{NM} = M_{Rh2O3} + M_{RuO2} + M_{PdO}$	0.25	Noble Metal Constraint [d]
BC_{15}	M_{P2O5}	2.5	Phosphate Constraint [d]
BC_{16}	$M_{P2O5} * M_{CaO}$	0.00065	Phosphate Constraint [d]
BC_{17}	M_{PbO}	5.	Trace Elements of Concern [d]
BC_{18}	M_{SiO2}	53.	Silica Validity Region [d]
BC_{19}	M_{SO3}[a]	0.5	Sulfate Constraint [d]
BC_{20}	M_{SrO}	4.5	High Liquidus Temperature [e]
BC_{21}	M_{ThO2}	6.	Thorium Validity Region [d]
BC_{22}	M_{UO3}	6.3	Uranium Validity Region [d]
BC_{23}	M_{Zr2O}	13.5	Non-Spinel Rule C[d]
BC_{24}	M_{minors}[b]	4.5	Minors Validity Region [d]

(a) The melter feed concentration before applying melter decontamination factors (DF's) or glass retention factors. Also known as *target concentration.*

(b) $M_{others} - M_{Bi2O3} - M_{CaO} - M_{CdO} - M_{Cr2O3} - M_{K2O} - M_{MgO} - M_{MnO} - M_{NiO} - M_{PbO} - M_{SO3} - M_{SrO} - M_{ThO2} - M_{Ti2O} - M_{UO3} - M_{ZrO2}$

(c) 24590-101-TSA-W000-0009-02-00001, *Final Report: Baseline HLW Glass Formulations for Bismuth Phosphate Wastes*

(d) PNNL-18501, *Glass Property Data and Models for Estimating High-Level Glass Volume*, J.D. Vienna, et al., October 2009.

(e) Even though PNNL-18501 validity range is 10.1wt% the HLW glass shell can not handle this high value. SrO affects the liquidus temperature, T_L, several factors more than any other oxide and causes negative B_2O_3 values in attempts to adjust very high T_L values due to high SrO. Therefore, the BC value for SrO is limited as shown.

Table 4-3 Minerals Used as Glass Formers and Their Contaminants*

Mineral	For	Bulk Formula	Al_2O_3	B_2O_3	CO_2	CaO	CdO	Cl	Cr_2O_3	Fe_2O_3	H_2Ob	HfO_2	K_2O	Li_2O	MgO	Mn_2O_3	Na_2O	Nb_2O_5	NiO	P_2O_5	PbO	SO_3	SiO_2	ThO_2	TiO_2	V_2O_5	ZnO	ZrO_2	Total	Total Glass Ox.	
ppm (mass basis)																															
Kyanite	Al_2O_3	Al_2SiO_5	570,000			400				7100			700		400		400						410,500		10,500				1,000,000	1,000,000	
Borax	B_2O_3	$Na_2B_4O_7{\cdot}10H_2O$		375,000				700		43	456,757						167,000					500							1,000,000	543,243	
Boric Acid	B_2O_3	H_3BO_3		565,300				18		9	434,382											292							1,000,000	565,618	
Wollastonite	CaO	$CaSiO_3$	2000			475,000				4000					1000	1113							516,687		200				1,000,000	1,000,000	
Iron Oxide	Fe_2O_3	Fe_2O_3	15,000			400				965,373					1000	1293				2635		799	13,500						1,000,000	1,000,000	
Lithium Carbonate	Li_2O	Li_2CO_3			596,454	14		100		400				402,000	995		4					33							1,000,000	403,546	
Olivine	MgO	Mg_2SiO_4-Fe_2SiO_4	1900			200			1300	76,800			100		480,100		200		3700				435,700						1,000,000	1,000,000	
Soda Ash	Na_2O	Na_2CO_3			414,300	49		182		3	200				41		585,168					56							1,000,000	585,500	
Silica	SiO_2	SiO_2	1350			80				160			170		80		20						998,060		80				1,000,000	1,000,000	
Rutile	TiO_2	TiO_2	5000						1600	7000								4000		458		250	22,000		936,192	4500		19,000	1,000,000	1,000,000	
Zinc Oxide	ZnO	ZnO					50			10							200				10						999,730		1,000,000	1,000,000	
Zircon Sand	ZrO_2	$ZrSiO_4$	2500							750		65,500											340,250	450	1050			589,500	1,000,000	1,000,000	
Sugar	Reductant	$C_{12}H_{22}O_{11}$			421,069						578,931																		1,000,000	0	
Lb/Lb (kg/kg) gf oxide requested																													gf Solids	Gases	Total
Kyanite-Al	Al_2O_3	Al_2SiO_5	0.96692			0.00068				0.01204			0.00119		0.00068		0.00068								0.01781				1.00000	0.00000	--
Kyanite-Si	Al_2O_3																						0.69635						0.69635	--	1.69635
Borax-B	B_2O_3	$Na_2B_4O_7{\cdot}10H_2O$		0.99670				0.00186		0.00011	1.21399											0.00133							1.00000	1.21399	--
Borax-Na	B_2O_3	$Na_2B_4O_7{\cdot}10H_2O$															0.44386												0.44386	0.00000	2.65786
Boric Acid	B_2O_3	H_3BO_3		0.99944				0.00003		0.00002	0.76798											0.00052							1.00000	0.76798	1.76798
Wollastonite-Ca	CaO	$CaSiO_3$	0.00414			0.98280				0.00828					0.00207	0.00230									0.00041				1.00000	0.00000	--
Wollastonite-Si	CaO	$CaSiO_3$																					1.06905						1.06905	--	2.06905
Iron Oxide	Fe_2O_3	Fe_2O_3	0.01500			0.00040				0.96537					0.00100	0.00129				0.00264		0.00080	0.01350						1.00000	0.00000	1.00000
Lithium Carbonate	Li_2O	Li_2CO_3			1.47803	0.00003		0.00025		0.00099				0.99617	0.00247		0.00001					0.00008							1.00000	1.47803	2.47803
Olivine-Mg	MgO	Mg_2SiO_4-Fe_2SiO_4	0.00390			0.00041			0.00267				0.00021		0.98482		0.00041		0.00759										1.00000	0.00000	
Olivine-Si	MgO	Mg_2SiO_4-Fe_2SiO_4																					0.89374						0.89374	--	--
Olivine-Fe	MgO	Mg_2SiO_4-Fe_2SiO_4								0.15754																			0.15754		2.05128
Soda Ash	Na_2O	Na_2CO_3			0.70760	0.00008		0.00031		0.00000	0.00034				0.00007		0.99943					0.00010							1.00000	0.70794	1.70794
Silica	SiO_2	SiO_2	0.00135			0.00008				0.00016			0.00017		0.00008		0.00002						0.99806		0.00008				1.00000	0.00000	1.00000
Rutile	TiO_2	TiO_2	0.00500						0.00160	0.00700								0.00400		0.00046		0.00025	0.02200		0.93619	0.00450		0.01900	1.00000	0.00000	1.00000
Zinc Oxide	ZnO	ZnO					0.00005			0.00001							0.00020				0.00001						0.99973		1.00000	0.00000	1.00000
Zircon-Zr	ZrO_2	$ZrSiO_4$	0.00379							0.00114		0.09928												0.00068	0.00159			0.89352	1.00000	0.00000	--
Zircon-Si	ZrO_2	$ZrSiO_4$																					0.51573						0.51573	--	1.51573
Sugar	Reductant	$C_{12}H_{22}O_{11}$			0.42107						0.57893																		0.00000	1.00000	1.00000

* **Note:** Boric acid and sugar do not normally contain molecular water, and that sugar, sodium carbonate, and lithium carbonate do actually contain molecular carbon dioxide. The are tracked as having water and carbon dioxide in them because they can be broken down into mass units that have the same stoichiometry as water and carbon dioxide.

Table 4-4 Upper-Bounding Rheological Properties

Slurry Type	Bounding Shear Strength and Bingham Yield Stress (Pa)	Bounding Consistency (cP)
Pretreated HLW feed	70 and 30	30
HLW melter feed	30 and 30	40

Source: 24590-101-TSA-W000-0004-172-00001 and CCN 065607.

Figure 4-1 HLW Melter Feed Process System

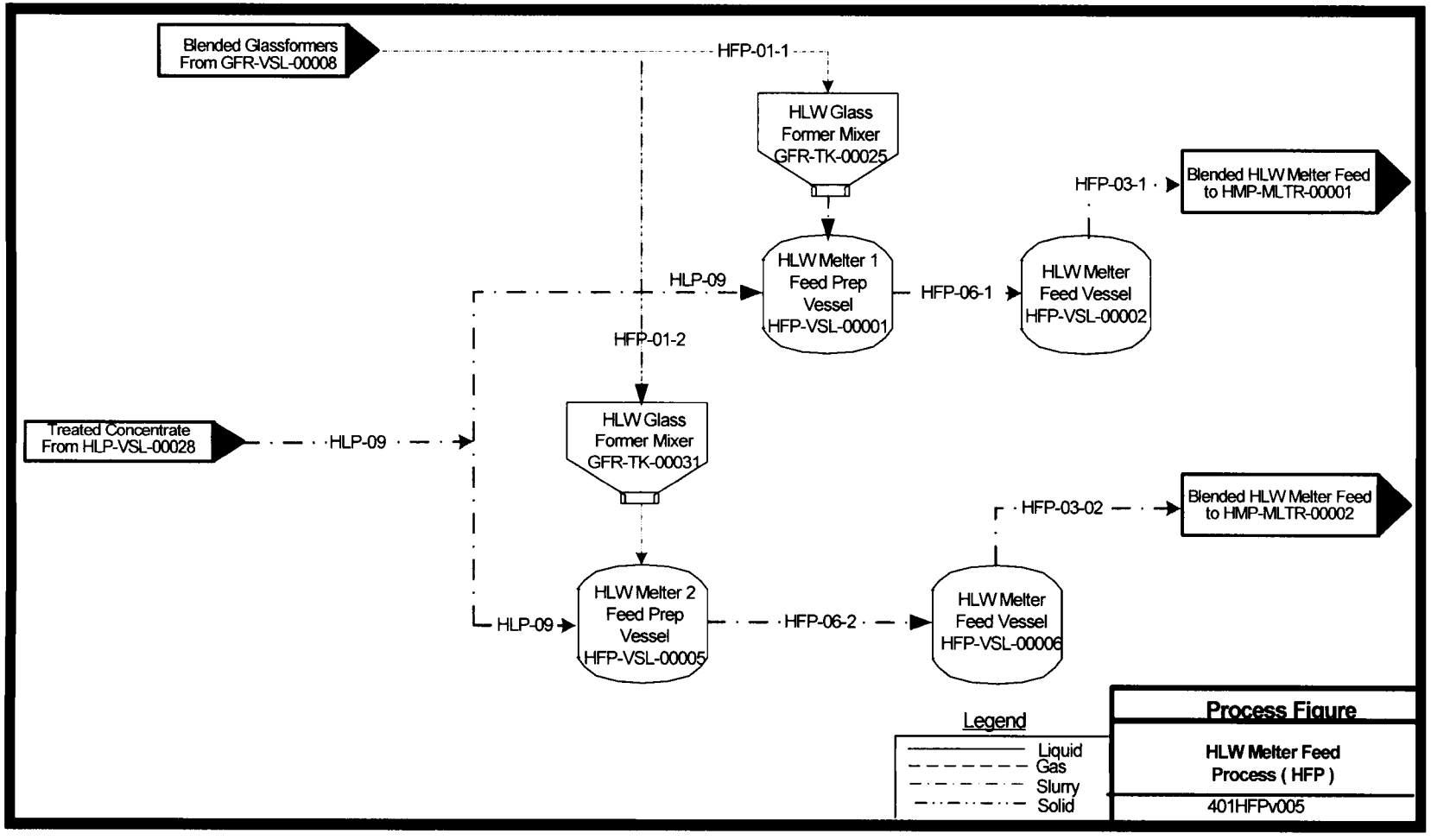
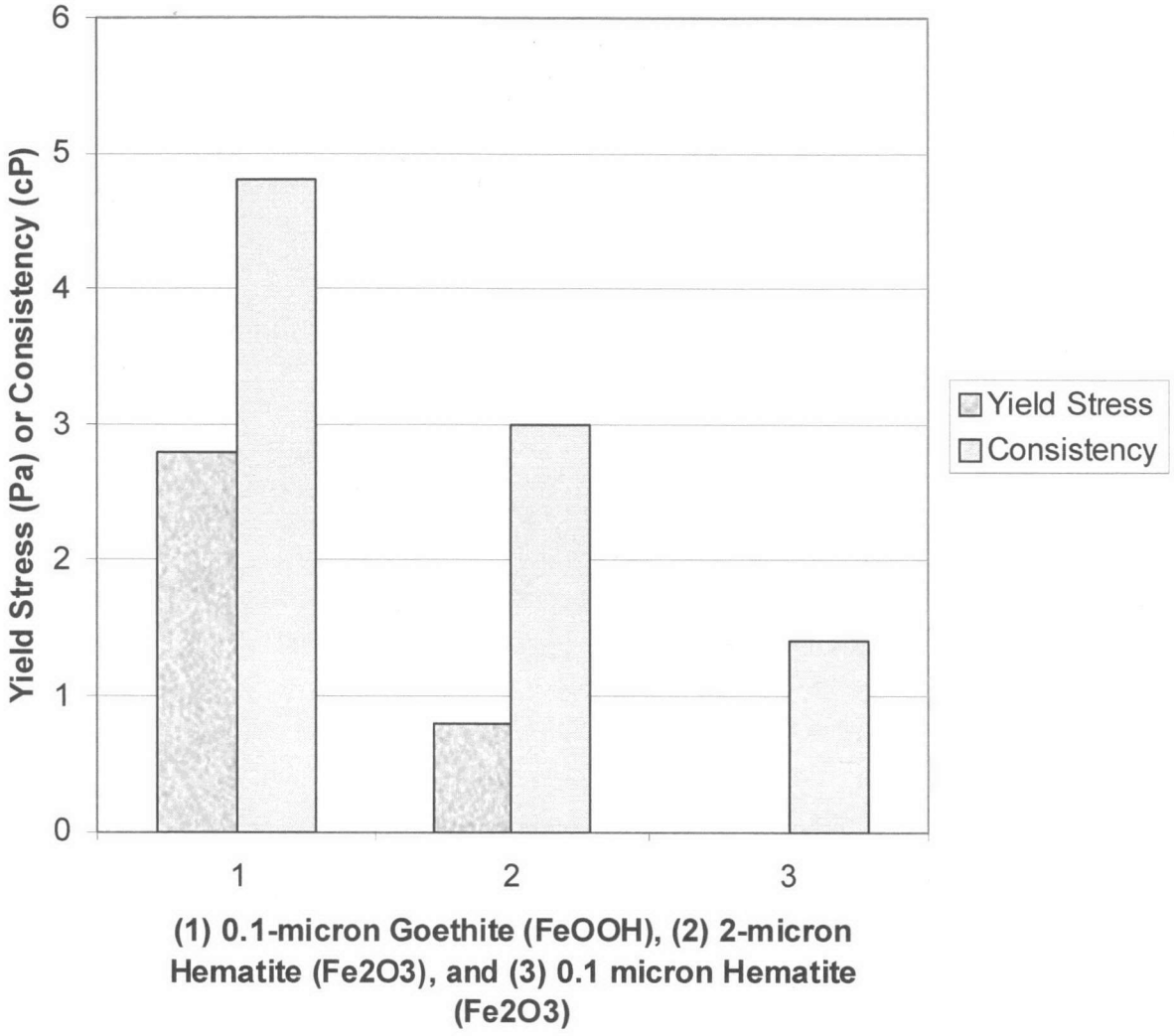


Figure 4-2 Yield Stress and Consistency of Slurries with Different Iron Minerals



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4.2 System HMP: HLW Melter Process

4.2.1 Function and Requirements

4.2.1.1 Melter Facility Function and Requirements

The function of the high-level waste (HLW) melter process system (HMP) is to convert a blended slurry of liquid HLW and glass forming chemical additives into molten glass. Direct flowsheet-related requirements for the HLW include waste solids loading, thermal heat generation from radionuclide concentration, toxic waste content, and various disposal requirements.

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7(b)(3)

> *Waste Treatment Capacity Requirements: The HLW Vitrification Facility shall be designed with two HLW melter systems to support a combined design capacity of 6 MTG/day with the original melters and up to 7.5 MTG/day with replacement melters.*

WTP SOW, Standards, Standard 5, Commissioning, Cold Commissioning, Section C.5(e)(3)(ii)

Table C.6-5.1 Cold Commissioning Capacity Testing Criteria

Facility	*Minimum Capacity*	*Treatment Capacity*	*Design Capacity*
LAW Pretreatment	2244 MT Na per Year	2620 MT Na per year	3740 MT Na per year
HLW Pretreatment	735 MT as-delivered solids per year	860 MT as-delivered solids per year	1225 MT as-delivered solids per year
LAW Vitrification	18 MT Glass per day	24 MT Glass per day	30 MT Glass per day
HLW Vitrification	3.6 MT Glass per day	4.2 MT Glass per day	6.0 MT Glass per day

WTP SOW, Operational Specification, Section C.8, Specification 1.2.2.1.2

1. *"Fill Height: Fill height shall be equivalent to at least 87percent of the volume of the empty canister. The average fill height over all the canisters shall be at least 95 percent of the volume of the empty canister."*
2. *"Maximum Heat Generation Rate: The maximum heat generation rate for any single canister shall not exceed 1500 watts per canister when delivered to DOE."*

WTP SOW, Operational Specification, Section C.8, Specification 1.2.2.1.5

> *Product Loading: Loading of non-volatile components in Envelope D shall be achieved, such that, the concentration of at least one of the waste components or waste component combinations in Table TS-1.1, Minimum Component Limits in High-Level Waste Glass exceeds its minimum weight percent in HLW glass as identified in Table TS-1.1 (e.g., for a high-iron waste, the waste product shall incorporate at least 12.5 weight percent iron oxide from the waste into the glass). The product loading shall not cause the limits in any other requirement of this specification to be violated. Product waste loading shall be calculated on an average basis for each batch transfer of Waste Envelope D. The waste*

loading may be adjusted downward if necessary to comply with Universal Treatment Standards leaching requirements.

Table TS-1.1 has been recreated in Section 4.1

4.2.1.2 Glass Function and Requirements

The glass made by the melters must be homogeneous and have the following intrinsic qualities to be compatible with the melters (24590-HLW-3PS-AE00-T0001):

Viscosity: 10 to 150 poise at 1100 °C

Electrical conductivity: 0.1 to 0.7 S/cm at 1000 to 1200 °C

Liquidus temperature: < 950 °C

For environmental disposal purposes, the glass must meet land disposal restrictions (LDR) in 40 CFR 268, *Land Disposal Restrictions* and be excluded from regulation as a hazardous waste under RCRA. The immobilized high-level waste (IHLW) glass product shall meet the requirements in the Waste Acceptance System Requirements Document ([WASRD] DOE/RW-0351) and Waste Acceptance Product Specification for Vitrified High Level Waste Forms ([WAPS] DOE/EM-0093). The high level waste vitrification technology-based treatment standard (HLVIT) has been identified as the LDR technology-based treatment standard for a number of the IHLW metals and anions. However, a few constituents of potential concern (COPC) (i.e., Be, Ni, Sb, and Tl) are not included in the HLVIT standard and still subject to the LDRs unless otherwise granted a variance under 40 CFR 268.44(h). In order to qualify Hanford tank waste for land disposal, the US Department of Energy (DOE) is seeking a treatability variance for the Hanford tank waste. The *Land Disposal Restriction Treatability Variance Petition for Hanford Tank Waste* (24590-WTP-RPT-ENV-03-003) requests a technology-based treatability variance for Be, Ni, Sb, and Tl based on data indicating that the WTP vitrification process is a best demonstrated available technology, the only commercially available technology, and will substantially diminish the toxicity and mobility of the hazardous constituents in the waste and the likelihood of their migration from the waste so that short-term and long-term threats to human health and the environment are minimized. Accordingly, glass function and requirements for compliance of IHLW with LDRs do not currently exist.

Furthermore, IHLW is planned to be disposed of in a geologic repository that will not be a RCRA permitted facility. The *Petition to Delist Immobilized High-Level Waste Generated at the Hanford Tank Waste Treatment and Immobilization Plant* (24590-WTP-RPT-ENV-06-001) proposes an upfront, conditional exclusion for IHLW in accordance with the bases described in 40 CFR 260.22 and WAC 173-303-072(3), (4), and (6). WTP proposes to produce IHLW that will meet the criteria for delisting by immobilizing hazardous constituents of concern such that they will not leach from the vitrified waste form at levels that would exceed health-based delisting limits listed in Table 4.2-1 (24590-WTP-RPT-ENV-06-001).

4.2.2 Process Description

The WTP flowsheet consists of two HLW melters. Each melter train consists of a dedicated melter feed vessel and film cooler. Because the melters are identical, with the same functions and requirements, only one system is described. Detailed plant assessment may determine that specific elements may not be duplicated, but the process description will remain as an essentially duplicated system. Each melter will have a nameplate rate of 3.75 metric tons of glass (MTG) per day with bubblers installed. A total of 7.5 MTG/day is made when both melters are operating.

The HLW melter receives feed slurry, consisting of pretreated waste concentrate and glass forming chemicals, from the HLW melter feed vessel. The HLW melter is fed via two air displacement slurry (ADS) pumps, each supplying a separate feed nozzle on the melter. The feed slurry falls from the nozzles, located in the melter lid, onto the molten glass surface in the melter. A simplified diagram of the melter system is depicted in Table 4.2-1.

The feed material forms a cold cap layer on the surface of the glass pool. Within the cold cap several physical and chemical processes occur simultaneously as the feed material is heated from ambient to melter glass temperature. First the water in the feed is evaporated, leaving a layer of dried waste and glass forming chemicals. The resulting steam exits the melter. As the temperature of the dried material continues to increase from heat transfer fed from the glass pool, various compounds decompose, oxides form, and gases are generated. As the temperature of cold-cap materials continues to increase, the calcined feed materials dissolve into the upper surface of the glass pool and are swept away by convection glass currents, and become part of the homogenous melt blend. The glass is discharged into cylindrical stainless steel canisters, where it cools to IHLW glass form.

The melter generates gases that are drawn from the melter into the HLW Melter Offgas Treatment Process System (HOP). The melter offgas contains aerosols and entrained solid particulates. The particulates can clog the offgas piping between the melter and the submerged bed scrubber (SBS). The film cooler provides a laminar cushion air flow at pipe wall, limiting particulate buildup on the offgas piping and providing initial cooling of the gas before treatment in the HOP system.

If the HLW melter pressure becomes positive with regard to cave pressure, radioactive gases and particulates may be released from the melter, which would bypass offgas unit operations. The melter offgas system is designed to provide a constant negative gauge pressure on the melter by using blowers to draw gases away from the melter. Should a failure occur in the primary offgas motive system (most likely due to flow blockage between the melter and SBS), a secondary or backup path to the SBS is provided. In the event of pressurization, a pressure relief device vents the offgas to the process cave.

There are various air streams into the melter and the melter offgas system. These streams include:

- Air in-leakage to the melter caused by operating the melter under vacuum, (rate of in-leakage depends on the melter condition and the vacuum applied)
- Air from the operation of the bubblers and other equipment
- Air into the film cooler
- Control air introduced to control melter pressure

4.2.3 Basis

4.2.3.1 General

The HLW vitrification process has two melters, each will have a nameplate rate of 3.75 MTG/day. A total of 7.5 MTG/day is made with both melters operating.

Many of the flowsheet inputs are derived from analyzing results from tests at VSL. These inputs include bubbling requirements, throughput, operating temperatures for melter, and cold cap and disengagement space, as well as decontamination factors (DF) for various species in the feed.

The process figure (Table 4.2-1) depicts the liquid, slurry (liquid and solids in suspension), gases, and glass flows for the HLW melter. The diagram shows the HLW melter, feed flows into the melter, air in-leakage into the melter, glass flow to the HLW canisters and the melter offgas flow. Associated with melter offgas flow are the offgas film cooler air and process control air used for pressure control.

The following are the process streams in the HMP. Typical temperatures for some streams are given. Values for other streams are calculated on the basis of the set temperatures and conditions of other streams in the flowsheet.

Melter Streams

Input

- Melter feed from melter feed vessel (temperature calculated)
- Melter air in-leakage (air from the cell, typically at 35 °C)
- Instrument air (fixed air, set at 16 °C)
- Bubbler air (fixed air to melter bubblers, 16 °C)

Output

- Melter offgas (modeled at 450 °C with cold cap)
- Glass product (set at 1150 °C)

The glass pool temperature is normally set in the flowsheet. The glass chemistry is calculated and adjusted to a best fit to empirical data (Section 4.1).

HLW Glass Density

There are three common HLW glass densities used in design. They are all valid, depending on application. They are:

- Molten glass density in the melter[1], ~2.4 g/cm^3. This density is to be used when the glass is in the molten state within the glass pool of the melter or is being poured from the melter. Once solidified, the intrinsic or bulk glass densities shall be used as applicable.
- Intrinsic – solid glass without bubbles, ~2.66 g/cm^3. This is the density of the glass without any bubbles or undissolved particles in the glass[2].
- Bulk – solids glass with entrained bubbles and voids, ~2.57 g/cm^3. This is the bulk density of the glass with typical amount of entrained bubbles present[2].

For flowsheet modeling purposes, to provide consistency, and to avoid confusion between glass densities and canister wall thickness, the WTP models will use 3000 kg HLW glass per canister.

Glass, like many other materials, becomes less dense when molten. However, glass does not have a definite melting point and density. Therefore, glass density gradually changes with temperature. Figure 4.2-3 show the glass density transition from molten glass to solid glass at room temperature (24590-HLW-U0C-30-00011).

[1] Empirical data from DM1200 melter system with glass pool bubbling (24590-101-TSA-W000-0009-144-00005, 24590-101-TSA-W000-0009-144-00006), CCN 078482, 24590-HLW-UOC-30-00011.

[2] Density calculated from the median value of all the available R&T crucible density data and estimated volume percent void content from 24590-101-TSA-W000-0009-72-04.

Film Cooler Streams

Input

- Melter offgas (approx. 450 °C)
- Film cooler air (309 scfm at 16 °C)
- Control air addition (at 16 °C)

Output

- SBS inlet offgas (calculated, approx. 217 °C)

4.2.3.2 HLW Melter

The melter is a metal "box" with cooling panels that surround a region of ceramic blocks (the refractory). The refractory provides thermal insulation and resistance to chemical attack from waste and glass forming chemicals.

The melter's glass pool temperature is maintained by electrical resistance heating of the glass pool. Alternating current is passed through the molten glass pool via electrodes.

Glass temperatures within the melter are measured by thermocouples at various depths. From this thermocouple matrix, an average glass pool temperature is calculated. The glass pool temperature is maintained between 1125 and 1175 °C, with a set point of 1150 °C. Average glass pool temperatures are controlled by adjusting power to the electrodes.

- Design data
  - Filled volume[1]: 4.15 m^3, 1097 gal
  - Mean glass melt density [2]: 2400 kg/m^3 = 2.4 g/cm^3
  - Temperature[3]: 1150 °C (2102 °F)

  [1] Based on internal glass pool refractory dimensions up to nominal melt-line in Table 7.1 of 24590-101-TSA-W000-0010-407-566

  [2] See *Glass Density* topic in Section 4.2.3.1above

  [3] 24590-HLW-3YD-HMP-00001
- Operating logic
  - The melter is continuously fed with a slurry of waste and glass forming chemicals from the melter feed vessel (Section 4.1). Two ADS pumps are used to feed the melter, one on the west side and one on the east side
  - Total feed rate depends on the oxide density of the melter feed and temperature of the melter plenum.
  - Glass pool temperature is set at 1150 °C. Control of temperature is by applied voltage to joule heating system electrodes
- Services
  - Cooling water (plant cooling water system): cooling of melter refractory is via the water jacket system
  - Instrument air (instrument service air system): pressure control air, bubbler operations, electrode and electrode extension cooling and film cooler

  - Demineralized water (demineralized water system): feed startup from idle operation, plenum cool down, film cooler washes and feed nozzle flushes
  - Argon for purging glass melt level/density probes and air lift lances
- Energy contributions/chemistry: see mass and energy balance (Sections 4.2.3.3 and 4.2.3.4)

4.2.3.3 Melter Mass Balance

4.2.3.3.1 Melter Ventilation In-leakage and Purge Air

The melter plenum area is the gas space above the glass pool. Glass pool components (such as glass pool level detection instrumentation and temperature instrumentation) are installed in the plenum through "penetrations" in the melter roof.

The control loop maintains a plenum target setpoint pressure of -5 in. WG. The plenum area is protected from over-pressurization by a pressure relief device. Over-pressurization could cause an unintended glass pour.

With a consistent cold cap, the target plenum temperature is maintained between 400 and 600 °C by adjusting the rate of feed addition to the melter and by adjusting bubble flowrate.

The melter plenum pressure is regulated by injecting air into the offgas line downstream of the melter, through an automatically controlled valve. The total air in to the HLW melter from its different components per Duratek mass and energy balance (Table 3, 24590-QL-HC4-W000-00011-04-00271) is listed below.

Component(s)	Flow Rates (scfm) per Melter:
In-leakage:	
Lid component weep holes	34
Jack bolts	21
Electrode extensions	3
Discharge chambers (2) pour flanges	34
	92 scfm

Purges:	
ADS feed blowdown	2
Bubblers (7)	10.5
Backup offgas duct purge	30
Plenum viewing CCTV	10
Argon level detector	0.06
Air lifts (2 each)	~0
	53 scfm
Total In-leakage and Purges	145 scfm

However, melter air in-leakage predictions in Duratek mass and energy balance are for "new" melter and do not account for the thermal effects over time that have been known to increase melter in-leakage air. Melter in-leakage calculated by considering these thermal effects and melter pressure relief flapper valve contribution is listed below (24590-HLW-M4C-HOP-00011). Note that fixed air additions remain the same and CCTV purges are excluded from fixed air additions since they will not be normally installed (24590-HLW-M4C-HOP-00011). The following melter air input values will be used in the flowsheet.

- All scfm flowrates are at 20 °C and 1 atm
- Melter air in-leakage: 160 scfm (dry) - Water vapor in air: 0.015 lb H_2O/lb dry air
- Melter fixed air addition: 32 scfm (bubbler air not included)
- Bubbler air: 10.5 scfm
- Pressure control air: 200 scfm (part of HOP system)

Basis for flowsheet parameters is current melter design.

Reports 24590-101-TSA-W000-0009-144-02 and 24590-101-TSA-W000-0009-144-01 present pilot melter tests conducted on HLW simulants to determine the effect of bubbling rates on the glass production rates. These results are compiled in Table 4.2-4 and shown in Figure 4.2-4.

4.2.3.3.2 Partitioning

The waste and glass forming additives enter through the top of the melter as a slurry. The slurry quickly dries and forms a cold cap on the molten glass pool. Heat decomposes the cold cap into elemental oxides (and other minor constituents) that dissolve into the glass pool and exit as glass product and along with gases (with evaporated water) which exit the melter plenum to the film cooler. In-leakage air eventually enters the melter plenum and exits with the other gases to the film cooler. Dusting caused by drying of the cold cap and splatter also enters the offgas.

Empirical (pilot testing) data is given preference over computationally derived data. The revised Decontamination Factors (DFs) listed in **Table 4.2-3** are based on the average of Research and Technology (R&T) reports. These R&T reports, data analysis, rationale, and justification used for DF calculation are listed in 24590-HLW-RPT-RT-13-001 and 24590-WTP-M4C-V37T-00008. Further description on how the DFs were derived are given in LAW melter Section 3.2.3.4.2, *Partitioning in the Melter*.

4.2.3.3.3 Cold Cap Reactions

The feed typically forms a cold cap that transitions from a liquid (slurry), to solid, to molten glass. Chemical reactions take place in different regions of this cold cap, including generation of steam from boiling of the water component of the slurry feed; burning off of organics, including sugar (added to the waste and glass former chemicals to reduce NO_x); oxidation of waste and glass formers; and dissolution of oxidized waste and glass former chemicals to form molten glass.

The cold cap acts as a thermal insulator between the hot molten glass and the plenum area of the melter (Hrma 1982). Chemical reaction logic is derived from descriptive chemistry references (Rock 1985, Miessler and Tarr 1991, Weast 1975). Data on additional unreacted cold cap offgas constituents can be found in 24590-101-TSA-W000-0009-106-13, which was prepared for use at Savannah River Technology Center in their cold cap chemistry and offgas flammability models. The melter reactions are used to estimate energy requirements and to balance mass flows in the flowsheet.

The melter is to operate with approximately 90 % of the glass pool covered with cold cap, which allows the plenum to be maintained between 400 and 600 °C, with a target temperature of 400 °C. Depending on specific behavior of the cold cap, the rate of feed addition to the melter is adjusted to maintain this target temperature. This is a key real-time process control data point that impacts melter throughput.

Bubblers are also important for glass production rates. R&T has determined that bubbling is necessary to achieve the desired production rate of 3 MTG/day in the HLW melters. This is documented in 24590-HLW-RPT-RT-01-003.

HLW pilot melter data (nine runs on DM1200 using AZ-101 feed simulant) was evaluated for gross particulate emissions (Matlack 2002). The data was scaled to the WTP melter, based on melt surface area. The average particulate emissions rate, without melt pool air bubbling, is predicted to be 1.8 g/min (0.2 lb/hr), which corresponds to a 0.9 MTG/day WTP production rate. With melt pool bubbling, the predicted particulate emissions rate increased to 8 g/min (1.1 lb/hr), which corresponds to a 3 MTG/day WTP production rate. The particle size distribution in the DM1200 melter offgas is not significantly affected by melt pool air bubbling. The >15 micron size range accounts for more than 60 wt % of the emissions (24590-HLW-3YD-HOP-00001).

Acid gas generating species (SO_4^{-2}, Se, NO_2^-, NO_3^-, F^-, Cl^-, I^-, and CO_3^{-2} to a lesser extent) generate acid gases at the cold cap because of the water present. The metals are converted to oxides, which then react with water to form hydroxide particulates. These metal hydroxide entrained solids then react with acid gases to form salt.

Metal Oxides

Metal salts fed to the melter are converted to oxides. The mass balance and general flowsheet convention used for those metals with multiple oxide states is to use the most oxidized state. Most of the metal oxide enters the molten glass pool and leaves as glass product. A very small amount is lost to the melter offgas stream as particulates (or solids) in that stream. Partitioning of these metals is in accordance with empirically determined DFs. As examples, metal oxides and hydroxides are shown:

Equation 4.2-1

$$R_2O \rightarrow (1\text{-}1/DF)R_2O\downarrow + (1/DF)R_2O\uparrow$$

Equation 4.2-2

$$2ROH \rightarrow (1\text{-}1/DF)R_2O\downarrow + (1/DF)R_2O\uparrow + H_2O\uparrow$$

where:

R represents any metal

DF is the decontamination factor for a given metal R or metal oxide

$\downarrow$ means that the component listed to the left goes down into the glass

$\uparrow$ means that the component listed to the left goes up with the offgases

The above equations can be written in terms of hypothetical charged species; therefore, the equivalents for the above equations are:

Equation 4.2-3

$$2R^{+} + O^{-2} \rightarrow (1\text{-}1/DF)2R^{+}\downarrow + (1/DF)2R^{+}\uparrow + (1 - 1/DF)O^{-2}\downarrow + (1/DF)O^{-2}\uparrow$$

Equation 4.2-4

$$2R^{+} + 2OH^{-} \rightarrow (1 - 1/DF)2R^{+}\downarrow + (1/DF)2R^{+}\uparrow + 2H^{+}\uparrow + (1\text{-}1/DF)O^{-2}\downarrow + (1/DF)O^{-2}\uparrow$$

Then to balance charges between streams, the following needs to be done:

Equation 4.2-5

$$(n/2)O^{-2}\uparrow \rightarrow (n/2)O^{-2}\downarrow$$

where:

n is the total number of R^{+} ions minus all anions (such as Cl^{-}, SO_4^{-2}, including O^{-2}) in the glass. The appropriate amount of $O^{-2}\uparrow$ is then transferred from the offgas to the glass product (i.e., $O^{-2}\downarrow$) by Equation 4.2-5.

Then to balance for water, the H+ ions must be reacted with the remaining O^{-2} to produce water in the offgas:

Equation 4.2-6

$$2\ H^{+}\uparrow + O^{-2}\uparrow \rightarrow H_2O\uparrow$$

The data from the R&T reports are used, when available, to develop the revised DFs. R&T reports used to revise DFs for the metals are listed in 24590-WTP-M4C-V37T-00008. The revised DFs are listed in **Table 4.2-3** and used in the flowsheet.

Mercury is an exception to the metal oxide behavior. Virtually all mercury that enters the melter is vaporized and sent to the offgas, 24590-WTP-RPT-PR-01-011, *Mercury Pathway and Treatment Assessment for the WTP*. If the melter feed molar ratio of [Hg/Cl] is 0.1 or less, virtually all the mercury is converted to soluble $HgCl_2$ gas in the melter plenum; if the ratio of [Hg/Cl] is greater than 0.5, the majority of the mercury remains in the elemental form (Hg^0) in the plenum (24590-101-TSA-W000-0004-125-00004, *WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant*).

Nitrates, Nitrites, and Ammonia

Table 4.2-2 shows the NO_x emissions for HLW simulants which were vitrified in the DM1200 melter. The data shows that on average, 60 % of the feed nitrates and nitrites are exhausted from the melter as nitrogen oxides gasses (NO, NO_2, and N_2O). The remaining 40 % leaves as N_2 and a small amount of NH_3. The majority of the nitrogen oxides exhausted from the HLW melter is NO, accounting for on average 96 % of the total NO_x emitted. The amount of NO_x leaving the HLW melter is much smaller than for low-activity waste (LAW), since the HLW feed is lower in nitrates than the LAW feed. In many cases, the HLW data for NO_2, N_2O, and NH_3 were below detection limits. Figure 4.2-2 compares the HLW and LAW data for nitrogen compounds in the melter exhaust (see Section 3.2.3.4). The figure shows that the same general trend is found; that approximately 60 % (62.6 % LAW compared with 60.12 % HLW) of the feed nitrates and nitrites are exhausted as nitrogen oxide compounds, the majority of which are NO. For HLW less NO_2, N_2O, and NH_3 were detected, and a slightly higher percent of NO (82 % LAW vs. 96 % HLW). The quantities of nitrogen oxides in the HLW melter exhaust are very small, and there is a high degree of variation in the emissions during all tests. It will be advantageous to use one set of stoichiometric numbers for the nitrates and nitrites to simplify the melter model. The LAW data and equations discussed in Section 3.2.3.4 will represent the HLW nitrogen oxide emissions within a reasonable approximation in the flowsheet.

The equations developed in Section 3.2.3.4 are restated below as Equation 4.2-7:

Equation 4.2-7

$$RNO_3 + 0.0362H_2O \rightarrow 0.5R_2O\downarrow + 0.2546N_2\uparrow + 0.4239NO\uparrow + 00.0428NO_2\uparrow + 00.0242NH_3\uparrow + 1.013O_2\uparrow$$

Equation 4.2-8

$$RNO_2 + 0.0362H_2O \rightarrow 0.5R_2O\downarrow + 0.2546N_2\uparrow + 0.4239NO\uparrow + 00.0428NO_2\uparrow + 00.0242NH_3\uparrow + 0.513O_2\uparrow$$

The R&T experimental data (24590-101-TSA-W000-0009-34-03, 24590-101-TSA-W000-0009-98-07, 24590-101-TSA-W000-0009-144-01, 24590-101-TSA-W000-0009-144-02) has shown a near neutral pH in the SBS. In the flowsheet model, the actual ammonia produced from the melter is an iterative process with the SBS pH. A stoichiometric ammonia multiplier is used to increase or decrease the amount of ammonia generated such that the SBS condensate is neutral. The multiplier is one plus the percent increase or decrease; for example, if the NH_3 is required to increase by 2 %, then the NH_3 multiplier would be 1.02. The nitrogen used to adjust the ammonia is taken or added to the amount of N_2 produced. Using the NH_3 multiplier (xNH_3), Equation 4.2-8 can be written as follows:

Equation 4.2-9

$$RNO_2 + 0.0362(xNH_3)\,H_2O \rightarrow 0.5R_2O + 0.2546\text{-}0.0121*(xNH_3\text{-}1)\,N_2 + 0.4239\,NO + 0.0428NO_2 + 0.513 + 0.0181(xNH_3\text{-}1)O_2 + 0.0242(xNH_3)\,NH_3$$

The ammonia produced in Equation 4.2-9cannot exceed the amount of N_2 produced; hence, the value of the ammonia multiplier, xNH_3, cannot exceed 22.1.

Sulfates and Sulfites

Sulfates are destroyed in the cold cap to produce metal oxides that are absorbed by the glass pool, and SO_x (primarily SO_2) gases are released to the plenum.

Equation 4.2-10

$$R_2SO_4 \rightarrow R_2O\downarrow + aSO_3\uparrow + (1\text{-}a)SO_2\uparrow + [(1\text{-}a)/2]O_2\uparrow$$

Likewise, for sulfite:

Equation 4.2-11

$$R_2SO_3 \rightarrow R_2O\downarrow + SO_2\uparrow$$

The VSL offgas pilot studies (24590-101-TSA-W000-0009-74-01) show that most of the sulfur comes off the melter as SO_2 gas with little or no SO_3 in the offgas. Precipitates of sulfur in the SBS are reported as sulfate, even though sulfite may be present. VSL does not make the distinction between sulfate (SO_4^{-2}) and sulfite (SO_3^{-2}) in their analysis and reports. Thus, with SO_2 being the predominant SO_x specie in the melter offgas, one could argue that more sulfite is produced in the SBS than sulfate. Adjustment of value "a" will change the ratio between sulfates and sulfites.

Carbonates

Equation 4.2-12

$$R_2CO_3 \rightarrow R_2O\downarrow + aCO_2\uparrow + (1\text{-}a)CO\uparrow + [(1\text{-}a)/2]O_2\uparrow$$

The VSL offgas pilot studies (24590-101-TSA-W000-0009-74-01 and CCN 06527) show that most of the carbon becomes CO_2 with little or no CO in the offgas. Adjustment of the value "a" may be necessary to more closely match the pilot studies. Some of the glass formers supply significant quantities of carbonates.

Boric Acid and Borates

Boric acid and borates mainly come from glass formers. The mass balance reactions for these are:

Equation 4.2-13

$$2H_3BO_3 + \rightarrow (1\text{-}1/DF)B_2O_3\downarrow + (1/DF)B_2O_3\uparrow(\text{particulate/solid}) + 3H_2O\uparrow$$

Or in flowsheet terms:

Equation 4.2-14

$$2B^{+3} + 3O^{-2} + 3H_2O \rightarrow (1\text{-}1/DF)2B^{+3}\downarrow + (1/DF)2B^{+3}\uparrow(\text{particulate/solid}) + 3H_2O\uparrow + (1 - 1/DF)3O^{-2}\downarrow + (1/DF)3O^{-2}\uparrow$$

The HLW process is converting from boric acid addition to borax. The equation for borax is:

Equation 4.2-15

$$Na_2B_4O_7 \cdot 10H_2O \rightarrow (1\text{-}1/DF_{Na+})Na_2O\downarrow + (1\text{-}1/DF_{B+3})2B_2O_3\downarrow + (1/DF_{Na+})Na_2O\uparrow + (1/DF_{B+3})2B_2O_3\uparrow + 10\ H_2O\uparrow$$

Hydroxides

Hydroxides are covered in discussion of other reactions throughout this section.

Organics

Organics are present in the feed. The vast majority of these are in the form of complexants, which were used in the Hanford process for separating species. These complexants include: ethylenediamine tetra-acetic acid (EDTA), N-(2-hydroxyethyl) ethylenediamine tri-acetic acid (HEDTA), acetate, formate, oxalate, gluconate, glycolic acid, citric acid, iminodiacetic acid (IDA), and nitrilotriacetic acid (NTA). All the R&T organics data was collected on LAW simulants only and therefore will be also used for HLW. R&T reports 24590-101-TSA-W000-0009-106-18, 24590-101-TSA-W000-0009-107-01, 24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-111-02, and 24590-101-TSA-W000-0009-120-06 showed that the organic wastes are not entirely oxidized in the melter or its plenum. As a result, these partially oxidized compounds may form a number of intermediate products within the melter, prior to the thermal catalytic oxidizer. One prevalent intermediate product that has been detected in a number of test runs is acetonitrile (also known as methyl cyanide). Acetonitrile is a partial decomposition product of EDTA, HEDTA, IDA, and, contingent on the availability of nitrogen, sugar. A considerable number of other compounds have been detected in the melter offgases, including volatile organic compounds (e.g., acetone and acyrlonitrile) (Figure 4.2-5); chlorinated organic compounds (e.g., carbon tetrachloride and trichloroethene) (Figure 4.2-6); semi-volatile organic compounds (e.g., styrene, diethyl phthalate, nitrobenzene, and 2-nitrophenol) (Figure 4.2-7 through Figure 4.2-9); and very small amounts of dioxins, furans (Figure 4.2-10), and polychlorinated biphenyls (PCB) (Figure 4.2-11). Figure 4.2-12 and Figure 4.2-13 show additional compounds found in melter offgas that were detected in the DM1200 melter while processing Envelope C1 simulant waste. Melter DFs for destroying spiking compounds (chlorobenzene, trichloroethylene, and naphthalene) are shown in Figure 4.2-12.

Figure 4.2-5 shows that the melters are likely to produce some organic offgas emissions in the form of acrylonitrile, acetone, and acetonitrile for all three LAW envelopes. The quantity of acetonitrile, on a mass-per-mass basis, that was produced ranged between 0.2 and 4.25 % of the total organic compound feed mass. Acrylonitrile ranged between 0.0014 and 0.3 % of the organic feed mass. Acetone ranged from about 75 % of the acrylonitrile mass to non-detectable levels. Bromomethane and benzene may be produced at 0.000006 to 0.02 % of the organic feed mass in A and C wastes.

Figure 4.2-6 shows the results from the DM1200 melter tests with A1 and C1 spiked samples. In the DM1200 A1-spiked test, chlorobenzene and trichloroethene were both at about 0.8 % of the organic feed to the melter. However, all the chlorinated organics, other than chlorobenzene and trichloroethene, were measured at ≤ 0.03 % of the organic feed mass.

Figure 4.2-7 shows the results for other organics, nearly all of which were created downstream of the melter. The largest constituent was xylene in the DM3300 Envelope A test at 0.02 % of the organic feed. All other values were below this point and most other melter test organic masses were below 0.003 % of the organic feed mass.

Figure 4.2-8 shows some additional organics, which were likely created after the melter. The highest readings were for the DM3300 Envelope A test, at 0.0078 % of the organic feed (2,4-dinitrophenol) and at 0.0063 % of the organic feed (nitrobenzene). Most of the detections were at less than 0.001 % of the organic feed mass.

Figure 4.2-9 shows some semi-volatiles that were measured after the melter. The greatest concentration was for 2-nitrophenol at 0.0067 % of the organic feed mass (DM3300 Envelope A test). 2-nitrophenol was measured at concentrations ranging from 0.0067 % to a minimum of 0.000010 % mg/mg.

4-nitrophenol was measured from a high of 0.0059 % (DM3300 Envelope A test) to non-detection. The vast majority of the remaining compounds were at 0.001 % or lower of organic feed mass.

Figure 4.2-10 shows a distribution of dioxin and furan mass measurements ranging from a high of 1.14×10^{-10} mg/mg organic feed (DM3300 Envelope B test) to undetectable concentrations of some specific compounds in the melter offgases. Most of the dioxin/furan concentrations were less than 1.0×10^{-11} mg/mg and greater than 1.0×10^{-13} mg/mg of total organic feed.

Figure 4.2-11 shows measured PCB concentrations for the melter offgas. Measured quantities varied from a maximum of 3.22×10^{-10} mg/mg organic feed (DM3300 Envelope, B test) to undetectable levels for certain compounds.

Figure 4.2-12 shows observed DFs for the organic spiking compounds in the DM1200 tests for LAW Envelopes A and C (24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-111-02).

Figure 4.2-13 shows the relationship between the type of organic feed to the melter (e.g., sugar or complexants) and the generation of the three most prominent offgas constituents, such as acetonitrile. The graphs, based on the R&T reports, tend to show that sugar is the greatest contributor by far. When sugar feed is reduced by a factor of 10, the formation of these products of incomplete combustion (PIC) dropped by several orders of magnitude. However, when the complexant feed was eliminated, there was only a minimal reduction in the PIC formation rate.

Figure 4.2-14shows the relationship between the type of organic feed to the melter (e.g., sugar or complexants) and the generation of chlorinated dibenzo dioxins (CDD), chlorinated dibenzo furans (CDF), and PCBs. The graphs, based on the R&T reports, tend to show that sugar is the greatest contributor; therefore, one could expect little generation of these compounds from HLW vitrification. The graph also shows that complexants may actually retard the formation of these compounds, but that needs to be verified.

Figure 4.2-15 shows the apparent lack of relationship between the proportions of sugar and complexants in the organic feed and the overall organic destruction and removal efficiencies (DRE) achieved in the melter. The implication of this is that sugar and the complexants are equally oxidized in the melter and that the average DRE is about 98.5 % (average DF = 66.7). Small dips in the DREs were noticeable for the spiked tests (A12S and C12S) due to the lower DREs for the spiking compounds. See the discussion of Figure 3.2-11 in Section 3.2 on the above DREs, for the spiking compound DFs. Conclusion: DFs for sugar and complexants = 66.7.

Figure 4.2-16 shows the relationship between the sugar feed, the complexant feed, the organic spikes, and the resultant total offgas mass flow. Note that the offgas mass flow increases to meet the spiked compounds mass flow data points for the DM1200 A1 (A12S) and for the DM1200 C1 (C12S) test runs. This increase is due to the poor destruction for the spiking compounds, when compared to the balance of the organic feed. Note also that there is no apparent correlation between the relative percentages of sugar and complexant with the organic offgas formation rate.

Figure 4.2-17 shows the relationship between the sugar feed, the complexant feed, the organic spikes, and the resultant total chlorinated dibenzo dioxins, chlorinated dibenzo furans, and polychlorinated biphenyls (CDD/CDF/PCB) production and resultant acetonitrile/acrylonitrile/acetone (ACE) production. Unlike the results for Figure 4.2-17 for total organic offgas mass flow, this figure better defines the source of certain priority offgas constituents.

The figure indicates that when sugar feed mass exceeds complexant feed mass, generation of ACE compounds and of CDD/CDF/PCB is elevated. Conversely, when complexants are the dominant contributor to organic feed, ACE and CDD/CDF/PCB formation is reduced. ACE is reduced by about 3 orders of magnitude and CDD/CDF/PCB by about a factor of 5. Notable exceptions are with the spiked tests. In test A12S, both ACE and CDD/CDF/PCB were elevated above equivalent non-spiked generation rates. The same applies regarding CDD/CDF/PCB in the C12S test. Of interest is the fact that ACE in the C12S test was depressed further by the spikes. Conclusion: Sugar is a dominant precursor for ACE and a more important precursor for CDD/CDF/PCB formation than are the complexants.

When complexant content is greater than sugar content, both offgas groups are depressed. Spiking increases the production of CDD/CDF/PCB, but sometimes apparently suppresses the production of ACE. A conservative estimate is that sugar contributes up to 100 times more ACE generation than complexants and 5 times more CDD/CDF/PCB production than complexants. Some organics are given a melter DF of 10. This means that 10 % of the organic is volatized without transformation or is transformed into an intermediate PIC and the remaining 90 % is completely oxidized. In the Envelope A1 tests on the DM1200 melter, offgas products were equal to 0.24 % of the organic feed for the non-spiked melter and 2.45 % for the spiked melter. In all tests, non-spiked organic feed consisted of sugar plus complexants and spiked feed consisted of sugar, complexants, and the three spiking compounds. In the DM1200 tests for Envelope C1, 0.00194 % of the unspiked mass and 1.27 % of the spiked mass were recorded as offgas products. In the DM3300 melter test for Envelope A, the mass of offgas products equaled 4.77 % of the organic waste feed. In the DM3300 melter test for Envelope C, the offgas product mass was about 1.34 % of the organic feed mass. And in the DM3300 test for Envelope B, the offgas product mass was about 0.25 % of the total organic feed mass (24590-101-TSA-W000-0009-111-02, 24590-101-TSA-W000-0009-111-01, 24590-101-TSA-W000-0009-107-01, and 24590-101-TSA-W000-0009-120-06). The overall averages were 1.32 % for non-spiked feed and 1.86 % for spiked feed.

Until confirming or conflicting data is received, DF = 10 will be used to forecast destruction for all of the complexants in Equation 4.2-16 through Equation 4.2-23. The equations for oxidation of organics follow. Some of the oxygen for combusting comes from the nitrates in the waste. Pilot melter studies indicate that the nitrates are not fully reduced (24590-101-TSA-W000-0009-111-02). Also, in reality, not all organics burn to completion (that is, to H_2O, CO_2, and N_2) in the melter. Adjustments for lack of complete combustion and nitrate reduction are made. The adjustments are given in the *nitrates*, *nitrites*, and *carbonates* sections. Adjustments to DFs will be made to more closely match what is seen in pilot melter tests.

The following oxidation equations for the complexants are presented in two steps. The first step represents the intermediate products (i.e., PICs) that may be produced. Acetonitrile, which has been readily detected in the pilot melters, has been used as an indicator compound for modeling purposes. The second step oxidizes the rest of the offgas products to basic compounds, (e.g., H_2O, CO_2, HCl). In nearly all cases, the complete two-step reaction occurs in the melter (conversion factor [CF] = 0.98855). However, in a small number of cases (an average CF = 0.01145) the reaction is unable to run to completion and the intermediate products continue as offgases. The subsequent PICs must be processed in the offgas system to meet air permit conditions.

It is important to note that R&T data tend to indicate that sugar is the source of most of the offgas products, such as acetonitrile, acrylonitrile, acetone, and constituents such as PCB, dioxins, and furans. See Figure 3.2-14 which implies that acetonitrile production, for example, is more dependent on sugar feed content than complexant content. Test B33N (Envelope B, DM3300 melter, non-spiked) had no EDTA or HEDTA in the feed, but still had significant acetonitrile, acrylonitrile, and acetone offgas content. Other tests which had significant EDTA and HEDTA feed had little or none of those products

(Envelope C tests on DM1200 melter [C12N and C12S], for example). Figure 3.2-15 indicates that total PCB/dioxin/furan production is not reduced when complexant content is reduced. In fact, the DM3300 test of Envelope B (B33N) shows an increase in those offgas constituents when the complexants are reduced. Conversely, PCB/dioxin/furan production appears to be reduced when the complexant feed approaches the sugar feed.

Equation 4.2-16

Oxalate

$C_2O_4^{-}{}_{(s)} \rightarrow 2\ CO_{2(g)}$ CF = 1.0000

Equation 4.2-17

Formate

$CHO_2^{-}{}_{(s)} \rightarrow 0.25\ O_2 \rightarrow CO_{2(g)} + 0.5\ H_2O_{(g)}$ CF = 1.0000

Equation 4.2-18

Acetate

$C_2H_3O_2^{-}{}_{(s)} + 1.75\ O_2 \rightarrow 2\ CO_{2(g)} + 1.5\ H_2O_{(g)}$ CF = 1.0000

Equation 4.2-19

Glycolic Acid

$C_2H_3O_3{}_{(s)}^{-} + 1.25\ O_2 \rightarrow 2\ CO_{2(g)} + 1.5\ H_2O_{(g)}$ CF = 1.0000

Equation 4.2-20

IDA

$C_4H_7NO_{4(s)} + 3.75\ O_2 \rightarrow 4\ CO_{2(g)} + 3.5\ H_2O_{(g)} + 0.5\ N_{2(g)}$ CF = 0.985056

$C_4H_7NO_{4(s)} + O_2 \rightarrow C_2H_3N_{(g)} + 2\ CO_{2(g)} + 2\ H_{2\ (g)}$ CF = 0.014944

ΔN_2 = -(0.492528 moles $C_4H_7NO_4$)

ΔO_2 = -(0.985056 moles $C_4H_7NO_4$)

ΔNO_2 = +(0.985056 moles $C_4H_7NO_4$)

Equation 4.2-21

Citric Acid

$C_6H_5O_7^{-3}{}_{(s)} + 3.75\ O_2 \rightarrow 6\ CO_{2(g)} + 2.5\ H_2O_{(g)}$ CF = 0.985056

$C_6H_5O_7^{-3}{}_{(s)} \rightarrow 0.833\ C_6H_{6(g)} + CO_{2(g)} + 2.5\ O_{2(g)}$ CF = 0.014944

Equation 4.2-22

HEDTA

$C_{10}H_{15}N_2O_7^{-3}{}_{(s)} + 10.25\ O_2 \rightarrow 10\ CO_{2(g)} + 7.5\ H_2O_{(g)} + N_{2(g)}$ CF = 0.985056

$C_{10}H_{15}N_2O_7^{-3}{}_{(s)} + 4.75\ O_2 \rightarrow 2\ C_2H_3N_{(g)} + 6\ CO_{2(g)} + 4.5\ H_2O_{(g)}$ CF = 0.014944

$0.985056\ N_2 + 1.970112\ O_2 \rightarrow 1.970112\ NO_2$ CF = 1.0000

$\Delta N_2 = -(0.985056$ moles $C_{10}H_{15}N_2O_7^{-3})$

$\Delta O_2 = -(1.970112$ moles $C_{10}H_{15}N_2O_7^{-3})$

$\Delta NO_2 = +(1.970112$ moles $C_{10}H_{15}N_2O_7^{-3})$

Equation 4.2-23

EDTA

$C_{10}H_{12}N_2O_8^{-4}{}_{(s)} + 9\ O_2 \rightarrow 10\ CO_{2(g)} + 6\ H_2O_{(g)} + N_{2(g)}$ CF = 0.985056

$C_{10}H_{12}N_2O_8^{-4}{}_{(s)} \rightarrow 2\ C_2H_3N_{(g)} + C_6H_{6(g)} + 4\ O_{2(g)}$ CF = 0.014944

$0.985056\ N_2 + 1.970112\ O_2 \rightarrow 1.970112\ NO_2$ CF = 1.0000

$\Delta N_2 = -(0.985056$ moles $C_{10}H_{12}N_2O_8^{-4})$

$\Delta O_2 = -(1.970112$ moles $C_{10}H_{12}N_2O_8^{-4})$

$\Delta NO_2 = +(1.970112$ moles $C_{10}H_{12}N_2O_8^{-4})$

The following are oxidation reactions for organic tracking compounds currently used in the flowsheets. Each compound is representative of one of the tracking groups used in the emissions runs. These reactions represent complete oxidation, whether in the melter or the thermal catalytic oxidizer. PICs, resulting from partial oxidation of these compounds, are not shown and will be included as they are identified. Some of these compounds are themselves formed as PICs from the partial oxidation of waste feed organics, such as the complexants, in the melter plenum. DFs will be used to determine the extent of oxidation of these compounds in the melters.

Tracking Compound Oxidation Reactions

CAS Number	Compound	Formula	Oxidation Reaction
126-73-8	Tributyl phosphate	C12H27O4P	C12H27O4P + 18.75O2 > 12CO2 + 13.5H2O + PO4
84-66-2	Diethyl phthalate	C12H14O4	C12H14O4 + 13.5O2 > 12CO2 + 7H2O
62-75-9	N-Nitroso-N, N-dimethylamine	C2H6N2O	C2H6N2O + 5O2 > 2CO2 + 3H2O + 2NO2
58-90-2	2,3,4,6-Tetrachlorophenol	C6H2Cl4O	C6H2Cl4O + H2O + 5O2 > 6CO2 + 4HCl
75-05-8	Acetonitrile	C2H3N	C2H3N + 3.75O2 > 2CO2 + 1.5H2O + NO2
208-96-8	Acenaphthylene	C12H8	C12H8 + 14O2 > 12CO2 + 4H2O
132-64-9	Dibenzofuran	C12H8O	C12H8O + 13.5O2 > 12CO2 + 4H2O
91-20-3	Naphthalene	C10H8	C10H8 + 12O2 > 10CO2 + 4H2O
120-82-1	1,2,4-Trichlorobenzene	C6H3Cl3	C6H3Cl3 + 6O2 > 6CO2 + 3HCl
71-43-2	Benzene	C6H6	C6H6 + 7.5O2 > 6CO2 + 3H2O

CAS Number	Compound	Formula	Oxidation Reaction
79-01-6	Trichloroethylene	C2HCl3	2C2HCl3 + 2.5H2O + 2.75O2 > 4CO2 + 6HCl
127-18-4	Perchloroethylene	C2Cl4	C2Cl4 + 2H2O > 2CO2 + 4HCl
56-23-5	Carbon Tetrachloride	CCl4	CCl4 + 2H2O > CO2 + 4HCl
110-82-7	Cyclohexane	C6H12	C6H12 + 9O2 > 6CO2 + 6H2O
106-97-8	Butane	C4H10	C4H10 + 6.5O2 > 4CO2 + 5H2O
111-84-2	n-Nonane	C9H20	C9H20 + 14O2 > 9CO2 + 10H2O
50-32-8	Benzo(a)pyrene	C20H12	C20H12 + 23O2 > 20CO2 + 6H2O
84-74-2	Di-n-butyl phthalate	C16H22O4	C16H22O4 + 19.5O2 > 16CO2 + 11H2O
129-00-0	Pyrene	C16H10	C16H10 + 18.5O2 > 16CO2 + 5H2O
1336-36-3	Polychlorinated biphenyls (PCBs)	C12H4CL6	C12H4CL6 + 12O2 + H2 > 12CO2 + 6HCl
629-50-5	Tridecane	C13H28	$C13H28_{(l)}$ + 20 O2 → 13 CO2 + 14 H2O (CF = 0.9091) $C13H28_{(l)}$ + 5 O2 → 2 $C6H6_{(g)}$ + CO2 + 8 H2O (CF = 0.0909)

Offgas constituent compounds, mostly PICs, have been identified in VSL and Duratek reports on the processing of WTP Envelope A, B, or C waste simulants. The identified PICs are shown on the following table along with their corresponding Chemical Abstract Service (CAS) number and chemical formula. The reaction for complete oxidation of the compound is also shown. Due to the large number of these compounds and capacity of the flowsheets to handle additional constituents, they are presented here for reference only.

PIC Oxidation Reactions

CAS Number	Compound	Formula	Oxidation Reaction
100-02-7	4-Nitro-phenol	C6H5NO3	C6H5NO3 + 6.75O2 > 6CO2 + 2.5H20 +NO2
105-67-9	2,4 Dimethyl-phenol	C8H11O	C8H11O + 10.25O2 > 8CO2 + 5.5H20
121-14-2	2,4 Dinitro-toluene	C7H6N2O4	C7H6N2O4 + 8.5O2 > 7CO2 + 3H20 + 2NO2
1746-01-6	2,3,7,8-TCDD	C12Cl4O2	C12Cl4O2 + 2H2 + 10O2 > 12CO2 + 4 HCl
19408-74-3	1,2,3,7,8,9-HxCDD	C12Cl6O2	C12Cl6O2 + 3H2 + 9.5O2 > 12CO2 + 6 HCl
31508-00-06	PCB 118	C12H5CL5	C12H5CL5 + 12O2 > 12CO2 + 5HCl
32598-13-3	PCB 77	C12H6CL4	C12H6CL4 + 12.5O2 > 12CO2 + H20 + 4HCl
32598-14-4	PCB 105	C12H5CL5	C12H5CL5 + 12O2 > 12CO2 + 5HCl
3268-87-9	OCDD	C12Cl8O2	C12Cl8O2 + 4H2 + 9O2 > 12CO2 + 8HCl
32774-16-6	PCB 169	C12H4CL6	C12H4CL6 + H2 + 11.5O2 > 12CO2 + 6HCl

CAS Number	Compound	Formula	Oxidation Reaction
35822-46-9	1,2,3,4,6,7,8-HpCDD	C12Cl7O2	C12Cl7O2 + 3.5H2 + 9.25O2 > 12CO2 + 7HCl
38380-08-4	PCB 156	C12H4CL6	C12H4CL6 + H2 + 11.5O2 > 12CO2 + 6HCl
69782-90-7	PCB 157	C12H4CL6	C12H4CL6 + H2 + 11.5O2 > 12CO2 + 6HCl
39001-02-0	OCDF	C12H4CL8O	C12H4CL8O + 2H2 + 10.5O2 > 12CO2 + 8 HCl
39227-28-6	1,2,3,4,7,8-HxCDD	C12Cl6O2	C12Cl6O2 + 3H2 + 9.5O2 > 12CO2 + 6 HCl
40321-76-4	1,2,3,7,8-PeCDD	C12Cl5O2	C12Cl5O2 + 2.5H2 + 9.75O2 > 12CO2 + 5 HCl
51207-31-9	2,3,7,8-TCDF	C12H4CL4O	C12H4CL4O + 11.5O2 > 12CO2 + 4 HCl
51-28-5	2,4-Dinitro-phenol	C6H4N2O5	C6H4N2O5 + 6.5O2 > 6CO2 + 2H2O + 2NO2
534-52-1	4,6-Dinitro-2-methyl-phenol	C7H6N2O5	C7H6N2O5 + 8O2 > 7CO2 + 3H20 + 2 NO2
55673-89-7	1,2,3,4,7,8,9-HpCDF	C12H4CL7O	C12H4CL7O + 1.5H2 + 10.75O2 > 12CO2+ 7HCl
56-23-5	Carbon Tetrachloride	CCl4	CCl4 + 2H2O > CO2 + 4HCl
57117-31-4	2,3,4,7,8-PeCDF	C12H4CL5O	C12H4CL5O + 0.5H2 + 11.25O2 > 12CO2 + 5 HCl
57117-41-6	1,2,3,7,8-PeCDF	C12H4CL5O	C12H4CL5O + 0.5H2 + 11.25O2 > 12CO2 + 5HCl
57117-44-9	1,2,3,6,7,8-HxCDF	C12H4CL6O	C12H4CL6O + H2 + 11O2 > 12CO2 + 6 HCl
57653-85-7	1,2,3,6,7,8-HxCDD	C12Cl6O2	C12Cl6O2 + 3H2 + 9.5O2 > 12CO2 + 6 HCl
60851-34-5	2,3,4,6,7,8-HxCDF	C12H4CL6O	C12H4CL6O + H2 + 11O2 > 12CO2 + 6 HCl
67562-39-4	1,2,3,4,6,7,8-HpCDF	C12H4CL7O	C12H4CL7O + 1.5H2 + 10.75O2 > 12CO2 + 7 HCl
67-64-1	Acetone	C3H6O	C3H6O + 4O2 > 3CO2 + 3H2O
67-66-3	Chloroform	CHCl3	CHCl3 + 2H2 + 0.5O2 > CO2 + 3HCl
70648-26-9	1,2,3,4,7,8-HxCDF	C12H4CL6O	C12H4CL6O + H2 + 11O2 > 12CO2 + 6 HCl
71-43-2	Benzene	C6H6	C6H6 + 7.5O2 > 6CO2 + 3H2O
72918-21-9	1,2,3,7,8,9-HxCDF	C12H4CL6O	C12H4CL6O + H2 + 11O2 > 12CO2 + 6 HCl
74-83-9	Bromomethane	CH3Br	CH3Br + 1.5O2 > 1CO2 + H20 + HBr
74-87-3	Chloromethane	CH3Cl	CH3Cl + 1.5O2 > CO2 + H2O + HCl
74-88-4	Iodomethane	CH3I	CH3I + 1.5O2 > CO2 + H20 + HI
75-05-8	Acetonitrile	C2H3N	C2H3N + 3.75O2 > 2CO2 + 1.5H2O + NO2
75-15-0	Carbon Disulfide	CS2	CS2 + 3O2 > CO2 +2SO2
78-93-3	2-Butanone	C4H8O	C4H8O + 5.5O2 > 4CO2 + 4H2O
79-01-6	Trichloroethene	C2HCl3	2C2HCl3 + 2.5H2O + 2.75O2 > 4CO2 + 6HCl
84-66-2	Diethyl phthalate	C12H14O4	C12H14O4 + 13.5O2 > 12CO2 + 7H2O
84-74-2	Di-n-butyl Phthalate	C16H22O4	C16H22O4 + 19.5O2 > 16CO2 + 11H2O

CAS Number	Compound	Formula	Oxidation Reaction
85-01-8	Phenanthrene	C14H10	C14H10 + 16.5O2 > 14CO2 + 5H20
85-68-7	Butyl Benzyl Phthalate	C19H20O4	C19H20O4 +22O2 > 19CO2 + 10H2O
88-75-5	2-Nitro-phenol	C6H5NO3	C6H5NO3 + 6.75O2 > 6CO2 + 2.5H20 +NO2
91-20-3	Naphthalene	C10H8	C10H8 + 12O2 > 10CO2 + 4H2O
91-57-6	2-Methyl-naphthalene	C11H10	C11H10 + 13.5O2 > 11CO2 + 5H20
98-95-3	Nitro-benzene	C6H5NO2	C6H5NO2 + 7.25O2 > 6CO2 + 2.5H2O + NO2
57465-28-8	PCB 126	C12H5CL5	C12H5CL5 + 12O2 > 12CO2 + 5HCl
70362-50-4	PCB 81	C12H6CL4	C12H6CL4 + 12.5O2 > 12CO2 + H20 + 4HCl
74472-37-0	PCB 114	C12H5CL5	C12H5CL5 + 12O2 > 12CO2 + 5 HCl
65510-44-3	PCB 123	C12H5CL5	C12H5CL5 + 12O2 > 12CO2 + 5 HCl
52663-72-6	PCB 167	C12H4CL6	C12H4CL6 + H2 + 11.5O2 > 12CO2 + 6 HCl
39635-31-9	PCB 189	C12H4CL6	C12H4CL6 + H2 + 11.5O2 > 12CO2 + 6 HCl

Phosphates

Most of the phosphates go into the glass. However, a small fraction is lost to the offgas per the following equation:

Equation 4.2-24

$$2\ PO_4^{-3} \rightarrow P_2O_5(\text{solid})\uparrow + 3\ O^{-2}\downarrow$$

Halides

The acid gases behave like the sulfate (some are expected to form acid gases and salt particulates). The exception is iodine, which can be expected to also form elemental iodine gas. Ratios between the acid and salt will be adjusted to approximate what is seen in the melter pilot results.

Equation 4.2-25

$$2\ Cl^- + H_2O \rightarrow 2\ HCl(g)\uparrow + O^{-2}\downarrow \text{ and}$$

Equation 4.2-26

$$Cl^- \rightarrow Cl^-\uparrow \text{ (particulate, g)}$$

Equation 4.2-27

$$2\ F^- + H_2O \rightarrow 2\ HF(g)\uparrow + O^{-2}\downarrow \text{ and}$$

Equation 4.2-28

$$F^- \rightarrow F^-\uparrow \text{(particulate, g)}$$

Equation 4.2-29

$$2\ I^- + H_2O \rightarrow 2\ HI(g)\uparrow + O^{-2}\downarrow \text{ and}$$

Equation 4.2-30

$$I^- \rightarrow I^-\uparrow(\text{particulate, g}) \text{ and}$$

Equation 4.2-31

$$2I^- \rightarrow I_2\uparrow(g)$$

Radionuclides

Radionuclides will follow their non-radionuclide components, if present. For example, all ^{14}C forms $^{14}CO_2$ in the melter, so ^{14}C follows CO_2 in the offgas system.

4.2.3.3.4 Enhanced Cesium Volatility on the Presence of Technetium

Literature data has shown that volatility of Cs in a melter environment can be enhanced under the presence of high technetium concentrations. Due to the deletion of the technetium ion exchange system from the PT Facility flowsheet, the technetium to cesium ([Tc/Cs]) mass ratios dramatically increased in the LAW flowsheet. For HLW, the ratios remained unchanged or slightly decreased. Tests performed by R&T at the VSL DM100 melter to determine the impacts of these increased ratios in the LAW and HLW flowsheets using Re as a surrogate for technetium (24590-101-TSA-W000-00009-157-0001). Rhenium was selected based on documented similarities in chemical and physical behavior.

HLW results showed that feed Cs volatility increased from 4 to 34 % when the [Re/Cs] ratios were changed between 0.5 and 20. At higher [Re/Cs] mass ratios (400 to 10,000) the feed Cs volatility percentage experienced was between 58 and 100 %. Per the baseline run in the 2005 Dynamic Flowsheet Assessment (24590-WTP-MRQ-PO-05-0014), the expected [Tc/Cs] mass ratios at the HLW melter feed vessels range from 0.002 to 95 with an overall average of 10. Of these numbers, 50 % are below a [Tc/Cs] mass ratio of 1 and 49 % are between 1 and 50. This indicates that any enhanced Cs volatility from the melter is not going to be significant for the HLW Facility (as it is within the range currently predicted in the flowsheet), and when it does occur the HLW Facility design should be more than adequate to handle the additional Cs. Current volatility predicted in the flowsheet is shown in Table 4.2-4 and was derived by averaging all the Cs DFs from the DM1200 tests. Therefore, no changes to the flowsheet models are warranted at this time.

4.2.3.4 Production Rate and Melter Power

Temperature in the glass pool is maintained by joule heating. Electrical currrent for joule heating is delivered to the glass pool via large electrodes. Enough heat must be supplied for dissolution of the feed components into the glass pool, heating of components to glass pool temperatures, decomposition of the waste and glass formers, boiling off water, heating air in-leakage and air to bubblers and purges, loss of heat from glass transferred to the canister, and replacing heat lost throughout the melter structure.

Glass exits the melter through one of two separate discharge chambers heated with electrical resistance heaters. Air flows into the discharge chambers and melter to maintain contamination control, and is

exhausted with the other gases. Cooling water panels around the melter collect heat lost through the refractory (walls and bottom).

An energy balance around the HLW melter is detailed in 24590-QL-HC4-W000-00011-04-00271 Rev 00A, Duratek Calculation, CAL-WTP-24001, Rev 2, *HLW Mass and Energy Balance*.

Energy contributors to the melters are:

- Joule heat dissipation directly in the glass
- Resistance heaters in the discharge chambers
- Combustion of sugar added with the melter feed
- Combustion of organics in the waste
- Radioactive decay

Energy absorbers (for example, heat is required to reduce nitrate, sulfate, and carbonate compounds into metal oxides, which are formed and absorbed into the glass pool, and NO_x, SO_x, and CO_x gases that are lost to the offgas system) for the melters are:

- Endothermic reactions in the cold cap. Evaporation/boiling of water in the slurry
- Heating of water, steam, and gases lost to the offgas system
- Dissolution of components into the glass pool
- Raising temperature of glass constituents to the glass conditions

Energy losses for the melters are:

- Heat loss through the walls and bottom of the melter to cooling water panel
- Heat loss through the melter lid to the room environment
- Air in-leakage
- Air to bubblers, purges, and glass air lift
- Electrode cooling

Both melters are normally considered to be in operation. However, with some operating scenarios a melter may be placed in "hot idle." In a "hot idle" condition, the glass pool is at or near operating temperature, and airflows through the melter are maintained. No cold cap is present, so the lid loses more heat to the room environment.

4.2.3.4.1 Desired Melter Production Rate

Table 4.2-5 shows glass production rate verses the number of bubblers placed in an HLW melter. The data comes from Memorandum CCN: 144619 Jim Rouse and Rich Peters to Chris Musick, *EFRT M17: Film Cooler Blockages*, dated December 22, 2006. The CCN calculation uses VSL DM 1200 pilot melter data and then adjusts them for the HLW melter configuration.

Figure 4.2-18 shows Excel curve fit for the data in Table 4.2-5. The equation is for the seven bubblers data from Table 4.2-5:

Equation 4.2-32

$R = 0.0080 * Yield + 1.40$

where: R is the desired melter production rate, MTG/day per melter
The maximum R value is 3.00 for first 5 years and 3.75 there after.
Yield is the total glass forming oxides per liter in the melter feed, g TO/L slurry or g glass/L slurry (this assumes no losses to offgas)

The HLW glass chemistry model, known as the HLW Glass Shell (Section 4.1.3.4.3) shall be used to calculate the Yield value for the slurry in the MFPV and then apply Equation 4.2-32 to determine the rate at the melter.

4.2.3.4.2 Power Need

The melter electrical system may not be able to supply the power necessary for the desired production rate of R. Therefore, the desired power need, P_n, shall be calculated. If P_n exceeds power available, then the production rate, R, needs to be trimmed back to match the power that can be delivered. The following derives the equations.

Table 4.2-6 (which is actually Table 6 from 24590-QL-HC4-W000-00011-04-00271 Rev 00A, Duratek Calculation, CAL-WTP-24001, Rev 2, *HLW Mass and Energy Balance*) lists HLW energy requirements for processing an AZ-101 glass formula at a production rate 1.5 and 3.0 metric tons of glass per day at two different feed compositions. The energy required to maintain the melter in an idle condition at 1000°C is also given. Notice that the individual energy elements in the table do not change except for the *energy to heat and convert feed* element. The energy for this element is determined separately by a curve fit in Figure 4.2-18. Figure 4.2-18 (which is actually Figure 5 from 24590-101-TSA-W000-0009-162-00001 Rev 00A, Duratek document REP-RPP-069 Rev 0, *Investigation of Glass Bubbling and Increased Production Rate*) is a curve fit for the amount of energy to produce 1 kilogram of glass. The curve fit equation is:

Equation 4.2-33

$y = 304.08x^{-7878}$

where: y is energy required to convert 1 kilogram of feed oxides into 1 kilogram of glass from room temperature to 1150°C, kW·hr/kg.
x is slurry feed oxide concentration, g glass oxides/L

Incorporating the data in Table 4.2-6 with the curve fit gives a relationship of P_n(est.) as a function of glass forming oxides.

$$P_n(\text{est}) = \left(304.08x^{-0.787}\frac{\text{kW}\cdot\text{hr}}{\text{kg glass oxides}}\right)\left(\frac{1}{24/\text{hr}}\right)\left(\frac{1000\text{ kg glass oxides}}{\text{MT glass/day}}\right)R(\text{MT glass/day}) + (32+193)\text{kW}$$

or,

Equation 4.2-34

$P_n(\text{est.}) = 12{,}670x^{-0.7878}R + 225$

where: P_n(est.) is the estimated melter power need, kW
R is the desired melter production rate, MTG/day
x is slurry feed oxide concentration, g glass oxides/L

Equation 4.2-34 was then used in Excel to produce a matrix of melter Power Need values based on batch oxide and solids concentrations in the MFPV batch as shown in Table 4.2-7. These values were then plotted and linear curve fits determined for the melter Power Need requirements verses oxide and solids concentration in the MFPV batch. The Power Need curve fits are shown in Figure 4.2-20. The actual need is the Power Need as determined by the greater power need between the oxides or solids in the batch. Using the curve fits in Figure 4.2-20 gives the following Power Need equation, Equation 4.2-35.

Equation 4.2-35

$$\therefore P_n = \text{Max}[(3{,}728{,}499WF_{ox}^{6} - 6{,}123{,}043WF_{ox}^{5} + 4{,}046{,}560WF_{ox}^{4} - 1{,}378{,}954WF_{ox}^{3} + 258{,}058WF_{ox}^{2} - 25{,}992WF_{ox} + 1{,}933), (467{,}932WF_{TS}^{6} - 1{,}086{,}029WF_{TS}^{5} + 1{,}014{,}344WF_{TS}^{4} - 488{,}511WF_{TS}^{3} + 129{,}201WF_{TS}^{2} - 18{,}391WF_{TS} + 1{,}930)]$$

where: P_n is the melter power need, kW
R is the desired melter production rate, MTG/day
WF_{ox} is MFPVoxide concentration, (kg waste oxide + kg glass former oxide) / kg total mass, wt fraction total oxides
WF_{TS} is MFPV total solids concentration, both dissolved and undissolved solids, (kg dissolved solids + kg suspended solids + kg glass former) / kg total mass, wt fraction total solids

Actual Rate – Adjustment for Power Limitations

If the power need, P_n, exceeds the available power, then R needs to be trimmed back to match the maximum power that can be delivered.

IF P_n > Pmax then R = R * Pmax / P_n

where: Pmax = 800 kW.

Else R = R

4.2.3.5 Film Cooler and Control Air Mass and Energy Balance (HOP System)

Radiant heat from the surface of the melt results in extremely high plenum and (therefore) offgas temperatures. Due to the significant air and gas flow through the melter plenum, and the slurry being boiled by the cold cap, feed and solids are carried over to the offgas piping. The film cooler is designed to provide initial cooling of the hot melter offgases and mitigate the buildup of solids in offgas piping between the melter and the SBS.

Gases enter the film cooler at 450 °C typically. Air is also injected slightly downstream of the film cooler for pressure control. The energy contributors/absorbers for the pieces of equipment are:

- Film cooler air supply: 300 scfm at 16 °C
- Film cooler offgas discharge: Mass determined by mass balance
- Temperature determined by energy balance
- Injection air for pressure control: 200 scfm at 16 °C
- SBS inlet: Mass determined by mass balance
- Temperature determined by energy balance

Cooling air and control air values are reported in *HLW Melter Offgas System Design Basis Flowsheets* (24590-HLW-M4C-HOP-00011).

The film-cooler is cleaned intermittently with demineralized water. This is represented in the flowsheet as a 10 gal/day per film cooler demineralized water stream. The film cooler handles the combined airflow of film cooler air and melter offgas.

4.2.3.6 HLW Canister

The glass disposal canisters used to cast the molten glass are designed as 2 ft in diameter and 14.75 ft tall. To obtain the best HLW glass product quality, glass is added to the canister (glass pour) at 4 to 5 times the average glass production rate. Therefore, the glass discharges are controlled in a batch mode, while slurry feeding to the melter is continuous.

When to start and stop a glass pour is determined based on glass pool level. Working depth of the glass pool is at 44 in. The operating band of the pool depth is approximately 1 in. Cycle time between glass pours (start to start) depends on glass production rate and the level in the melter. When to start and stop a melter glass discharge is determined by using a level detector so that the level of glass in the melter is relatively constant. For flowsheet purposes, the cycle time is the time for the melter to produce the quantity of a glass pour, or 250 kg.

$$\text{Cycle time} = \frac{\text{Pour Mass}}{\text{Glass Production Rate (kg/hr)}}$$

- Design data: HLW canister (24590-HLW-M0C-30-00003)
  - Total volume (100 %):
    328.4 gal (43.9 ft^3) thin wall canister
    313.2 gal (41.9 ft^3) thick 3/8" wall canister
  - Filled volume (95 %):
    312 gal (41.7 ft^3) thin wall canister
    297.7 gal (39.8 ft^3) thick 3/8" wall canister
  - Density*: 2570 kg/m^3
  - Glass mass flowrate: 62.5-125 kg/hr (steady-state)

- Temperature (glass pour): 1150 °C (2102 °F)
- Glass flow volume: 13 gal/hr (steady state) and 48 gal/hr (dynamic)
  0.5 hr (30 min) duration of pour, 250 kg/pour
  2.0 hr (120 min) between pours (start-start) at baseline
  3 MTG/day.

* See *Glass Density* topic in Section 4.2.3.1above

The basis for vessel information is derived from engineering drawings and mechanical systems calculations per the SOW. Operating data and parameters are based on 24590-HLW-3YD-HMP-00001.

For flowsheet modeling purposes, to provide consistency, and to avoid confusion between glass densities and canister wall thickness, the WTP models will use 3000 kg HLW glass per canister.

4.2.3.6.1 Radioactive Decay Heat in HLW Glass

The major heat producing radionuclides in HLW glass are from Sr, Tc, Am, and Cs decay. The sum of heat can be significant for HLW canisters and cannot be over 1500 Watts (see Section 4.2.1.1). The specific heat of radionuclides of interest can be determined by the following relationship:

Equation 4.2-36

$$q_{\text{decay heat},\,i} = (\text{W/Ci})_i * (\text{Ci} / 3.70 \times 10^{10}\ \text{Bq}) * (1.0 \times 10^{12}\ \text{Bq/TBq}) * (\text{TBq/kgmol})_i$$

$$= (\text{W/kgmol})$$

Where the individual values for the significant heat generators are:

Isotope	W/Ci	TBq/kgmol
^{90}Sr	6.69×10^{-3}	4.60×10^{5}
^{99}Tc	5.01×10^{-4}	6.21×10^{1}
^{137}Cs	4.95×10^{-3}	4.40×10^{5}
^{241}Am	3.28×10^{-2}	3.06×10^{4}

The ^{90}Sr and ^{137}Cs decay heats also contain heat generated from the daughter products in secular equilibrium.

The mass of the glass containing the radionuclides is the glass pool in the melter. This mass can be calculated from volume and density values given for the glass pool in Section 4.2.3.2, HLW Melter. The concentration of radionuclides in the glass is calculated by the flowsheet.

4.2.3.6.2 Canister Level Detection

The purpose of the canister level detection system is to monitor the molten glass level in the HLW canister and to prevent canister overfilling. The primary level detection system is a thermal imaging

system that continuously monitors level over the entire canister. If the primary thermal imaging system malfunctions, the backup point radiation detection system shall indicate a filled canister. The backup is designed only to detect a discrete high glass level in the canister. The WTP requirement is for an average fill level to be no less than the 95 % volume level.

4.2.4 Ongoing Work and Potential Changes

None

4.2.5 References

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24590-101-TSA-W000-0009-111-02, Rev 00B, *Final Report – Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope A1 Simulants* (VSL-02R8800-2, Rev 0).

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24590-101-TSA-W000-0009-143-01, Rev 00B, *Final Report - Integrated Off-Gas System Tests on the Dm1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants* (VSL-03R3851-1, Rev 0).

24590-101-TSA-W000-0009-144-00005, Rev 00A, *DM1200 Tests with AZ-101 HLW Simulants.*

24590-101-TSA-W000-0009-144-00006, Rev 00A, *Final Report - Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification.*

24590-101-TSA-W000-0009-144-01, Rev 00B, *Final Report - Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers* (VSL-03R3800-1, Rev 0).

24590-101-TSA-W000-0009-144-02, Rev 00B, *Final Report - Integrated DM1200 Melter Testing of HLW AZ-102 Compositions Using Bubblers* (VSL-03R3800-2, Rev 0).

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24590-HLW-M4C-LFP-00001, Rev 00A, *HLW Melter Energy Balance for the ACM Model.*

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24590-HLW-RPT-RT-13-001, Rev 001, *Component Partitioning Between Glass and Offgas Streams in High-Level Waste Melters.*

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24590-QL-HC4-W000-00011-04-00271, Rev 00A, *HLW Mass and Energy Balance- HLW D.*

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Table 4.2-1 IHLW UTS-TCLP Limits for Constituents of Potential Concern[a]

Constituent of Concern	CAS Number	Delisting Level Limit (mg/L, TCLP)
Chromium	18540-29-9	4.95
Lead	7439-92-1	5.00
Mercury	7439-97-6	0.200
Nickel	7440-02-0	22.6
Silver	7440-22-4	3.07
Thallium	7440-28-0	0.282
Antimony	7440-36-0	0.659
Arsenic	7440-38-2	0.616
Barium	7440-39-3	100
Beryllium	7440-41-7	1.33
Cadmium	7440-43-9	0.480
Copper	7440-50-8	29,200
Vanadium	7440-62-2	16.9
Zinc	7440-66-6	225
Selenium	7782-49-2	1.00

CAS = Chemical Abstract Service
TCLP = Toxicity Characteristic Leaching Procedure

[a] Table excerpted from 24590-WTP-RPT-ENV-06-001, page 1-3.

Table 4.2-2 HLW Nitrogen Oxide Data Summary

	24590-101-TSA-W0009-144-00006; Rev. 00A, *Final Report Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification***					24590-101-TSA-W000-0009-144-00005, Rev. 00A *Final Report- DM1200 Tests with AZ-101 HLW Simulant*					Average
Waste Type	AZ-102			C-106/AY-102		101-AZ					
Test #	1A1 higher viscosity*	1A2 higher viscosity*	1B nominal rheology*	2A higher rheology*	2B higher waste loading*	3A	3B	3C	4C	5C	
Bubble rate l/min	65	65	65	65	90	8	40	65	65	65	
grams Glass/liter Feed	560	480	340	540	340	530	530	530	400	300	
Gas Flow Rate scfm (wet)	250.0	249.0	244.0	248.0	231.0	231.8	237.2	262.3	243.7	198.9	
Gas Flow Rate l/hr	424747.5	423048.5	414553.6	421349.5	392466.7	393865.5	403054.0	445609.9	414067.3	337953.6	
Gas Flow Rate mol/hr	17587.9	17517.5	17165.8	17447.2	16251.2	16309.1	16689.6	18451.8	17145.6	13993.9	
NO ppmv	200	180	140	35	42	130	200	260	120	98	
NO2 ppmv	3.6	4.7	6.1	<1	<1	5.1	4.1	6.7	4	2.8	
N2O ppmv	2.5	2.2	1.6	<1	<1	1.5	1.7	2	1.1	<1	
NH3 ppmv	<1	<1	<1	<1	<1	2.3	<1	<1	4.6	3.7	
N2 ppmv (calculated)	118.70	119.56	113.83	239.09	103.62	4.79	14.18	0.27	106.19	168.13	
NO mol/hr	3.52	3.15	2.40	0.61	0.68	2.12	3.34	4.80	2.06	1.37	
NO2 mol/hr	0.06	0.08	0.10	0.02	0.02	0.08	0.07	0.12	0.07	0.04	
N2O mol/hr	0.04	0.04	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.01	
Total NOx in Exhaust mol/hr	3.62	3.27	2.54	0.65	0.72	2.23	3.43	4.96	2.14	1.42	
%NO as NOX	97.0 %	96.3 %	94.8 %	94.6 %	95.5 %	95.2%	97.2 %	96.8 %	95.9 %	96.3 %	95.9 %
Feed rate gm/hr	156900	163200	175500	130800	191800	54900	86400	116700	112800	135100	
kg glass/kg feed	0.384	0.347	0.27	0.372	0.263	0.375	0.375	0.375	0.315	0.249	
Glass Rate gm/hr	60249.6	56630.4	47385	48657.6	50443.4	20587.5	32400	43762.5	35532	33639.9	
Waste Oxide %	24.25 %	24.25 %	24.25 %	27.75 %	37.10 %	25.25%	25.25 %	25.25 %	25.25 %	25.25 %	
g NO2/100 g Oxide	0.407	0.407	0.407	0.034	0.012	0.414	0.414	0.414	0.414	0.414	
g NO3/100 g Oxide	1.883	1.883	1.883	2.174	0.784	2.237	2.237	2.237	2.237	2.237	
NO2 in feed mol/hr	1.29	1.22	1.02	0.10	0.05	0.47	0.74	0.99	0.81	0.76	
NO3 in feed mol/hr	4.44	4.17	3.49	4.73	2.37	1.88	2.95	3.99	3.24	3.06	
Total feed NOx mol/hr	5.73	5.39	4.51	4.83	2.42	2.34	3.69	4.98	4.04	3.83	
% Feed NOx emitted as Nitrogen Oxide	63.26 %	60.79 %	56.26 %	13.35 %	29.61 %	95.07%	93.13 %	99.53 %	53.03 %	37.20 %	60.1 %
mol% NO	61.39 %	58.55 %	53.33 %	12.63 %	28.26 %	90.47%	90.51 %	96.31 %	50.87 %	35.81 %	57.8 %
mol% NO2	1.10 %	1.53 %	2.32 %	0.36 %	0.67 %	3.55%	1.86 %	2.48 %	1.70 %	1.02 %	1.7 %
mol% N2O	0.77 %	0.72 %	0.61 %	0.36 %	0.67 %	1.04%	0.77 %	0.74 %	0.47 %	0.37 %	0.7 %
mol% NH3	0.31 %	0.33 %	0.38 %	0.36 %	0.67 %	1.60%	0.45 %	0.37 %	1.95 %	1.35 %	0.8 %
mol% N2	36.43 %	38.89 %	43.36 %	86.29 %	69.72 %	3.33%	6.42 %	0.10 %	45.02 %	61.44 %	39.1 %
Total	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00%	100.00 %	100.00 %	100.00 %	100.00 %	100.0 %

* Air flow at WESP was used as melter flow was not reported.

Table 4.2-3 HLW Melter Decontamination Factors

a	*b*	*c*	*d*	*e*
Element	**Category**	**Data Set**	**Mean**	***Previous BARD Value***
Ac	Non-volatile	Non-volatile	107	78
Ag	Semi-volatile	Semi-volatile	49	125
Al	Non-volatile	Al	136	130
Am	Semi-volatile	Semi-volatile	49	50
As	Volatile	Volatile	4.4	54
B	Semi-volatile	B	46 †	86.3
Ba	Non-volatile	Non-volatile	107	106
Be	Non-volatile	Non-volatile	107	78
Bi	Semi-volatile	Semi-volatile	49	270
Ca	Non-volatile	Ca	75	86
Cd	Non-volatile	Non-volatile	107	128
Ce	Non-volatile	Non-volatile	107	78
Cl	Volatile	Volatile	2.94†	5.5
Cm	Non-volatile	Non-volatile	107	78
Co	Non-volatile	Non-volatile	107	78
Cr	Semi-volatile	Semi-volatile	48.91†	78
Cs	Volatile	Volatile	2.94	47
Cu	Non-volatile	Non-volatile	107	125
Eu	Non-volatile	Non-volatile	107	78
F	Volatile	F	1.63†	1.5
Fe	Non-volatile	Fe	92	101
Gd	Non-volatile	Non-volatile	107	--
Hg	Quantitative	--	--	1
I	Volatile	Volatile	2.94†	1.3
K	Semi-volatile	K	28	32
La	Non-volatile	Non-volatile	107	78
Li	Non-volatile	Li	187	204
Mg	Non-volatile	Mg	50	56
Mn	Non-volatile	Non-volatile	107	207
Mo	Semi-volatile	Semi-volatile	49	60
Na	Semi-volatile	Na	90	101
Nb	Non-volatile	Non-volatile	107	78

Table 4.2-3 HLW Melter Decontamination Factors

a	*b*	*c*	*d*	*e*
Element	**Category**	**Data Set**	**Mean**	***Previous BARD Value***
Nd	Non-volatile	Non-volatile	107	78
Ni	Non-volatile	Ni	118	118
Np	Non-volatile	Non-volatile	107	78
P	Non-volatile	Non-volatile	107	95
Pa	Non-volatile	Non-volatile	1,031	78
Pb	Semi-volatile	Pb	57	63
Pd	Non-volatile	Non-volatile	107	78
Pr	Non-volatile	Non-volatile	107	78
Pu	Non-volatile	Non-volatile	107	78
Ra	Volatile	Volatile	2.94	3.9
Rb	Semi-volatile	Semi-volatile	49	51
Re	Volatile	Volatile	2.94	--
Rh	Non-volatile	Non-volatile	107	3.61
Ru	Semi-volatile	Semi-volatile	48.91	3.15
S	Volatile	S	1.77†	1.20
Tc	Volatile	Tc	1.6	1.7
U	None-volatile	U	77.5	80

Type	*Components*	*Mean **
Anions		
	Cl^-	See Element Cl †
	CO_3^{2-}	Destroyed
	F^-	See Element F †
	I^-	See Element I †
	CN^-	51
	NH_4^+	Destroyed
	NO_2^-	Destroyed
	NO_3^-	Destroyed
	O_2^-	Calculated
	OH^-(aq)	1 & Destroyed
	OH^-(s)	1 & Destroyed
	PO_4^{3-}	See Element P

Type	*Components*	*Mean* *
	SiO_4^{-4}	See Element Si
	SO_4^{2-}	See Element S †
Organics		
	acetate	Destroyed
	oxalate	Destroyed
	Citrate	Destroyed
	EDTA	Destroyed
	formate	Destroyed
	glycolate	Destroyed
	HEDTA	Destroyed
	IDA	Destroyed
	Sucrose	Destroyed
	Chlorobenzene	n/a
	Allyl Alcohol	1.59
	Naphthalene	1.05

*Engineering calculation 24590-WTP-M4C-V37T-00008, Rev 0, provides the justification, data analysis, and reference Research and Technology reports used to calculate HLW and LAW decontamination factors.

†The Halide and boron DFs utilized for the LAW melter implements a DF that is composed of solid, liquid, and a gaseous components. The process of combining these component terms is described to some extent in Appendix J of 24590-WTP-M4C-V37T-00008, Rev 0. Additional discussion of the use of component DFs is provided in BARD Section 3.3.

Table 4.2-4 Glass Production Rate as a Function of Bubbling Rate

Waste Feed	AZ-102		C-106/AY-102	
IHLW Production/Melter (MTG/day)	1.5	3	1.5	3
Bubbler Rate (lpm)	45	180	73	185
Bubbler Rate (scfm)	1.6	6.4	2.6	6.5

Table 4.2-5 Number of Bubblers vs. Glass Production

Bubblers	Glass Yield	Production
Each	g glass/L slurry	MTG/day
5 Bubblers	250	2.6
	300	2.9
	350	3.2
	400	3.5

Table 4.2-5 Number of Bubblers vs. Glass Production

Bubblers Each	Glass Yield g glass/L slurry	Production MTG/day
	450	3.8
6 Bubblers	250	3.0
	300	3.4
	350	3.7
	400	4.1
	450	4.4
7 Bubblers	250	3.4
	300	3.8
	350	4.2
	400	4.6
	450	5.0

Table 4.2-6 HLW Melter Energy Requirement

	1.5 MT/d		3.0 MT/d	
Feed Concentrations				
Feed free water content, kg/MT-glass	1423	2715	1423	2715
Feed concentration, g-oxide/L	573	325	573	325
Melter Running at Given Rates				
Energy to heat in-leakage and air purges, kW	32	32	32	32
Energy to heat and convert feed, kW	*127*	*196*	*253*	*392*
Total process energy load, kW	158	228	285	424
Feed-2 heat losses, kW	193	193	193	193
Total electrode power, kW	351	421	478	616

Melter Running Idle	
Energy to heat air & purges to 1000 C, kW	91
Idle-2 heat loss, kW	209
Idle-2 power requirement	300

Table 4.2-7 Melter Power Need, Pn verses Batch Oxide and Solids Concentrations

Glass, kg	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Oxides, g/L	50	60	70	80	90	100	110	120	130	140	150	160	170	180
Batch Volume, L	20,000	16,667	14,286	12,500	11,111	10,000	9,091	8,333	7,692	7,143	6,667	6,250	5,882	5,556
Solids Total, kg	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27
Water, kg	25,420.49	20,948.19	17,753.70	15,357.83	13,494.37	12,003.61	10,783.89	9,767.46	8,907.41	8,170.21	7,531.32	6,972.28	6,479.01	6,040.55
Total Batch, kg	26,833.76	22,361.46	19,166.97	16,771.10	14,907.64	13,416.88	12,197.16	11,180.73	10,320.68	9,583.48	8,944.59	8,385.55	7,892.28	7,453.82
Solids Conc., wt%	5.27%	6.32%	7.37%	8.43%	9.48%	10.53%	11.59%	12.64%	13.69%	14.75%	15.80%	16.85%	17.91%	18.96%
Oxide Conc., wt%	3.73%	4.47%	5.22%	5.96%	6.71%	7.45%	8.20%	8.94%	9.69%	10.43%	11.18%	11.93%	12.67%	13.42%
Solids Conc., g/L	71	85	99	113	127	141	155	170	184	198	212	226	240	254
Rate, R, MTG/day	1.80	1.88	1.96	2.04	2.12	2.20	2.28	2.36	2.44	2.52	2.60	2.68	2.76	2.84
Power Need, Pn, kW	1,274	1,174	1,102	1,047	1,003	969	940	916	896	879	864	851	840	830

Glass, kg	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Oxides, g/L	190	200	210	220	230	240	250	260	270	280	290	300	310	320
Batch Volume, L	5,263	5,000	4,762	4,545	4,348	4,167	4,000	3,846	3,704	3,571	3,448	3,333	3,226	3,125
Solids Total, kg	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27
Water, kg	5,648.24	5,295.17	4,975.72	4,685.31	4,420.16	4,177.10	3,953.48	3,747.07	3,555.94	3,378.47	3,213.24	3,059.02	2,914.76	2,779.50
Total Batch, kg	7,061.51	6,708.44	6,388.99	6,098.58	5,833.43	5,590.37	5,366.75	5,160.34	4,969.21	4,791.74	4,626.51	4,472.29	4,328.03	4,192.77
Solids Conc., wt%	20.01%	21.07%	22.12%	23.17%	24.23%	25.28%	26.33%	27.39%	28.44%	29.49%	30.55%	31.60%	32.65%	33.71%
Oxide Conc., wt%	14.16%	14.91%	15.65%	16.40%	17.14%	17.89%	18.63%	19.38%	20.12%	20.87%	21.61%	22.36%	23.11%	23.85%
Solids Conc., g/L	269	283	297	311	325	339	353	367	382	396	410	424	438	452
Rate, R, MTG/day	2.92	3.00	3.08	3.16	3.24	3.32	3.40	3.48	3.56	3.64	3.72	3.80	3.88	3.96
Power Need, Pn, kW	821	813	806	800	794	789	784	780	776	773	769	766	764	761

Glass, kg	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Oxides, g/L	330	340	350	360	370	380	390	400	410	420	430	440	450	460
Batch Volume, L	3,030	2,941	2,857	2,778	2,703	2,632	2,564	2,500	2,439	2,381	2,326	2,273	2,222	2,174
Solids Total, kg	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27
Water, kg	2,652.45	2,532.87	2,420.12	2,313.64	2,212.91	2,117.49	2,026.96	1,940.95	1,859.14	1,781.22	1,706.93	1,636.02	1,568.26	1,503.44
Total Batch, kg	4,065.72	3,946.14	3,833.39	3,726.91	3,626.18	3,530.76	3,440.23	3,354.22	3,272.41	3,194.49	3,120.20	3,049.29	2,981.53	2,916.71
Solids Conc., wt%	34.76%	35.81%	36.87%	37.92%	38.97%	40.03%	41.08%	42.13%	43.19%	44.24%	45.29%	46.35%	47.40%	48.45%
Oxide Conc., wt%	24.60%	25.34%	26.09%	26.83%	27.58%	28.32%	29.07%	29.81%	30.56%	31.30%	32.05%	32.79%	33.54%	34.29%
Solids Conc., g/L	466	481	495	509	523	537	551	565	579	594	608	622	636	650
Rate, R, MTG/day	4.04	4.12	4.20	4.28	4.36	4.44	4.52	4.60	4.68	4.76	4.84	4.92	5.00	5.08
Power Need, Pn, kW	759	757	755	753	752	750	749	748	746	745	744	744	743	742

Glass, kg	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Oxides, g/L	470	480	490	500	510	520	530	540	550	560	570	580	590	600
Batch Volume, L	2,128	2,083	2,041	2,000	1,961	1,923	1,887	1,852	1,818	1,786	1,754	1,724	1,695	1,667
Solids Total, kg	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27	1,413.27
Water, kg	1,441.38	1,381.91	1,324.87	1,270.11	1,217.49	1,166.90	1,118.22	1,071.34	1,026.16	982.60	940.57	899.98	860.78	822.88
Total Batch, kg	2,854.65	2,795.18	2,738.14	2,683.38	2,630.76	2,580.17	2,531.49	2,484.61	2,439.43	2,395.87	2,353.84	2,313.25	2,274.05	2,236.15
Solids Conc., wt%	49.51%	50.56%	51.61%	52.67%	53.72%	54.77%	55.83%	56.88%	57.93%	58.99%	60.04%	61.09%	62.15%	63.20%
Oxide Conc., wt%	35.03%	35.78%	36.52%	37.27%	38.01%	38.76%	39.50%	40.25%	40.99%	41.74%	42.48%	43.23%	43.97%	44.72%
Solids Conc., g/L	664	678	693	707	721	735	749	763	777	791	806	820	834	848
Rate, R, MTG/day	5.16	5.24	5.32	5.40	5.48	5.56	5.64	5.72	5.80	5.88	5.96	6.04	6.12	6.20
Power Need, Pn, kW	741	741	740	740	739	739	738	738	738	737	737	737	737	737

Table 4.2-8 Semivolatiles': Combined Liquid and Gas Decontamination Factors

Ion/Element	HLW
Iodine	1.30
Fluorine	1.24
Chlorine	1.36

This data is taken from 24590-WTP-M4C-V37T-00008, Attachment J.

Legend for Figures

The legend for use with Figures 4.2-3 to 4.2-16, is as follows:

A12N	DM1200 melter, Envelope A, non-spiked
A12S	DM1200 melter, Envelope A, spiked
B12N	DM1200 melter, Envelope B, non-spiked
C12N	DM1200 melter, Envelope C, non-spiked
C12S	DM1200 melter, Envelope C, spiked
A33N	DM3300 melter, Envelope A, non-spiked
B33N	DM3300 melter, Envelope B, non-spiked
C33N	DM3300 melter, Envelope C, non-spiked
Spare	unassigned field
TCDD	tetrachlorodibenzodioxin
PeCDD	pentachlorodibenzodioxin
HxCDD	hexachlorodibenzodioxin
HpCDD	heptachlorodibenzodioxin
OCDD	octachlorodibenzodioxin
TCDF	tetrachlorodibenzofuran
PeCDF	pentachlorodibenzofuran
HxCDF	hexachlorodibenzofuran
HpCDF	heptachlorodibenzofuran
OCDF	octachlorodibenzofuran
PCB	polychlorinated biphenyl
EDTA	ethylenediamine tetra-acetic acid
HEDTA	N-(2-hydroxyethyl) ethylenediamine tri-acetic acid
CDD/CDF/PCB	chlorodibenzodioxin/chlorodibenzofuran/polychlorinated biphenyl
DRE	destruction removal efficiency
Ace	acetonitrile/acrylonitrile/acetone

Figure 4.2-1 HLW Melter Process System

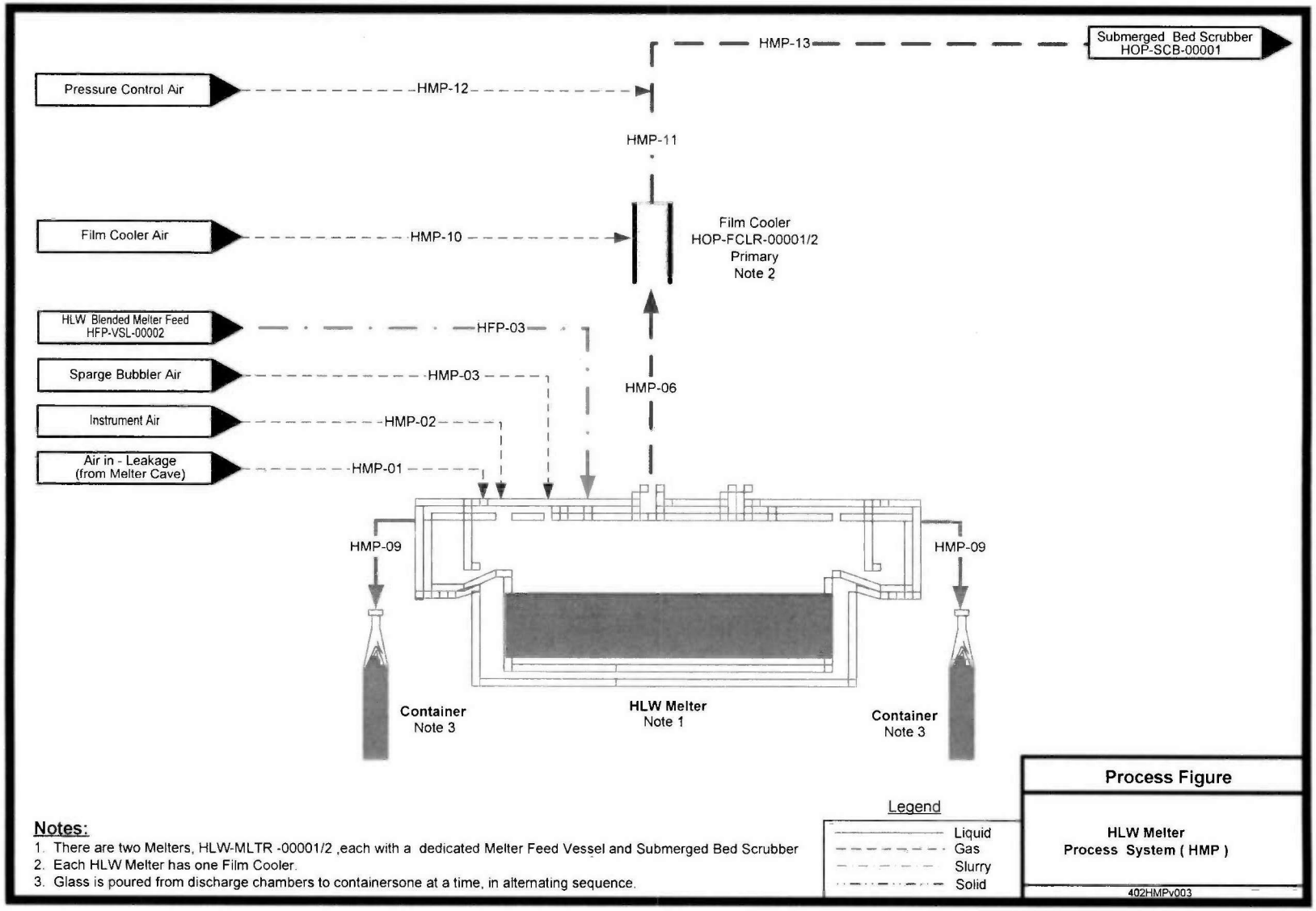


Figure 4.2-2 LAW and HLW Comparison of Nitrogen Compounds in the Melter Exhaust

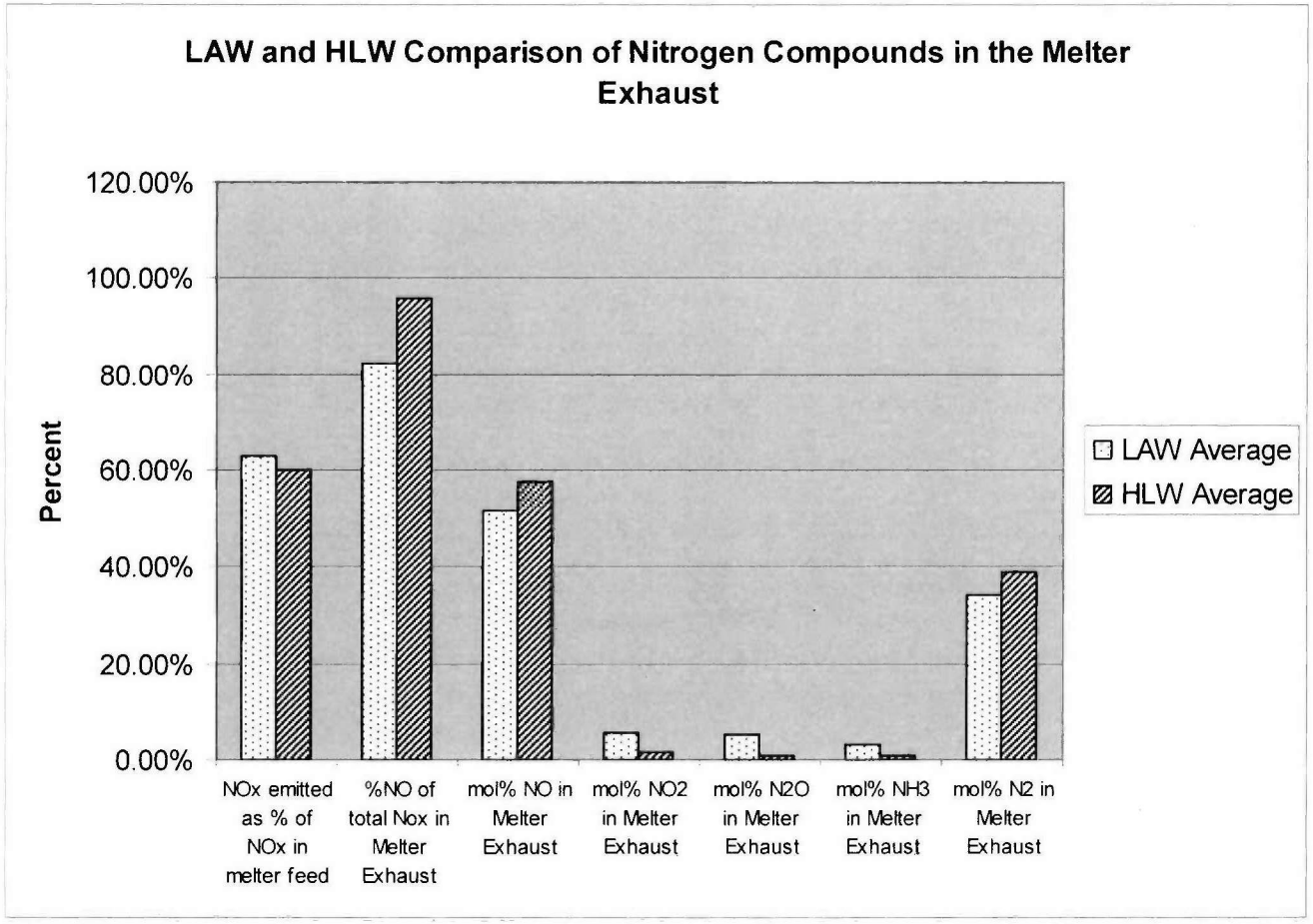


Figure 4.2-3 HLW Glass Density

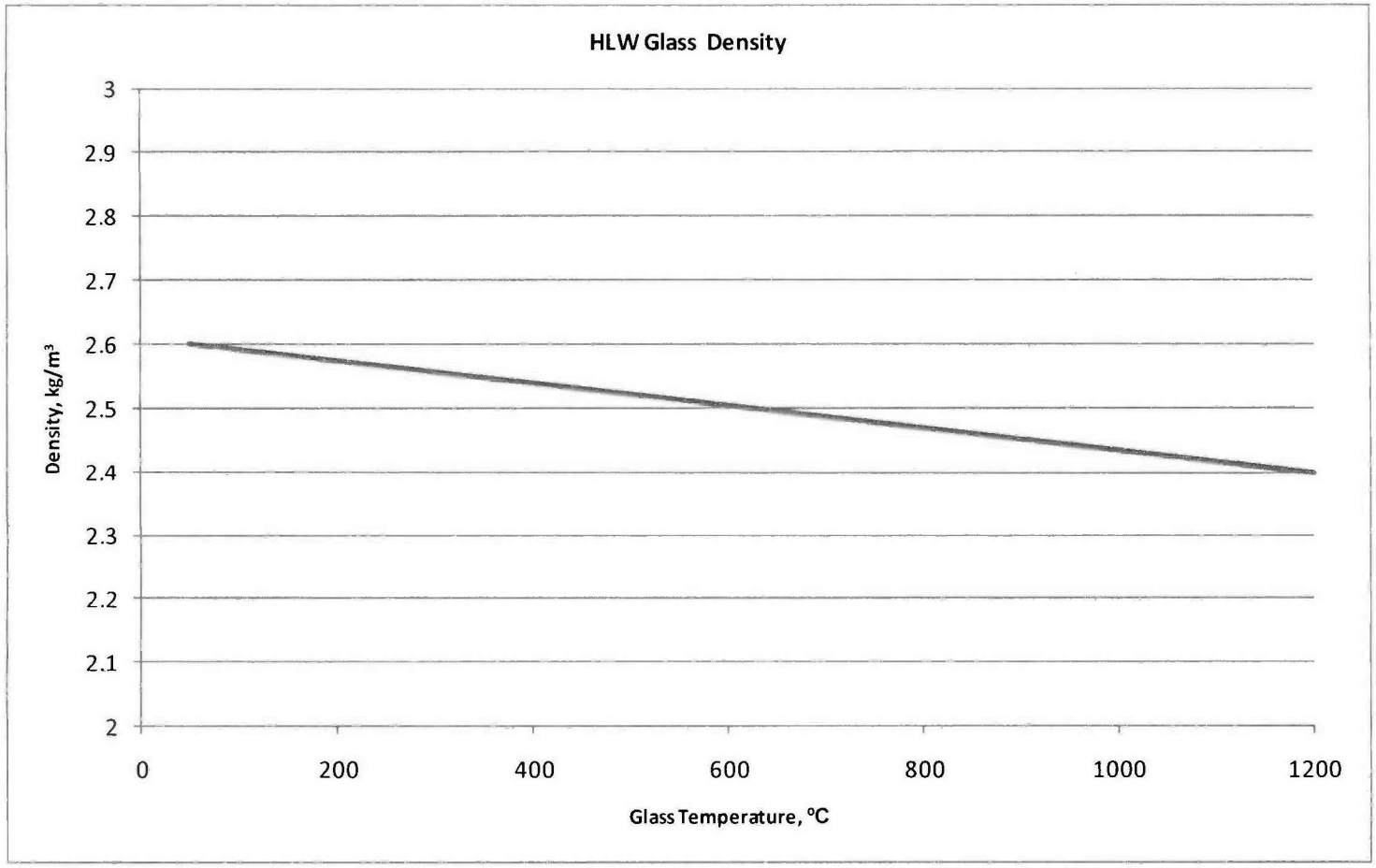


Figure 4.2-4 Bubbler Air vs. WTP HLW Glass Production per Melter

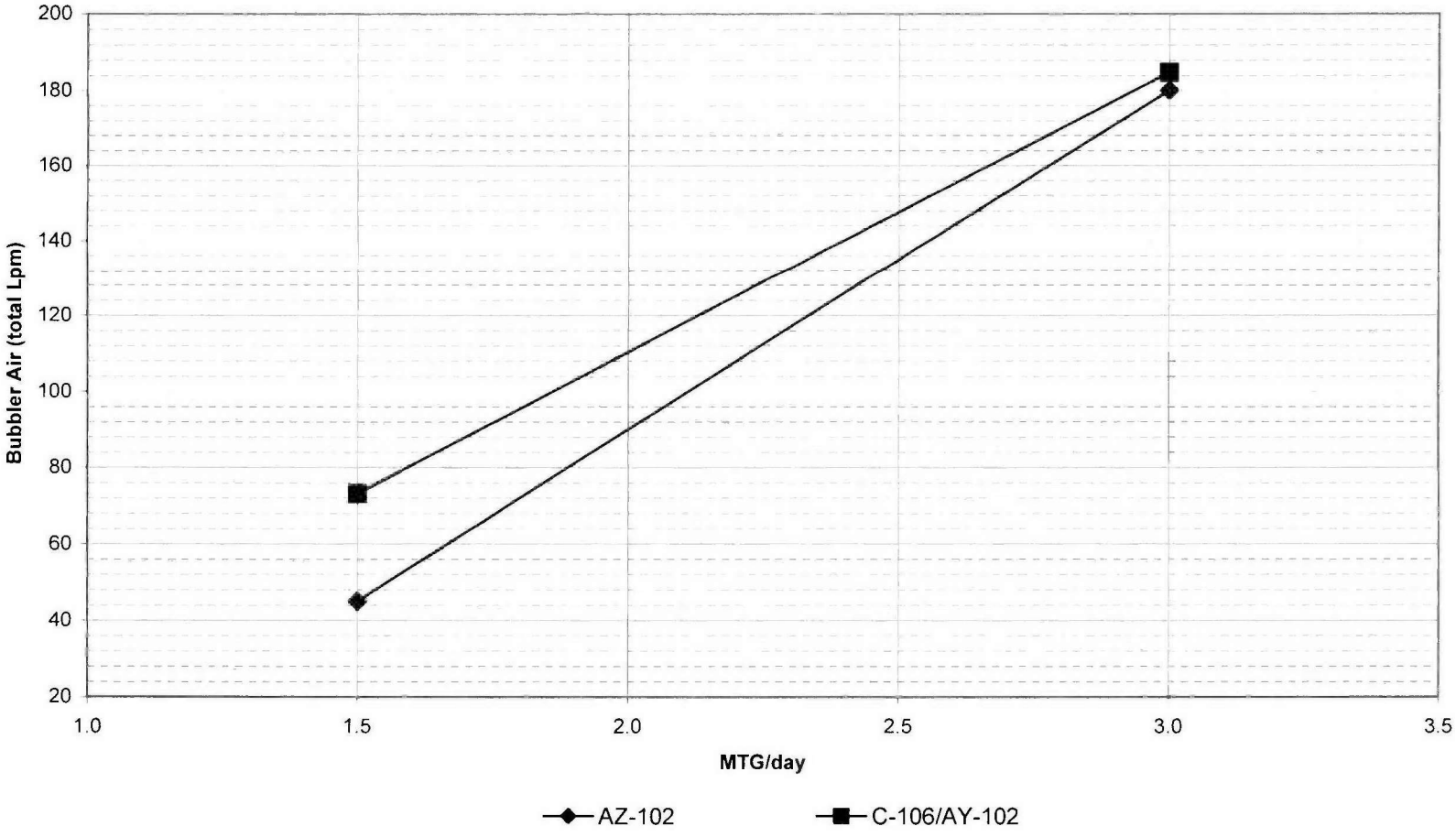


Figure 4.2-5 Melter Organic Offgas Emissions per Test Report

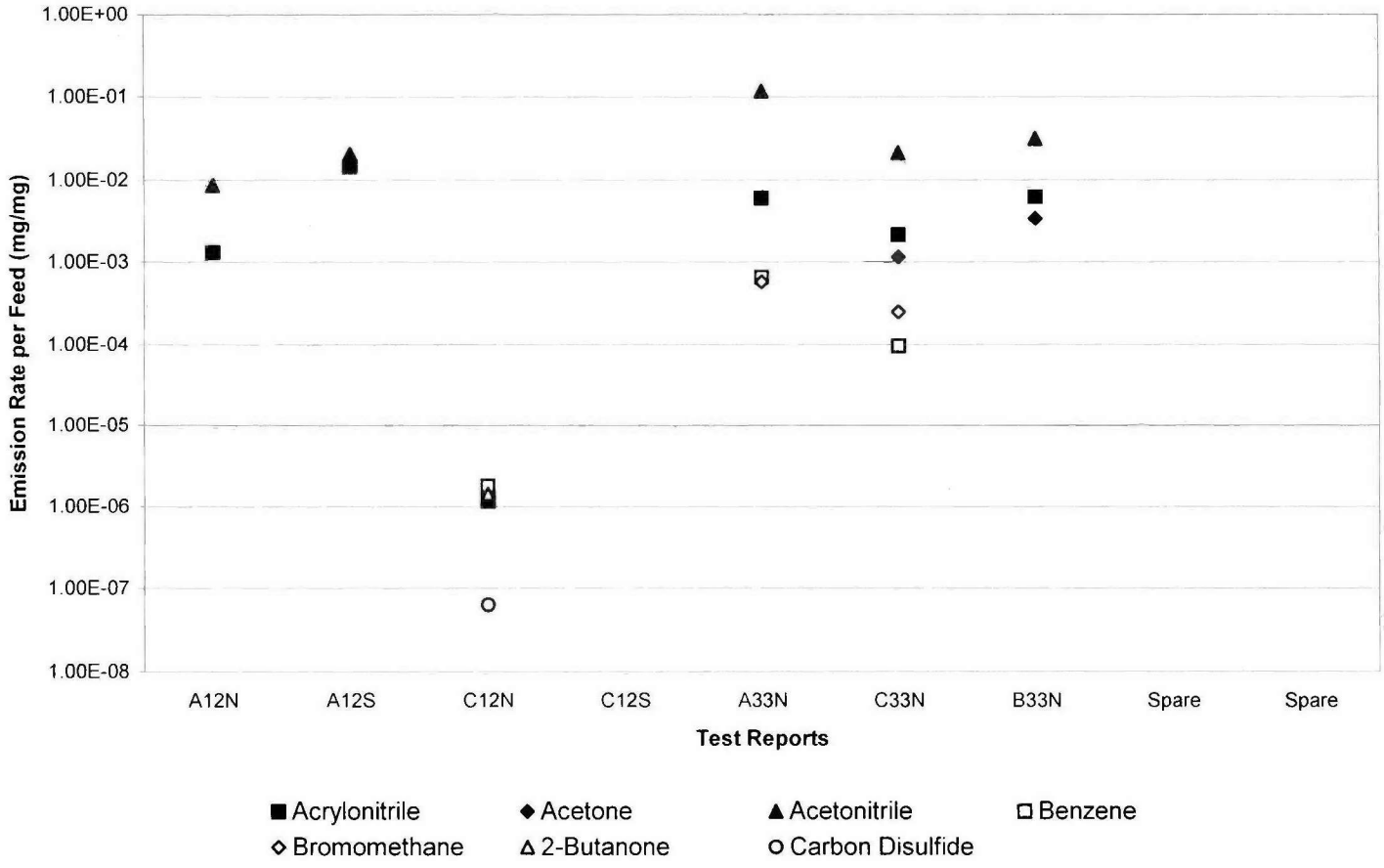


Figure 4.2-6 Melter Chlorinated Organic Offgas Emissions per Test Report

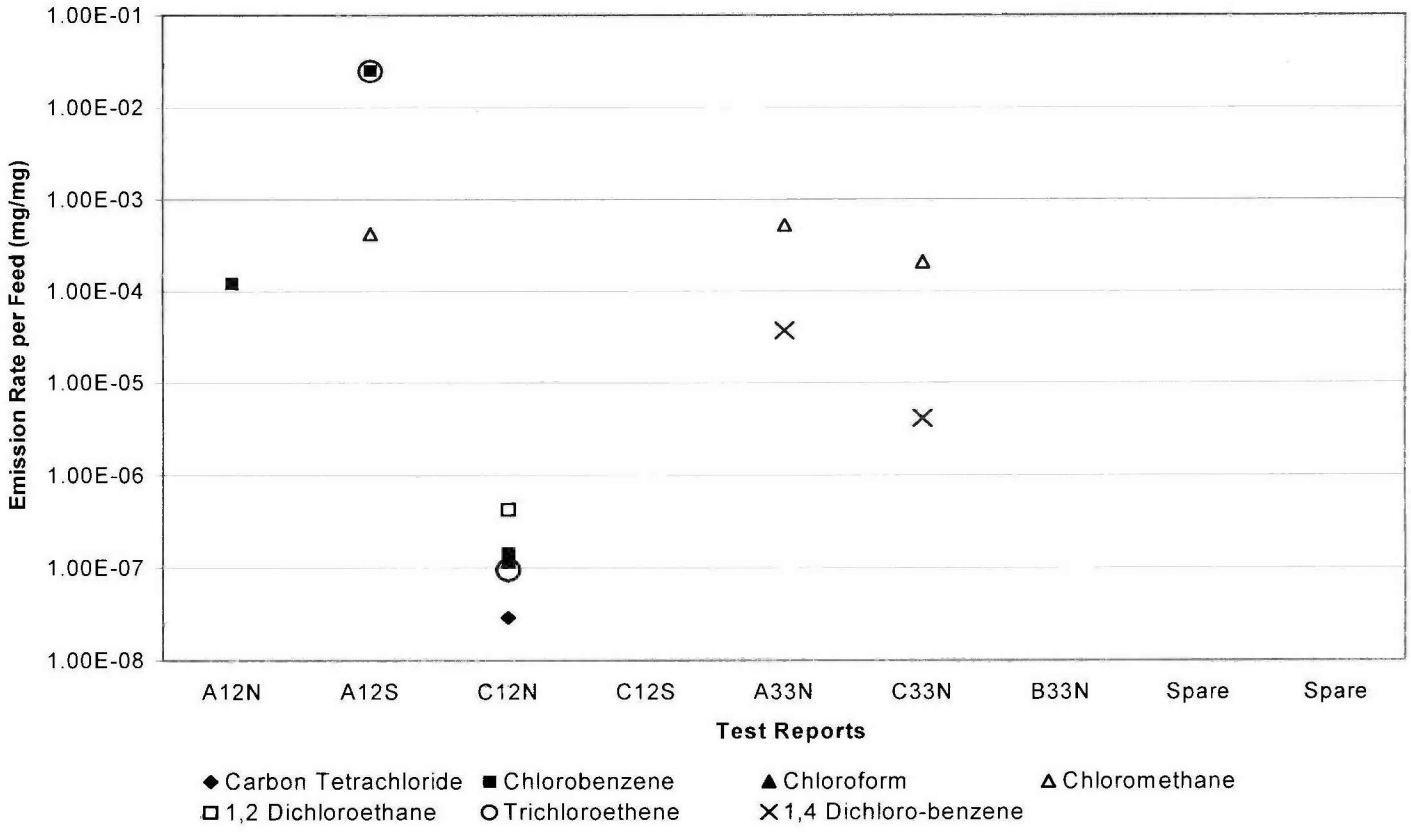


Figure 4.2-7 Melter Organic Offgas Emissions per Test Report

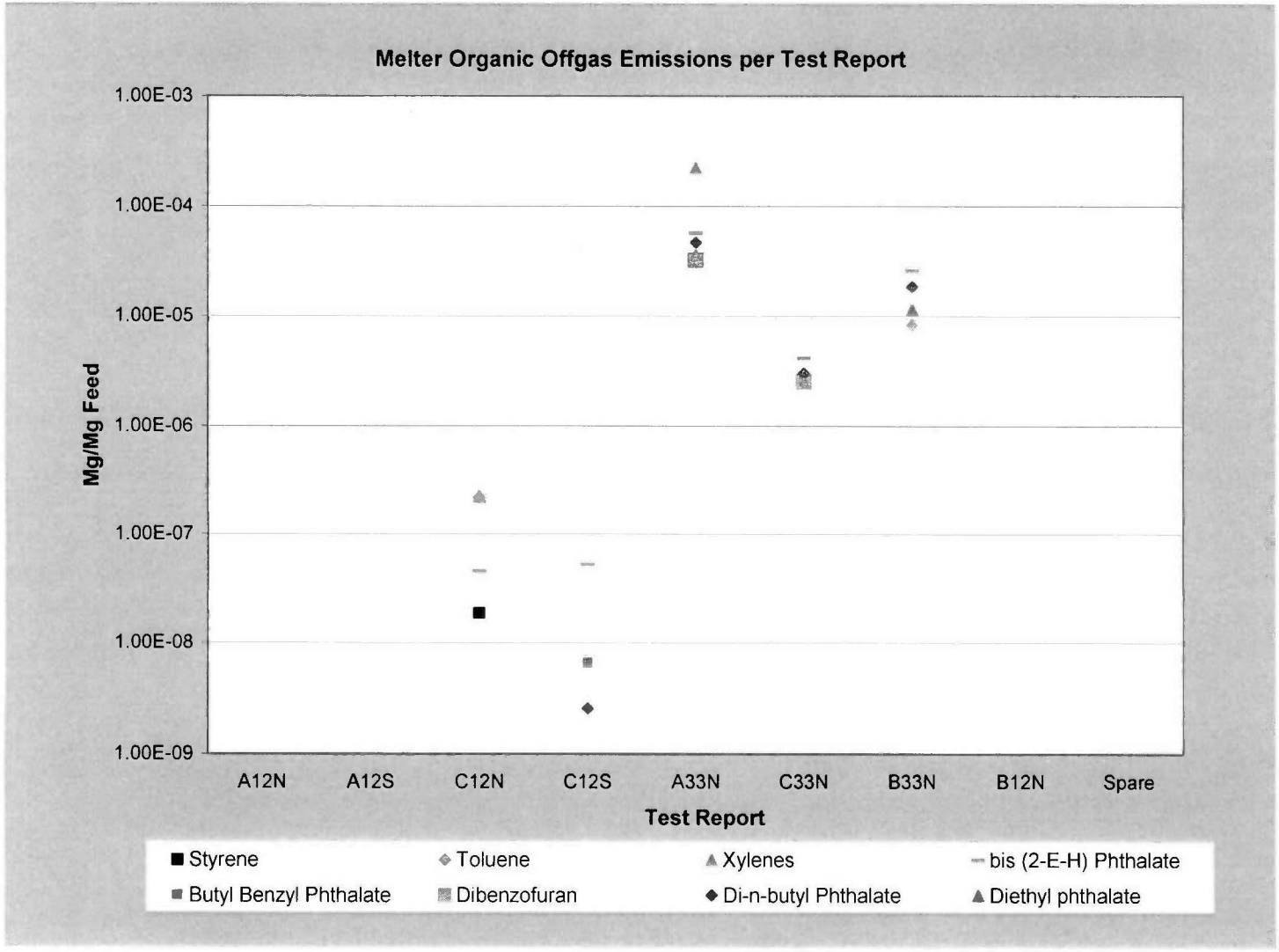


Figure 4.2-8 Melter Organic Offgas Emissions per Test Report

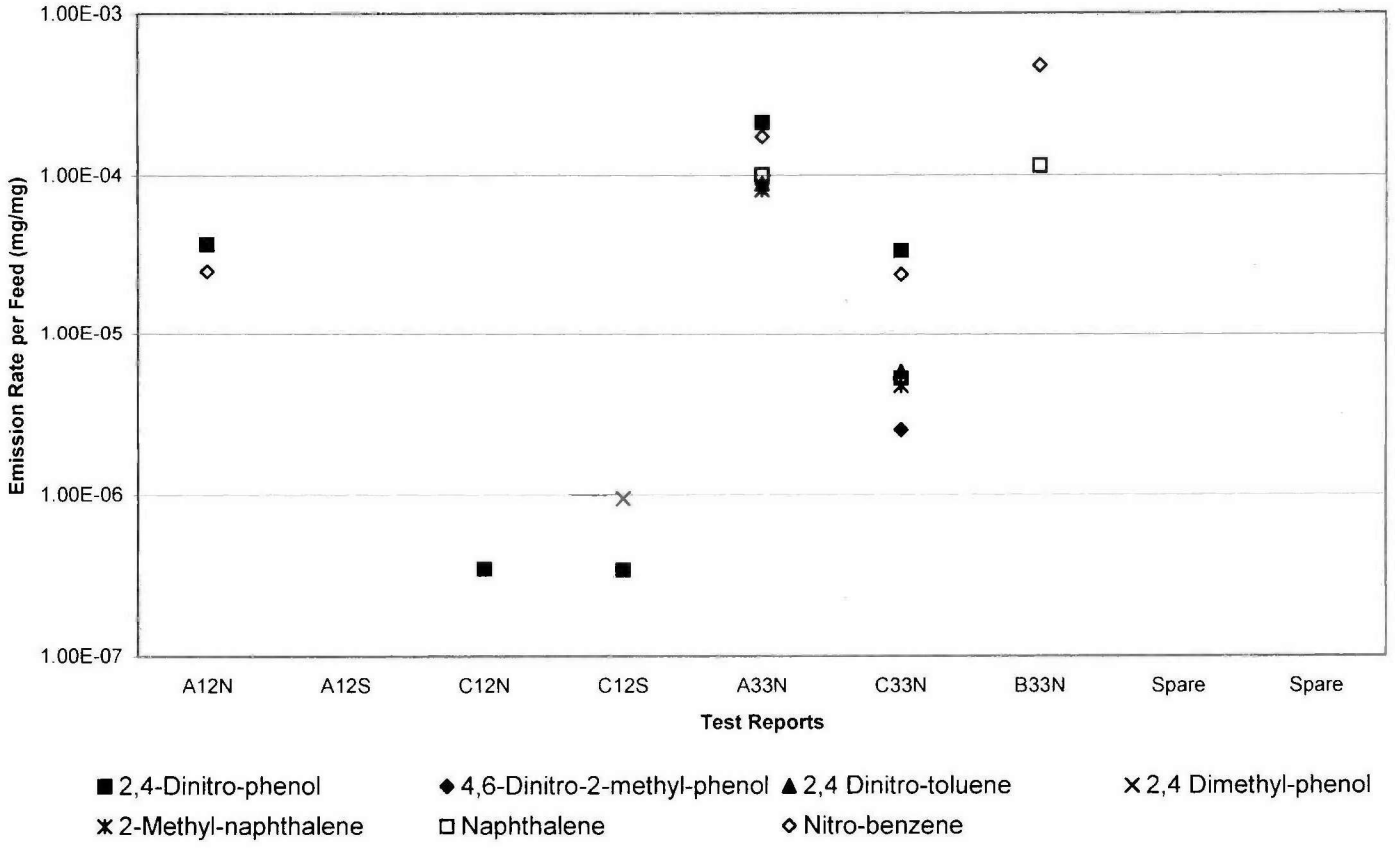


Figure 4.2-9 Melter Organic Offgas Emissions per Test Report

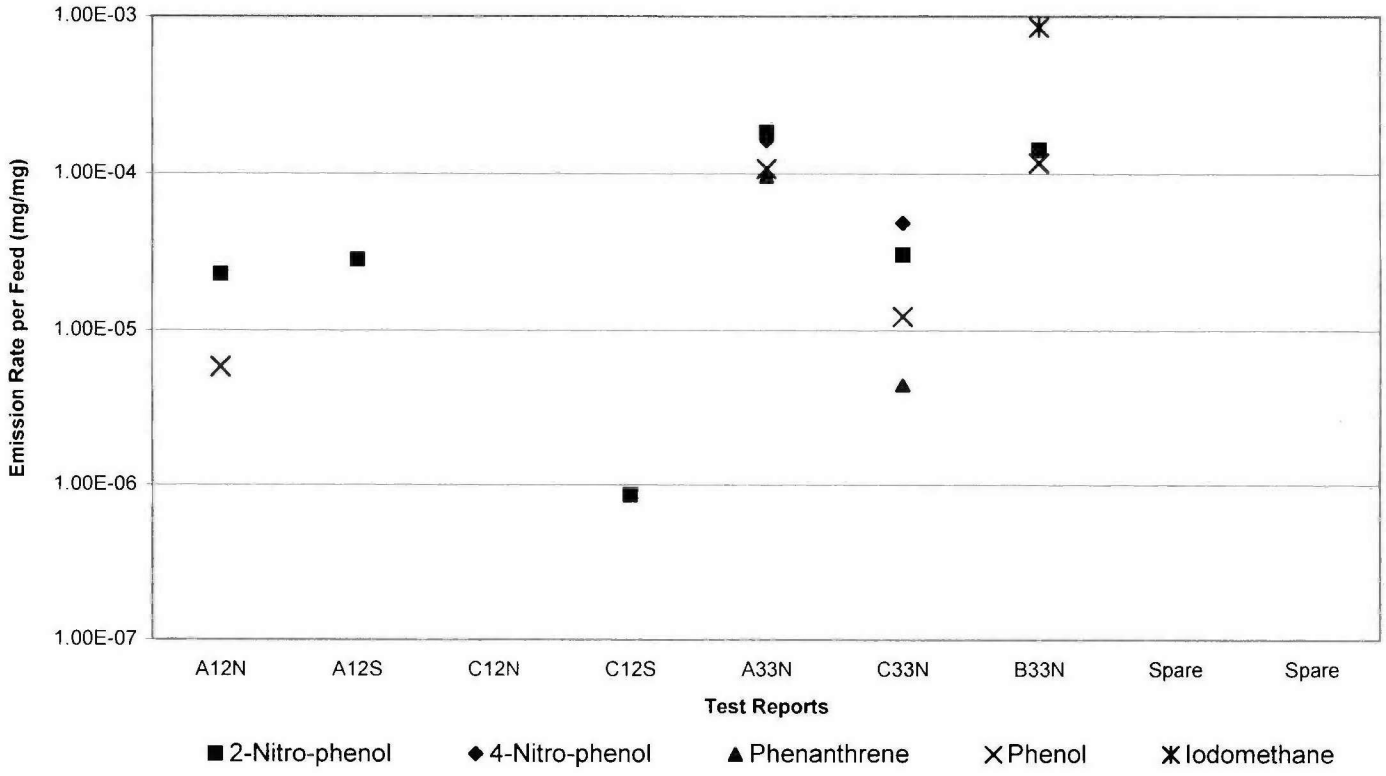


Figure 4.2-10 Melter Dioxin, Furan Emissions

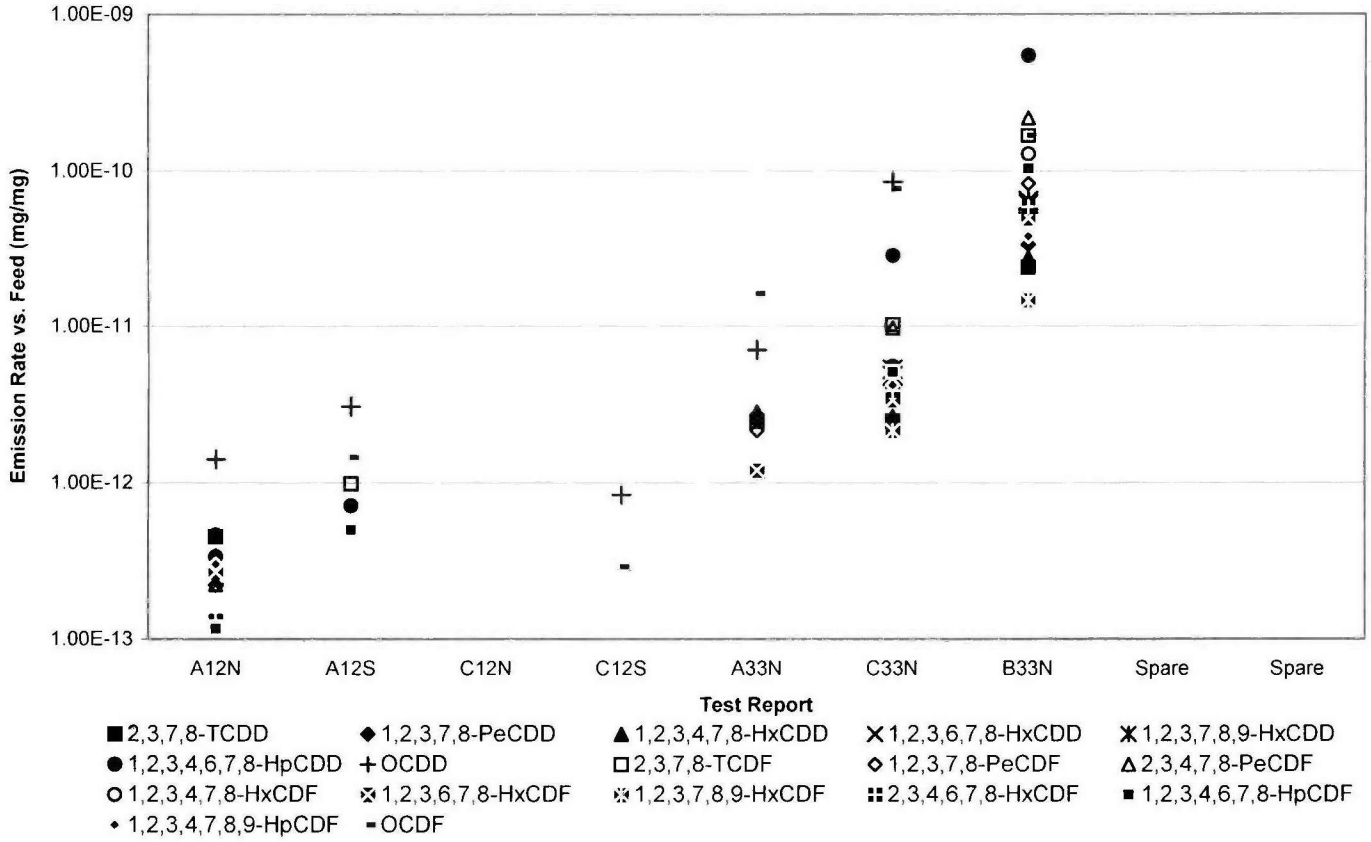


Figure 4.2-11 Melter PCB Emissions

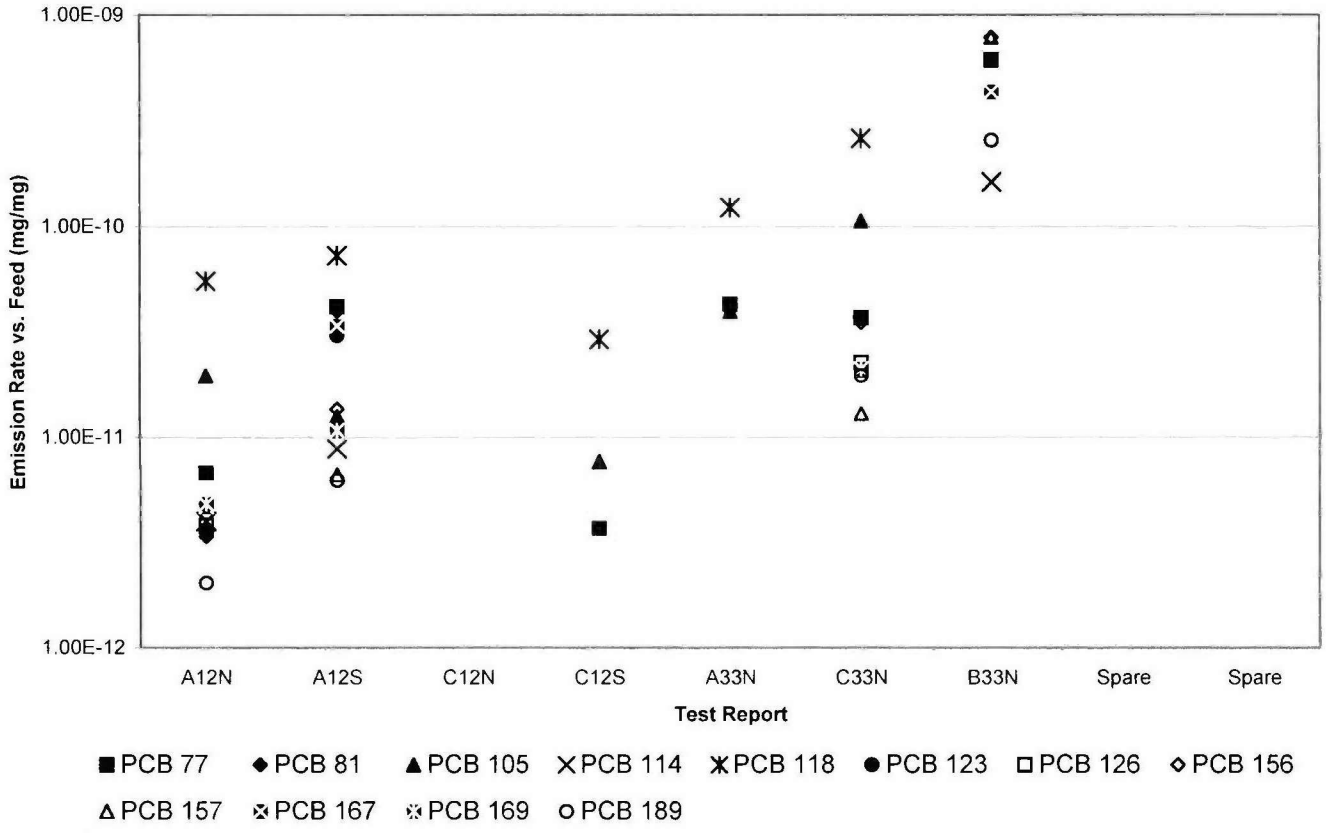


Figure 4.2-12 Melter Spike DFs

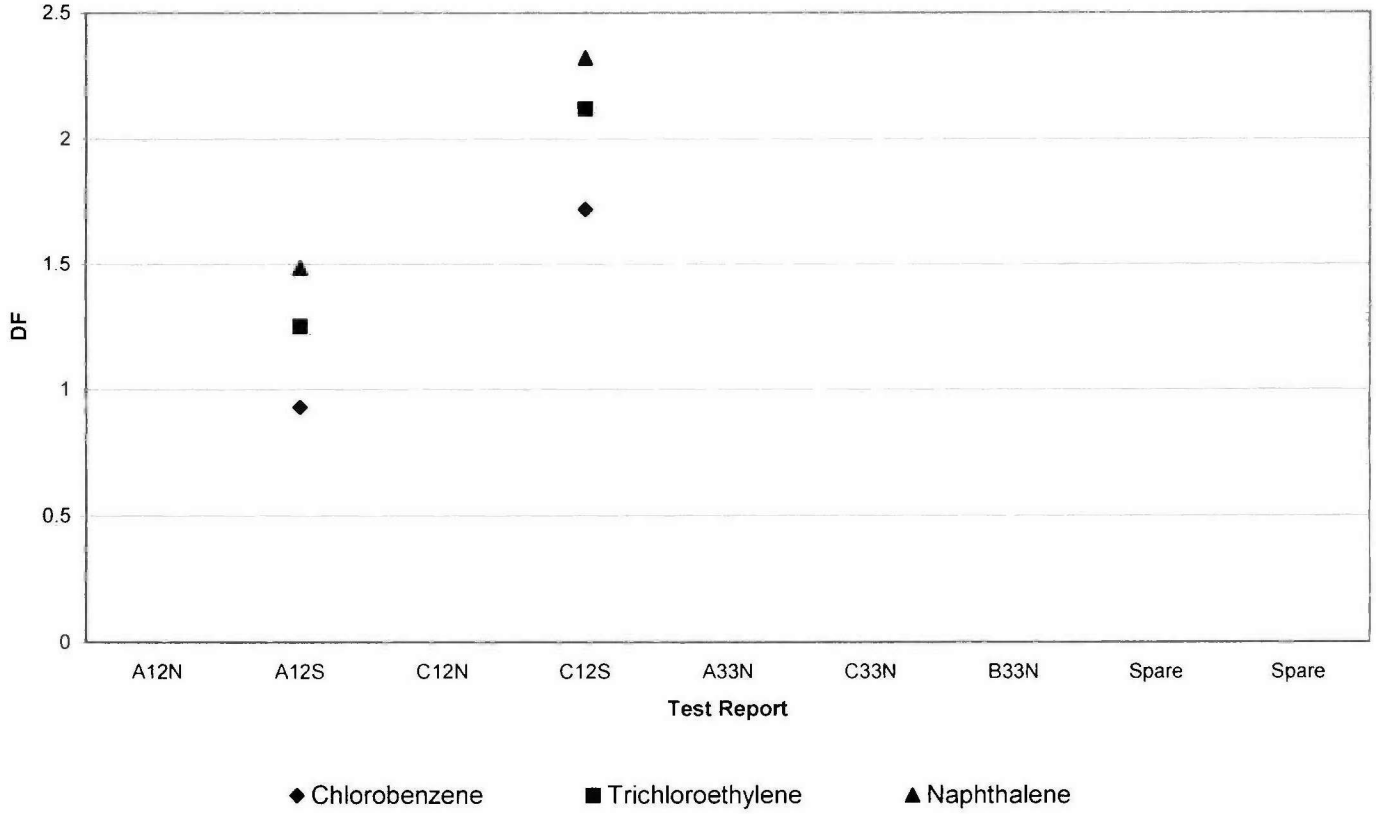


Figure 4.2-13 Comparison of Feed Type to Specific Offgas Generation

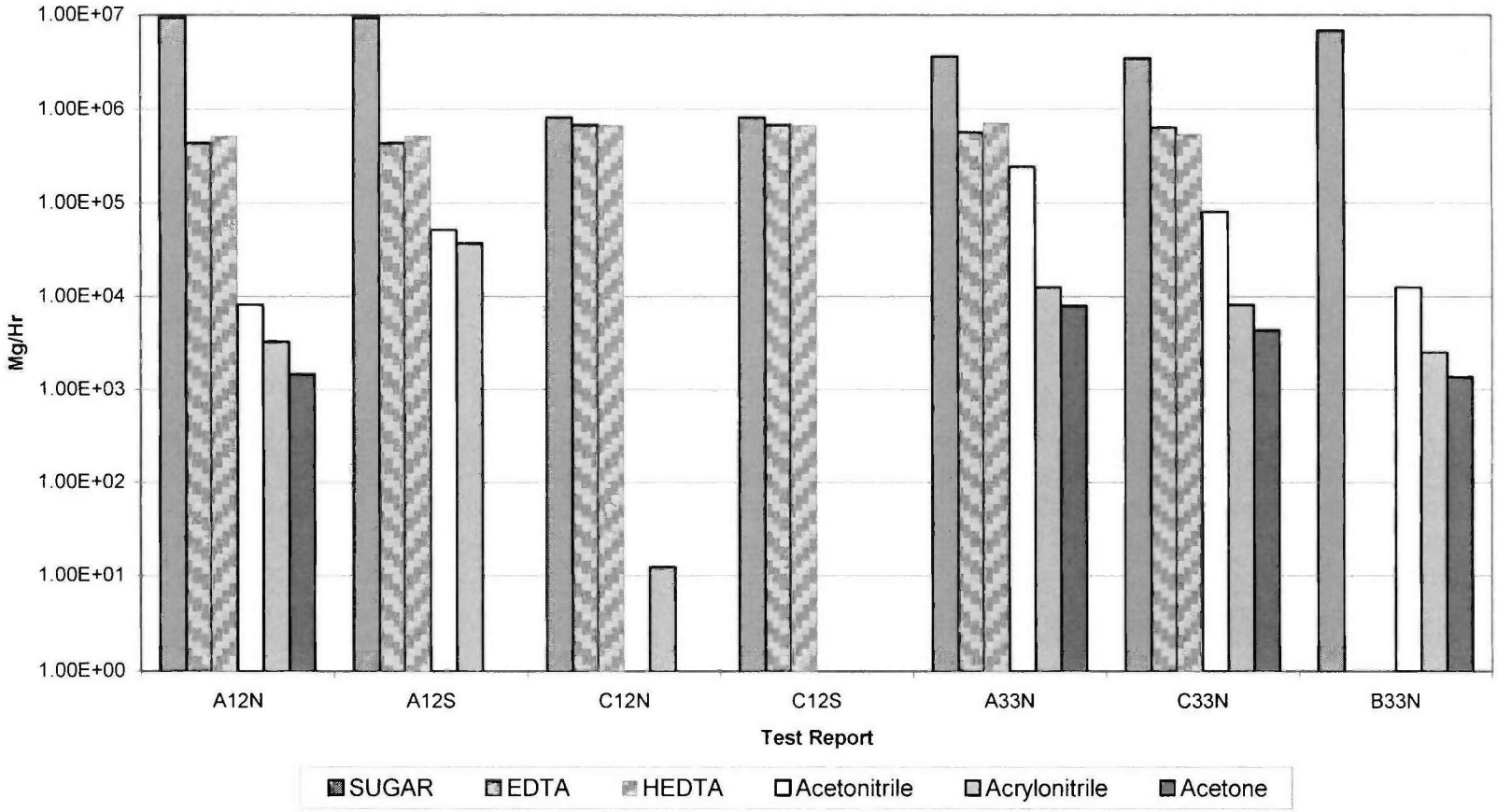


Figure 4.2-14 Comparison of Feed Type vs. Total CDD/CDF/PCB Production

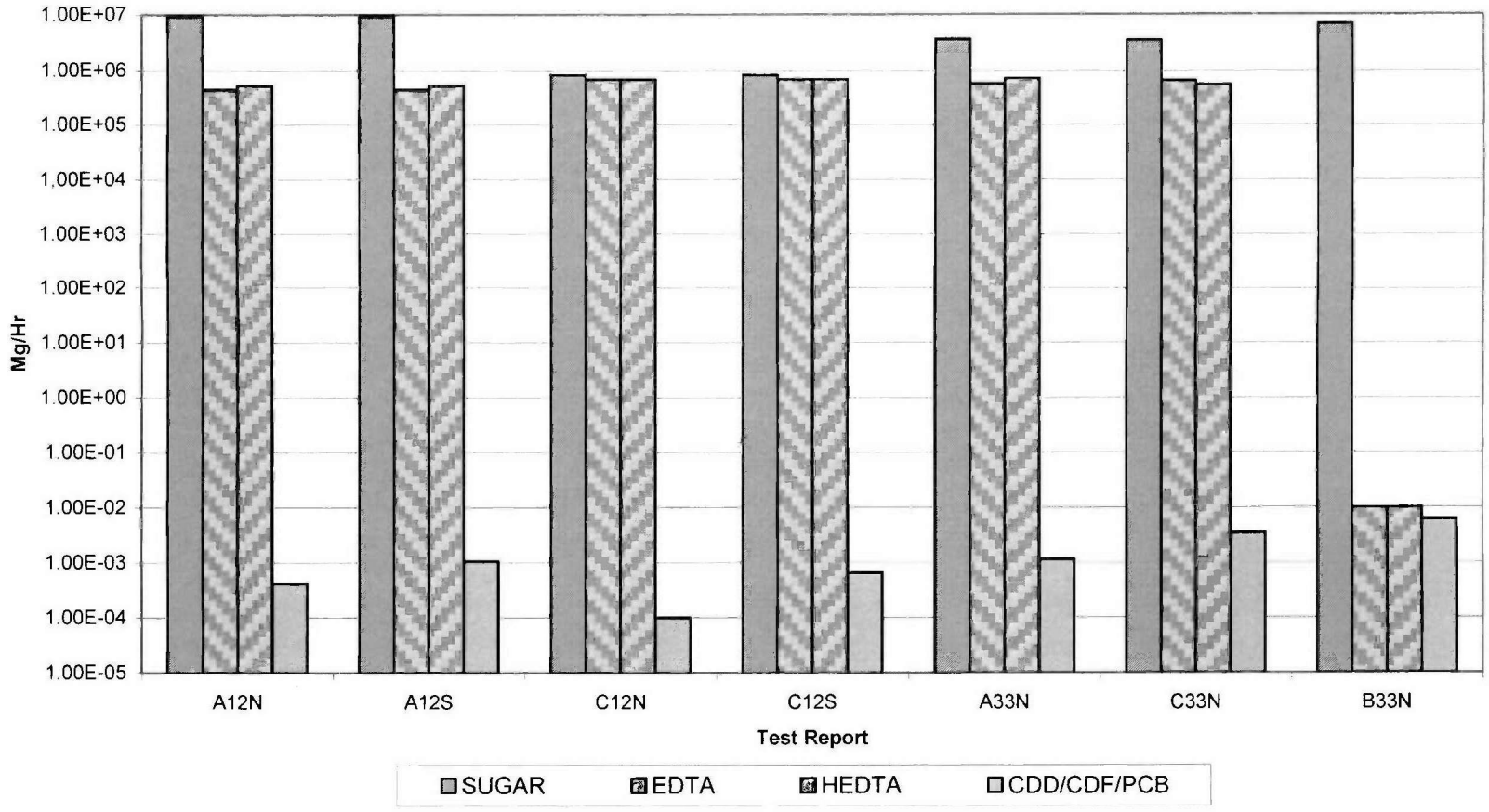


Figure 4.2-15 Comparison of Feed Types to DREs

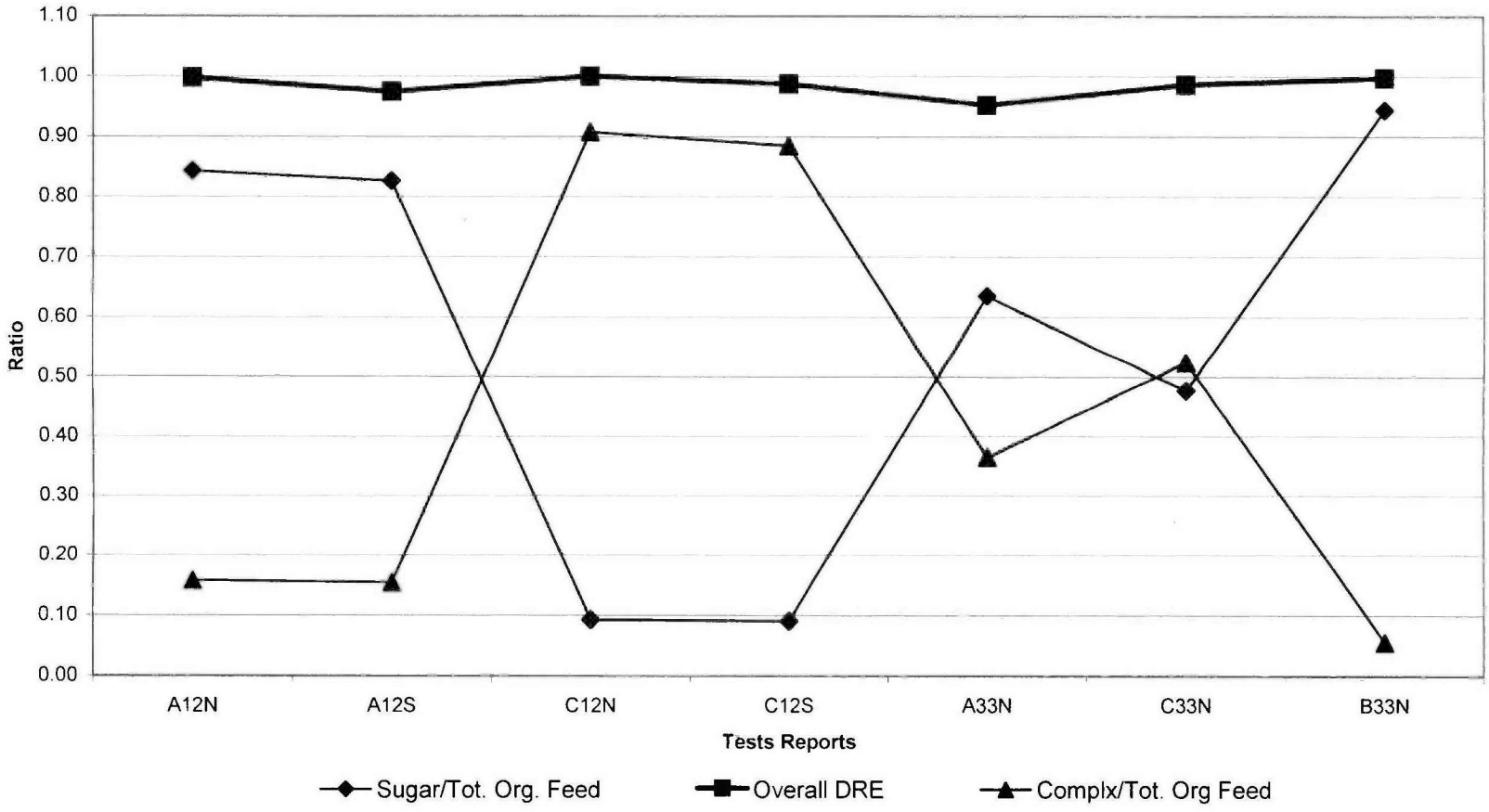


Figure 4.2-16 Relationship Between Feed Constituents and Total Organic Offgas Generation

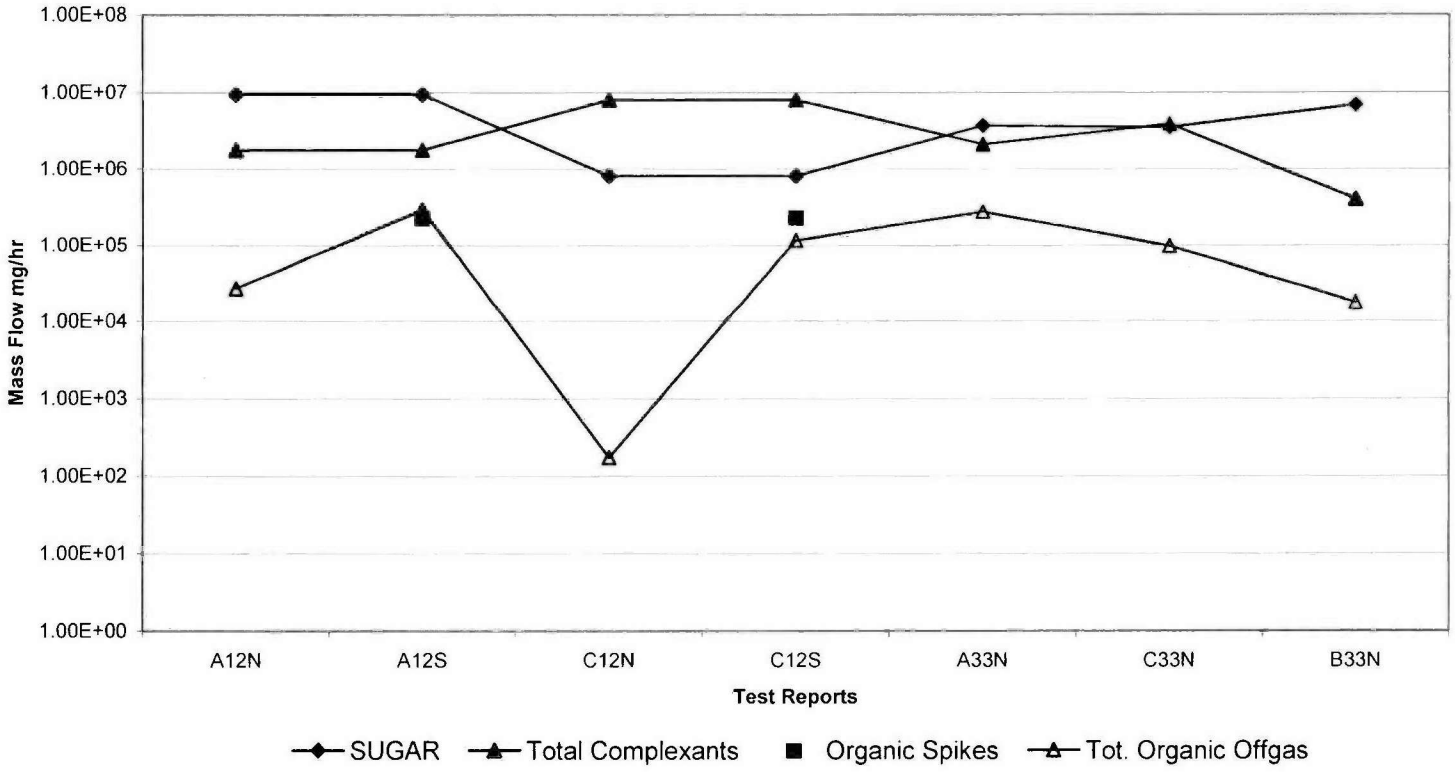


Figure 4.2-17 Relationship Between Feed Constituents and Priority Offgas Generation

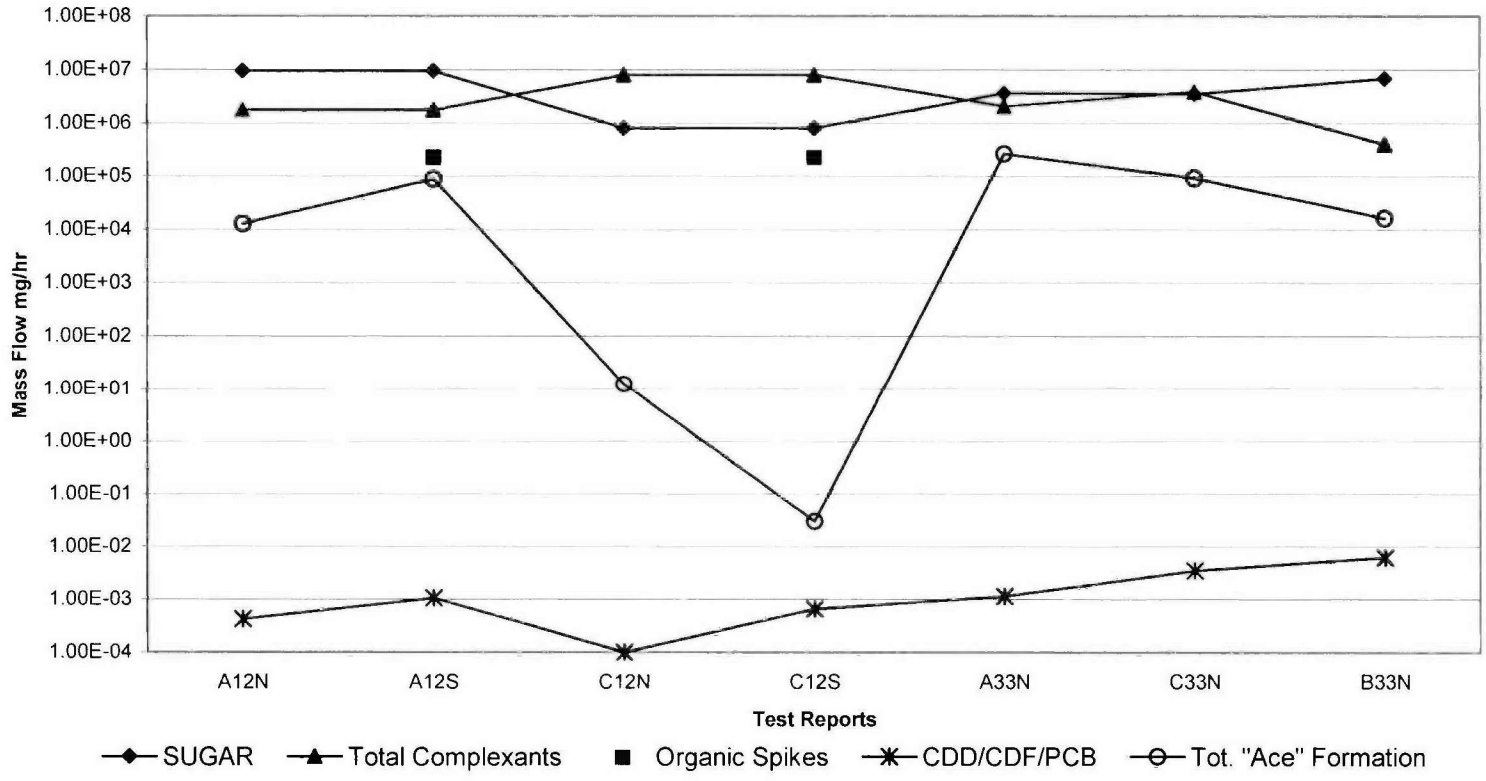


Figure 4.2-18 Calculated Energy Required to Produce a Kilogram of Glass with AZ-101 for a Range of Melter Feed Concentrations (melter heat losses ignored)

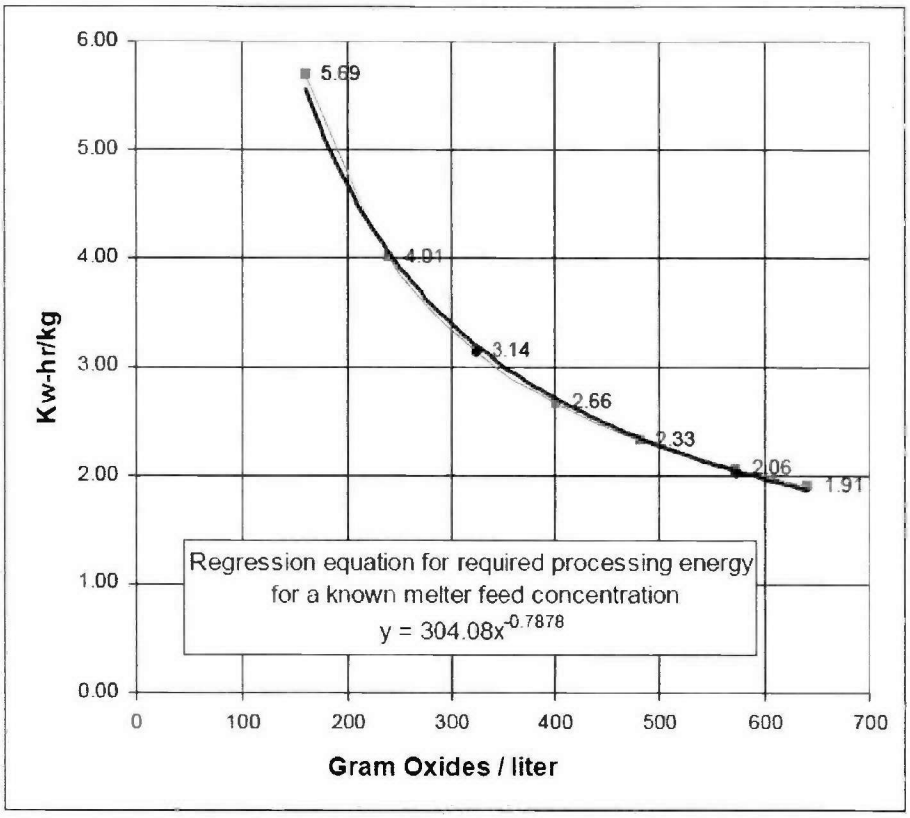


Figure 4.2-19 HLW Glass Production verses Number of Bubblers and Yield

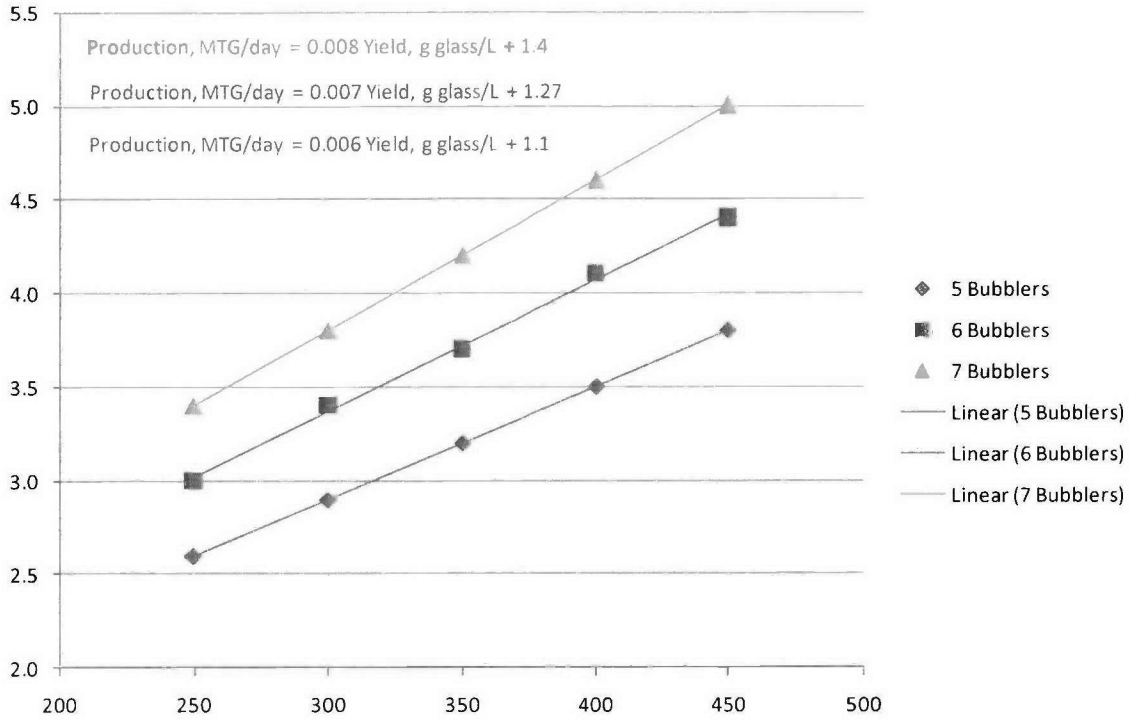
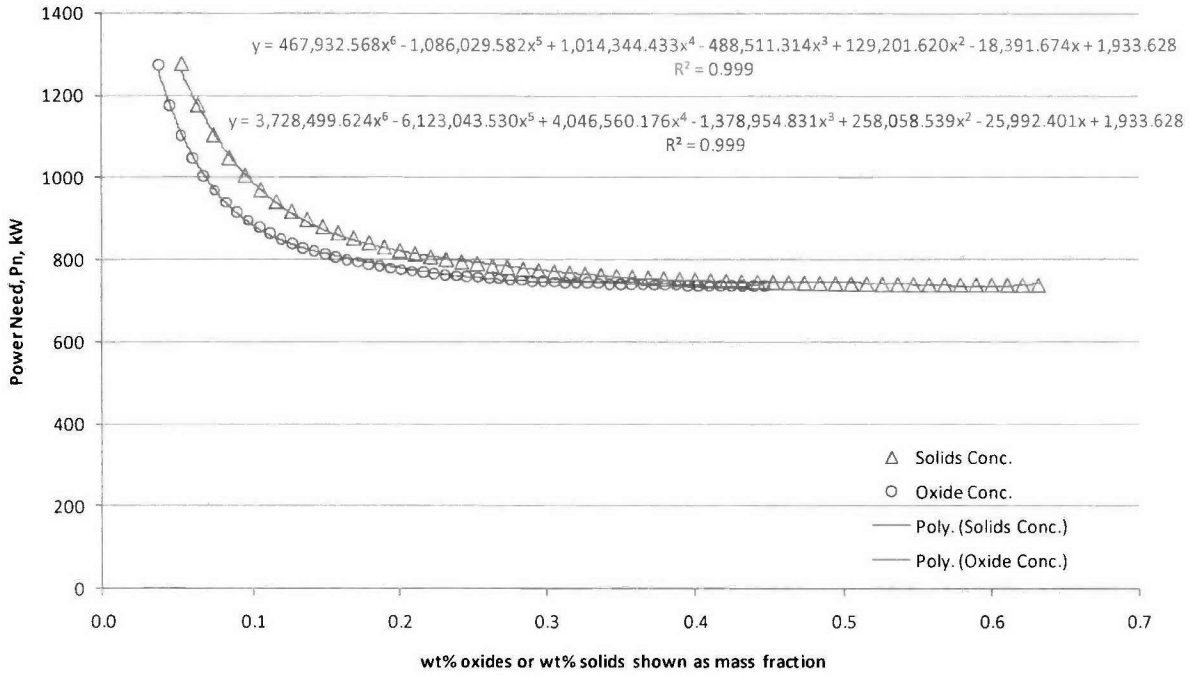


Figure 4.2-20 Melter Power Need, Pn verses Batch Oxide and Solids Concentrations



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4.3 System HOP: HLW Melter Offgas Treatment Process

4.3.1 Function and Requirements

The function of the high-level waste (HLW) primary and secondary offgas systems is to treat gases generated primarily by the HLW melter and the vessel vent system. Treatment of these gases allows an environmentally compliant release to the atmosphere. Required treatment of the gas consists of cooling, removing larger particulates (>1 μm), high-efficiency removal of submicron particulates including radionuclide aerosol, and removal of volatile organic compounds (VOC), nitrogen oxides (NO_x), radioactive iodine (^{129}I), gaseous halides, and mercury.

The safety-related functions identified for this system include:

- Preventing melter pressurization, mitigating the release of radioactive contaminants and hazardous gases to potentially occupied areas
- Permitting safe contact maintenance of the HLW secondary offgas system
- Providing a confinement barrier (physical and vacuum)
- Protecting the public, environment, and co-located workers from radionuclides and hazardous chemical exposure

The following is stated in the WTP *Statement of Work* (DE-AC27-01RV14136) Facility Specification, Section C.7 (a) (12):

> *Comply with applicable Federal, State and local requirements, including environmental permits and other regulatory approvals and authorizations. The WTP shall be designed and operated to ensure that exposure to the maximally exposed offsite individual (non-acute exposure) is ALARA but not more than 1.5 mrem per year and hazardous organic emissions are ALARA but not more than 0.375 tons per year from components regulated under 40 CFR 265 Subpart AA.*

System requirements are specified primarily in 24590-WTP-DB-ENG-01-001, *Basis of Design*, and 24590-HLW-3YD-HOP-00001, *Systems Description for the HLW Melter Offgas Treatment Process and Process Vessel Vent Exhaust (HOP and PVV Systems)*.

4.3.2 Process Description

Melter offgas generated from the HLW vitrification process consists primarily of the following:

- Air from melter bubbler operation, instrumentation, and in-leakage into the melters
- Air from film coolers
- Air from melter plenum pressure controls
- Water vapor evaporated from the melter feeds
- Acid gases generated from anion decomposition (such as CO, CO_2, NO_x, SO_x)
- Aerosols from dried melter feeds and melter cold-cap reaction solids

In addition, the HLW melters also generate small quantities of other volatile compounds. These include ^{14}C, tritium, ^{129}I, Cs, Tc, and various products of incomplete combustion (PIC) from oxidation or partial

decomposition of organics in the form of VOCs and semi-volatile organics. The isotopes ^{14}C and tritium are assumed to be in the form of carbon dioxide and water, respectively.

The HLW melter offgas treatment process system (HOP) has separate systems for decontamination of the offgas for each melter. The HOP is divided in two sections: the primary offgas treatment system and the secondary offgas treatment system. A simplified diagram of the HLW primary offgas treatment process is shown in Figure 4.3-1. The primary system consists of the equipment listed below. The equipment listed first applies to the melter 1 offgas train. The corresponding equipment for the melter 2 offgas train is listed second.

Primary Offgas Treatment System Equipment	Purpose
Film cooler (HOP-FCLR-00001, *HOP-FCLR-00002)*	Cools melter offgas below particle sticking temperature which minimizes the deposition of solids on offgas piping walls. Although the film cooler is part of the HOP system, the streams around and through the unit belong to the HLW melter process system (HMP). The film cooler is therefore shown in Figure 4.2-1 for the HMP system.
Submerged bed scrubber (SBS) (HOP-SCB-00001, *HOP-SCB-00002*)	Removes entrained particulates from the melter offgas. It also cools the offgas to a desired discharge temperature by quenching the gas with solution and transferring the heat to cooling water using cooling coils and jacket.
SBS condensate receiver vessel (HOP-VSL-00903, *HOP-VSL-00904*)	Collects condensate and wash solutions generated from the high-efficiency mist eliminators (HEME) and wet electrostatic precipitator (WESP). Collects excess condensate from the SBS, thereby maintaining a constant liquid level in the SBS.
Wet electrostatic precipitator (HOP-WESP-00001, *HOP-WESP-00002*)	Removes aerosols and particulates from the offgas stream down to submicron size.
Vessel ventilation subsystem	Collects offgas from HLW vessel vents in a header that feeds into the primary offgas system while maintaining a vacuum relative to the vessels.
High-efficiency mist eliminators (HOP-HEME-00001A/B, *HOP-HEME-00002A/B*)	Further remove radioactive aerosols from the HLW melter offgas and the vessel ventilation air and reduce the solids-loading rate on the high-efficiency particulate air (HEPA) filters.
HEPA electric preheater (HOP-HTR-00002A, HOP-HTR-00001B, and *HOP-HTR-00005A/B*)	Heats the offgas to reduce the stream humidity, preventing condensation in the filters.
WESP bulge inlet air heater (HOP-HTR-00003, *HOP-HTR-00006)*	Heats the air used to keep the WESP power insulators dry.
HEPA filters (HOP-HEPA-00001A/B, HOP-HEPA-00002A/B, *HOP-HEPA-00007A/B*, and *HOP-HEPA-00008A/B*)	Provide high-efficiency submicron particulate removal from the offgas.

After exiting the HEPA filters, the offgas line is routed to a secondary offgas treatment system for each melter. The secondary offgas treatment system removes VOCs, nitrogen oxides, ^{129}I, halides, and mercury; thereby allowing compliant offgas discharge from the stack. For a detailed description of both the primary and secondary systems refer to 24590-HLW-3YD-HOP-00001. A simplified diagram of the HLW secondary offgas treatment process system is shown in Figure 4.3-2. The secondary offgas treatment equipment and their functions are as follows.

Secondary Offgas Treatment System Equipment	Purpose
Booster extraction fans (HOP-FAN-00001A/B/C, *HOP-FAN-00009A/B/C*)	Provide the motive force for air movement of the melter offgas and the vessel ventilation offgas. Maintain the process offgas treatment system under a vacuum relative to the surroundings.
Sulfur impregnated activated carbon adsorbers (HOP-ADBR-00001A/B, *HOP-ADBR-00002A/B*)	Remove mercury from the offgas by adsorption.
Silver mordenite preheater (HOP-HX-00002, *HOP-HX-00004*)	Heats the offgas from the activated carbon adsorbers with the exhaust from the catalyst skid to reach the silver mordenite operating temperature.
Silver mordenite column (HOP-ABS-00002, *HOP-ABS-00003*)	Removes ^{129}I from the melter offgas stream. Also adsorbs volatile compounds that contain chlorine or fluorine.
Catalyst skid preheater (HOP-HX-00001, *HOP-HX-00003*)	Further heats the offgas exiting silver mordenite column with the heat generated from the NO_x selective catalytic reducer (SCR). This reduces the heat input requirements for the catalyst skid electric heater.
Catalyst skid electric heater (HOP-HTR-00001, *HOP-HTR-00007*)	Heats the offgas to the temperature required for the operation of the thermal catalytic oxidizer.
Thermal catalytic oxidizer (TCO) (HOP-SCO-00001, *HOP-SCO-00004*)	Oxidizes VOCs to carbon dioxide and water, and possibly acid gases.
Selective catalytic reducer (HOP-SCR-00001, *HOP-SCR-00002*)	Converts NO_x to nitrogen and water by reaction with ammonia.
Stack extraction fans (HOP-FAN-00008A/B/C, *HOP-FAN-00010A/B/C*)	Provide the motive force for air movement of the melter offgas and the vessel ventilation offgas up through the stack. Maintain the offgas treatment process system under a vacuum relative to the surroundings.

4.3.3 Basis

The descriptions below apply to both trains for treating the melter 1 and melter 2 offgases, respectively. For the primary system, each train has its own dedicated SBS, SBS condensate receiver vessel, WESP, vessel vent header, HEMEs, heaters, and HEPA filters. Similarly, for the secondary system, each train has its own dedicated booster fans, activated carbon adsorbers, heaters, silver mordenite columns, oxidizers, reducers, and stack fans.

4.3.3.1 HLW Film Cooler and Control Air

The film cooler (HOP-FCLR-00001, HOP-FCLR-00002) is designed to cool the offgas as soon as it leaves the melter. Cooling the offgas below the particle sticking temperature of entrained solids will minimize solids deposition on the film cooler and offgas piping walls. Cooling is accomplished by the injection of compressed air through the interior walls of the film cooler. The injection of compressed air also helps maintain a flow velocity near 60 ft/sec in the offgas piping leading into the SBS.

Melter plenum pressure is controlled by the injection of plant air near the outlet of the film cooler, the flow rate of plant air is automatically controlled to maintain melter plenum pressure at a relatively constant melter pressure even though the melter offgas generation rate fluctuates.

Flow rates for the film cooler and control air used by the flowsheet can be found in Section 4.2.3.1.

4.3.3.2 HLW Submerged Bed Scrubber and Condensate Receiver Vessel

The SBS (HOP-SCB-00001, HOP-SCB-00002) is designed for the aqueous scrubbing of entrained particulates from the melter offgas. This unit works in conjunction with the SBS condensate receiver vessel (HOP-VSL-00903, HOP-VSL-00904). It also cools the offgas to a desired discharge temperature through the use of cooling coils and a cooling jacket in the SBS and a cooling jacket on the SBS condensate receiver vessel. Process cooling water is the cooling medium. The offgas leaves the SBS in thermal equilibrium with the scrubbing solution.

As the offgas cools, water vapor condenses and increases the liquid water inventory. The rate of condensation is determined by how much the offgas temperature is lowered below its dew point. The excess water overflows into the SBS condensate receiver vessel, thereby maintaining a constant liquid level in the SBS. The receiver vessel in turn recycles the condensate to the SBS to maintain solids in suspension.

The SBS condensate receiver vessel collects condensate and wash solutions generated by the HEME, and solids, liquids, and wash solutions from the WESP. A portion of the total volume of this vessel and the SBS is expected to be pumped daily to the acid waste storage vessel (RLD-VSL-00007).

Pertinent design and operation parameters (Sections 4.3.3.2.1 through 4.3.3.2.6) include the following.

4.3.3.2.1 Design Data - HLW SBS and SBS Condensate Receiver Vessel

(24590-HLW-M6C-HOP-00005, 24590-HLW-ES-PR-04-0001, 24590-QL-POA-MKAS-00004-02-00050, 24590-HLW-MKD-HOP-00013, 24590-HLW-M4C-HOP-00011)

HOP-SCB-00001, HOP-SCB-00002

- See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.
- For particulate removal, the expected decontamination factors (DF) are in Table 4.3-1. DF is defined as the offgas mass flow rate entering the unit divided by offgas mass flow rate out of the unit for a particular component.
- Pressure drop: 30.8 in. WG

HOP-VSL-00903, HOP-VSL-00904

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate

4.3.3.2.2 Operating Logic - HLW SBS and SBS Condensate Receiver Vessel

(24590-HLW-3YD-HOP-00001, 24590-HLW-ES-PR-04-0001, 24590-HLW-MKD-HOP-00013, 24590-HLW-MPD-HOP-00001, 24590-HLW-M6C-RLD-00002)

HOP-SCB-00001, HOP-SCB-00002

- The SBS is kept at its working volume (see Appendix B). Condensate generated by offgas quenching overflows to the condensate receiver vessel (HOP-VSL-00903, HOP-VSL-00904).
- A portion of the contents of the vessel, depending on the condensation rate, is purged every 24 hr to RLD-VSL-00007 at 48 gpm via an air-ejector-induced siphon.
- Each SBS is purged until a low operating limit is reached in the condensate receiver vessel.
- Condensate from HOP-VSL-00903, HOP-VSL-00904 is pumped to the SBS to maintain solids suspension and a constant liquid level. The condensate recirculates at 80 gpm.
- A backup air ejector is installed.

HOP-VSL-00903, HOP-VSL-00904

- This vessel constantly recirculates condensate to the SBS at 80 gpm, via two reverse flow diverters (RFD) operating simultaneously. Recirculated condensate provides agitation in the SBS unit and replenishes condensate emptied from the SBS during purging.
- Solids suspension in this vessel is maintained by pulse jet mixers (PJM).

4.3.3.2.3 Energy Contributions - HLW SBS and SBS Condensate Receiver Vessel

(24590-HLW-3YD-HOP-00001)

- These units cool the offgas to 50 °C using process cooling water. The exiting offgas and the condensate are at thermal equilibrium.
- Energy contributions from the ejectors, PJMs, and RFDs are considered negligible.

4.3.3.2.4 Fluidics - HLW SBS and SBS Condensate Receiver Vessel

(24590-HLW-3YD-PJV-00001, 24590-HLW-3YN-PJV-00003)

There will be no airflow release expected from the PJMs/RFDs for HOP-VSL-00903 and HOP-VSL-00904 during normal melter operations.

4.3.3.2.5 Services - HLW SBS and SBS Condensate Receiver Vessel

(24590-HLW-3YD-HOP-00001)

- Demineralized water (DIW): used during startup to fill the vessels and during vessel washings
- Process cooling water: used for cooling of the process fluid, which cools the offgas

4.3.3.2.6 Chemistry - HLW SBS and SBS Condensate Receiver Vessel

(24590-101-TSA-W000-00009-34-03, 24590-101-TSA-W000-00009-87-09, 24590-101-TSA-W000-00009-98-07, 24590-101-TSA-W000-00009-106-18, 24590-101-TSA-W000-00009-107-01, 24590-101-TSA-W000-00009-111-01, 24590-101-TSA-W000-00009-111-02, 24590-101-TSA-W000-00009-120-06, 24590-101-TSA-W000-00009-125-00004, 24590-101-TSA-W000-00009-143-01, 24590-101-TSA-W000-00009-144-01, 24590-101-TSA-W000-00009-144-02, 24590-101-TSA-W000-00009-144-03, Pourbaix 1974, Kotz and Treichel 1996)

Various acid/base neutralization reactions are expected to occur in the SBS. Commercially available thermodynamic chemistry software (Environmental Simulation Program from OLI Systems, Inc.) calculates the most stable products for the Aspen Engineering Suite flowsheet. The most important anticipated reactions that are common to aqueous solutions are noted herein. These reactions represent the most common or likely reactions unless otherwise stated. Note that any reactions with CO_2 also apply to ^{14}C as it is considered to be in the form of CO_2. These reactions include the following:

Gases

$H_2O(g) \rightarrow H_2O(l)$
$H^+(l) + OH^-(l) \rightarrow H_2O(l)$
$CO_2(g) \rightarrow CO_2(l)$
$CO_2(l) + H_2O(l) \rightarrow H_2CO_3(l)$
$H_2CO_3(l) \rightarrow HCO_3^-(l) + H^+(l)$
$HCO_3^-(l) \rightarrow CO_3^{-2}(l) + H^+(l)$
$HCl(g) \rightarrow H^+(l) + Cl^-(l)$
$HF(g) \rightarrow H^+(l) + F^-(l)$
$NH_3(g) \rightarrow NH_3(l)$
$NH_3(l) + H_2O(l) \rightarrow NH_4^+(l) + OH^-(l)$
$P_2O_5(g) + 3H_2O(l) \rightarrow 6H^+(l) + 0.5PO_4^{-3}(l) + 1.5\ PO_4^{-3}(s)$

Sulfur and SO_x Reactions:

$SO_3(g) + H_2O(l) \rightarrow 2H^+(l) + SO_4^{-2}(l)$
$SO_2(g) + H_2O(l) \rightarrow 2H^+(l) + SO_3^{-2}(l)$

Even though sulfites are produced, they are reported as sulfates in Research and Technology (R&T) documents. Likewise, sulfur generation from the melter is reported as SO_2, so the following reaction best represents sulfur gas reaction in the flowsheet:

SO_x reactions represented as: $SO_2(g) + H_2O(l) + \frac{1}{2}O_2(g) \rightarrow 2H^+(l) + SO_4^{-2}(l)$

NO_x Reactions:

With enough O_2 and time present:	$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
In cold water:	$NO_2(g) + aH_2O(l) \rightarrow 2aH^+(l) + bNO_2^-(l) + cNO_3^-(g)$ (where a, b, and c are variables.)
In hot water:	$3NO_2(g) + H_2O(l) \rightarrow 2H^+(l) + 2NO_3^-(l) + NO(g)$

NO_x reactions are complex. There are R&T reports showing that both nitrates and nitrites are formed in the SBS fluid; dominance varies. Therefore, both the "hot" and "cold" reactions shown above appear to take place. Other forms of NO_x are possible (such as N_2O_3 and N_2O_5). To keep the modeling from becoming too complex, the following convention is used:

NO_x reactions represented as: $2NO(g) + H_2O(l) + 3/2\ O_2(g) \rightarrow 2H^+(l) + 2NO_3^-(l)$
$3NO_2(g) + H_2O(l) \rightarrow 2H^+(l) + 2NO_3^-(l) + NO(g)$

Solids Carryover Reactions

$2Na^+(s) + O^-(s) + H_2O(l) \rightarrow 2Na^+(l,s) + 2OH^-(l,s)$ Conversion Factor (CF) = 0.90

Cl^- and F^- are represented as reacting with Na^+ (the most abundant cation); therefore, the above Na^+ reaction needs to be shorted by mole amounts of Cl^- and F^- in the following two reactions:

$Na^+(s) + Cl^-(s) \rightarrow Na^+(l) + Cl^-(l)$
$Na^+(s) + F^-(s) \rightarrow Na^+(l) + F^-(l)$

Other Reactions:

$2Li^+(s) + O^{-2}(s) + H_2O(l) \rightarrow 2Li^+(l,s) + 2OH^-(l,s)$	CF = 0.95
$2K^+(s) + O^{-2}(s) + H_2O(l) \rightarrow 2K^+(l,s) + 2OH^-(l,s)$	CF = 0.95
$Ca^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Ca^{+2}(l,s) + 2OH^-(l,s)$	CF = 0.75
$Mg^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Mg^{+2}(l,s) + 2OH^-(l,s)$	
$Sr^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Sr^{+2}(l,s) + OH^-(l,s)$	CF = 0.65 (also applies to ^{90}Sr)
$Zn^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Zn^{+2}(l,s) + 2OH^-(l,s)$	
$Cd^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Cd^{+2}(l,s) + 2OH^-(l,s)$	
$Pb^{+2}(s) + O^{-2}(s) + H_2O(l) \rightarrow Pb^{+2}(l,s) + 2OH^-(l,s)$	
$2Al^{+3}(s) + 3O^{-2}(s) + 3H_2O(l) \rightarrow 2Al^{+3}(l,s) + 6OH^-(l,s)$	
$S^{+6}(s) + 3O^{-2}(s) + H_2O(l) \rightarrow 2H^+(l) + SO_4^{-2}(l)$	CF = 1.0

Other

The gaseous mercury from the melters is converted to soluble $HgCl_2$ gas or elemental mercury (Hg^0) in the melters' plenum. The fraction of Hg converted to $HgCl_2$ will be determined by the molar ratio of Hg:Cl in the melter feed. If the ratio of Hg:Cl is 0.1 or less, all mercury in the offgas will be converted to $HgCl_2$; if the Hg:Cl ratio is between 0.1 and 0.5, a portion of the mercury will be converted to $HgCl_2$; finally, if the ratio of Hg:Cl is greater than 0.5, the majority of mercury will be converted to Hg^0. $HgCl_2$, is soluble and is readily absorbed in the SBSs, while elemental mercury is insoluble and readily passes through the scrubbers (24590-101-TSA-W000-0004-125-00004, *WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant*). The absorption of $HgCl_2$ into the scrubber solution will be represented by the simplified reaction.

$$HgCl_2\ (g) \rightarrow HgCl_2\ (l) \qquad CF = 1.0$$

Whether elemental mercury is in the liquid or gaseous state will be determined by operating conditions within the offgas system.

All other constituents are split between gas and liquid phases according to the DFs.

Table 4.3-1 shows the HLW primary offgas system DF for individual species. When available, these DF values are based on reconciliation of data collected from integrated offgas system tests on the pilot melter processing specific simulants. If pilot test data are not available, values in the table are based on empirical data. When empirical data are not available, estimates are based on the relative volatility of the species. Non-volatile species are assigned values equal to the average of the DFs of Al, Fe, and Zr. When anion data are lacking, the anions are assumed to be associated with sodium (as it is the most abundant cation, and is the most likely cation to be associated with an anion), and the DF of the anion will be assigned the sodium DF.

4.3.3.3 Wet Electrostatic Precipitator

After the SBS, the offgas is routed to the WESP (HOP-WESP-00001, HOP-WESP-00002), which removes aerosols and particulates down to submicron size. Particles are charged and collected in the WESP tubes, which are positively charged. Collected particles drain down the tubes and are collected in the WESP dished bottom area. The collected wash water then gravity-drains into the SBS condensate collection vessel (HOP-VSL-00903, HOP-VSL-00904).

The WESP inlet is misted with a continuous DIW spray to aid in flushing the tubes and increased efficiency. A DIW spray at the top of the unit periodically rinses the tubes. Instrument air is added through the electrical bus housing as necessary to maintain a dry atmosphere in the electrical insulation. The instrument air is heated (HOP-HTR-00003, HOP-HTR-00006) before being injected into the WESP.

Pertinent design and operating parameters (Sections 4.3.3.3.1 through 4.3.3.3.5) include the following.

4.3.3.3.1 Design Data - WESP

(24590-QL-POA-MKE0-00001-18-00002)

- Pressure drop: 1.0 in. WG
- The expected DFs in this unit for offgas components are in Table 4.3-1

4.3.3.3.2 Operating Logic - WESP

(24590-QL-POA-MKE0-00001-18-00002, 24590-HLW-M4C-30-00003)

- Power is supplied to the unit to provide particle charging
- The unit is flushed once daily at 100 gpm for 5 min with DIW to facilitate particulate draining (equivalent to 0.347 gpm continuous)
- The unit is misted with DIW continuously at 0.12 gpm

4.3.3.3.3 Energy Contributions - WESP

(24590-QL-POA-MKE0-00001-18-00002)

Electrical power to the electrodes is the main source of energy in this unit. Approximately 12 kW are supplied to provide particle charging. It is expected that this power input will cause a slight increase in the offgas temperature. WESP offgas and condensate are at thermal equilibrium.

4.3.3.3.4 Services - WESP

(24590-QL-POA-MKE0-00001-18-00002, 24590-HLW-M4C-30-00003, 24590-HLW-M4C-HOP-00011)

- DIW: used to wash solids from the tube walls and misting with a combined flow of 0.47 gpm
- Instrument service air: 336 scfm, heated to 5 °F above the inlet offgas temperature, is introduced into the WESP to prevent shorting of the power to the internals
- Electrical power: supplied to the unit for proper operation

4.3.3.3.5 Chemistry - WESP

Anticipated common reactions associated with the WESP are identified below and account for the expected acidity of the bottoms stream, per pilot plant data.

Gases

$P_2O_5(s,g) + 3H_2O(l) \rightarrow 6H^+(l) + 2PO_4^{-3}(l)$
$H^+(l) + OH^-(l) \rightarrow H_2O(l)$
$2NO(g) + 1.5O_2(g) + H_2O(l) \rightarrow 2H^+(l) + 2NO_3^-(l)$
$2NO_2(g) + H_2O(l) + 0.5O_2(g) \rightarrow 2H^+(l) + 2NO_3^-(l)$
$SO_2(g) + H_2O(l) + 0.5O_2(g) \rightarrow 2H^+(l) + SO_4^{-2}(l)$
$CO_2(g) + H_2O(l) \rightarrow 2H^+(l) + CO_3^{-2}(l)$
$HCl(g) \rightarrow H^+(l) + Cl^-(l)$
$HF(g) \rightarrow H^+(l) + F^-(l)$
$HNO_3(l) \rightarrow H^+(l) + NO_3^-(l)$

Solids

$Na^+(s) + Cl^-(s) \rightarrow Na^+(l) + Cl^-(l)$
$Na^+(s) + F^-(s) \rightarrow Na^+(l) + F^-(l)$
$Na^+(s) + 0.5O^{-2}(s) + 0.5H_2O \rightarrow Na^+(l) + OH^-(l)$
$K^+(s) + 0.5O^{-2}(s) + 0.5H_2O \rightarrow K^+(l) + OH^-(l)$

4.3.3.4 WESP Bulge Inlet Air Heater

Air is injected to the WESP bulge to dry the power insulators and prevent short-circuiting. Instrument service air is heated (HOP-HTR-00003 and HOP-HTR-00006) to lower the stream humidity, thereby facilitating evaporation from the bulge.

Pertinent design and operating parameters (Sections 4.3.3.4.1 through 4.3.3.4.4) include the following.

4.3.3.4.1 Design Data - WESP Bulge Inlet Air Heater

(24590-HLW-MED-HOP-00030)

- ΔT rise from the heater = 45 °F
- ΔP across the heater = assumed less than 1 in. WG

4.3.3.4.2 Operating Logic - WESP Bulge Inlet Air Heater

Heater is in continuous operation while the system is functional.

4.3.3.4.3 Energy Contributions - WESP Bulge Inlet Air Heater

Electrical power: enough power is added to the heater to raise the offgas temperature by 45 °F.

4.3.3.4.4 Services - WESP Bulge Inlet Air Heater

Instrument service air contribution is accounted for in Section 4.3.3.3.

4.3.3.5 HLW Process Vessel Ventilation

The HLW vessel vent header joins the main offgas line that exits the WESP. The vessel vent system provides a vacuum on connecting vessels relative to the vessels' surroundings. Individual lines are provided to each vessel from a header. The header is connected in the melter cell to the primary offgas system between the WESP and HEME, which provides the vacuum source. Hydrogen may be generated in vessels and equipment due to thermolysis or radiolysis and is vented through the vessel ventilation system. The equations and methodology to determine the generated hydrogen component are located in Section 2.13.3.2.

Note: The melter 1 ventilation subsystem has many headers as shown in the table below. However, the melter 2 ventilation subsystem has headers from process vessels HFP-VSL-00005/6. For the steady state assessment of the offgas system, two separate runs will be required to assess design differences and flowrates.

Pertinent design and operating parameters (Sections 4.3.3.5.1 through 4.3.3.5.3) include the following.

4.3.3.5.1 Design Data - HLW Vessel Ventilation

(24590-HLW-3YD-HOP-00001, 24590-HLW-M4C-HOP-00011, SCT-M0SRLE60-00-194-00002)

- Vacuum in the vessels is maintained from -4 to -23 in. WG
- Stream temperature is approximately 95 °F
- The vessel ventilation release fractions (RF) and the vessel ventilation offgas generated (in scfm) for the collected vessel vents are shown below

where:

$$RF = \frac{\text{activity or mass /m}^3 \text{ in air}}{\text{activity or mass /m}^3 \text{ in liquor}}$$

(24590-WTP-RPT-ENV-01-014, 24590-HLW-M6C-PVV-00001)

Vessel Name	Vessel Number	Release Fraction	Offgas Generated (scfm)
Melter feed preparation vessel	HFP-VSL-00001/5	1.0E-07	55
Melter feed vessel	HFP-VSL-00002/6	1.0E-07	25
Waste neutralization vessel	HDH-VSL-00003	1.0E-08	15
Plant wash & drains vessel	RLD-VSL-00008	1.0E-08	15
Acidic waste storage vessel	RLD-VSL-00007	1.0E-08	15

4.3.3.5.2 Operating Logic - HLW Vessel Ventilation

(24590-HLW-3YD-HOP-00001)

The system continuously maintains the HLW vitrification vessels at vacuum to prevent contamination releases to the air. The system is in constant operation as long as the HLW extraction fans are operational.

4.3.3.5.3 Energy Contributions - HLW Vessel Ventilation

There are no external energy sources applied to this system. Mixing of the vessel vent header and the main offgas line will cause a slight temperature decrease in the mixed stream. This is due to differences in temperatures within the streams.

4.3.3.6 High Efficiency Mist Eliminator

After the HLW vessel vent header joins the main offgas line, the offgas flows to the HEME. There are two trains, each having a HEME, HEPA preheater, and HEPA filter. One train is operational while the

other one is on standby. The HEMEs (HOP-HEME-00001A/B, HOP-HEME-00002A/B) further remove aerosols from the HLW melter offgas stream and the vessel ventilation system to reduce the solids-loading rate and activity on the HEPA filters. Recommended DFs for polychlorinated biphenyls (PCB) and acetonitrile-related compounds in the HEMEs are shown in Table 4.3-1.

Pertinent design and operating parameters (Sections 4.3.3.6.1 - 4.3.3.6.4) include the following.

4.3.3.6.1 Design Data - HEME

(24590-HLW-MKC-HOP-00011)

- The expected DFs in this unit for offgas components are in Table 4.3-1.
- Pressure drop: 7.0 in. WG

4.3.3.6.2 Operating Logic - HEME

(24590-HLW-3YD-HOP-00001, 24590-HLW-MKC-HOP-00011)

- There are two units: One is operational while the other is on standby. A water mist is introduced to the offgas prior to the HEME inlet to maintain saturation and enhance contaminant removal within the unit. Condensate generated gravity-flows to the bottom of the unit and drains into the SBS condensate receiver vessel.
- When the pressure drop across the HEME reaches a predefined level (~20 in. WG), it will be taken offline and washed with DIW to remove accumulated solids. Insoluble solids may remain, however; their accumulation will eventually require replacing the HEME filter elements due to high differential pressure.
- The unit is flushed every 6 months with 700 gal of DIW (equivalent to 0.0027 gpm continuous).
- The unit is misted with DIW continuously at 0.05 gpm.

4.3.3.6.3 Energy Contributions - HEME

This is a passive unit and will not require energy inputs. The water addition may cause a slight temperature drop in the offgas stream.

4.3.3.6.4 Services - HEME

DIW: used for solids removal and continuous misting. A combined flow of 0.0527 gpm is supplied to the unit (24590-HLW-MKC-HOP-00011).

4.3.3.7 HEPA Electric Preheater

After the offgas exits the HEME, it is heated (HOP-HTR-00002A or HOP-HTR-00001B and HOP-HTR-00005A) or HOP-HTR-00005B) to lower the stream humidity, thereby preventing condensation in the HEPA filters.

Pertinent design and operating parameters (Sections 4.3.3.7.1 through 4.3.3.7.3) include the following.

4.3.3.7.1 Design Data - HEPA Electric Preheater

(24590-HLW-MEC-HOP-00012)

ΔT across the heater = 20 °C

4.3.3.7.2 Operating Logic - HEPA Electric Preheater

The heater is in continuous operation while the system is functional. Element redundancy is provided; therefore, failures are expected to have no impacts on throughput.

4.3.3.7.3 Energy Contributions - HEPA Electric Preheater

Electrical power: enough power is added to the heater to raise the offgas temperature by 20 °C.

4.3.3.8 HEPA Filters

The HEPA filters (HOP-HEPA-00001A/B, HOP-HEPA-00002A/B and HOP-HEPA-00007A/B, HOP-HEPA-00008A/B) remove the particulate contamination, to comply with environmental release limits and to allow the downstream equipment to be contact-maintained.

4.3.3.8.1 Design Data - HEPA Filters

(24590-HLW-3YD-HOP-00001, 24590-HLW-MAC-C5V-00006)

- Enough HEPAs are provided to support the system's maximum flowrate
- DFs for the HEPAs are in Table 4.3-2
- Pressure differential: 3.5 in. WG (average of dirty primary and secondary HEPAs) per HEPA filter bank in series

4.3.3.8.2 Operating Logic - HEPA Filters

(24590-HLW-3YD-HOP-00001)

Two sets of cylindrical HEPA filter banks, one set operational and one in standby, are used. Excessively high or low pressure drop in a HEPA filter bank triggers a switch to the standby line. Because of this redundancy, no impact to throughput is expected in the case of failure.

4.3.3.9 Booster Extraction Fans

The system contains two sets of variable speed fans, HOP-FAN-00001A/B/C and HOP-FAN-00009A/B/C. These fans provide a motive force for offgas movement and maintain melter pressure control. For each set of fans, two fans are operational with the third fan in standby. Pertinent design and operating parameters (Sections 4.3.3.9.1 through 4.3.3.9.4) include the following.

4.3.3.9.1 Design Data - Booster Extraction Fans

(24590-HLW-3YN-HOP-00006, 24590-HLW-MAD-HOP-00018)

- Motor power: 30 hp
- Static pressure: 85 in. WG

4.3.3.9.2 Operating Logic - Booster Extraction Fans

(24590-HLW-3YD-HOP-00001)

Two fans operate continuously for normal operations. The fans have variable frequency drives to allow adjustment of the flowrate to compensate for changes in the offgas. The booster fans in conjunction with the stack extraction fans provide the motive force for air movement of the melter offgas and the vessel ventilation offgas, and maintain the process offgas treatment system under vacuum relative to the surroundings.

4.3.3.9.3 Energy Contributions - Booster Extraction Fans

Electrical power supply to the fans is the only energy source provided. The fans themselves transfer some of the energy to the gas stream (heat of compression and fan inefficiency), causing a temperature rise in the stream.

4.3.3.9.4 Services - Booster Extraction Fans

Electrical power: supply will depend on the speed of the fans.

4.3.3.10 Activated Carbon Adsorbers

The offgas enters the sulfur-impregnated activated carbon adsorbers (HOP-ADBR-00001A/B, HOP-ADBR-00002A/B) for mercury removal after exiting the booster extraction fans. There are two carbon adsorbers in series for each train. Mercury removal is necessary to meet the maximum achievable control technology limits (24590-WTP-RPT-ENG-01-013) and to avoid poisoning in the catalytic skids. Recommended DFs for PCBs and acetonitrile related compounds are shown in Table 4.3-2.

Heavy organics, such as PCBs, are commonly removed from gas streams with activated carbon. These molecules compete with other contaminants for active sites in the carbon beds, which may increase the carbon changeout frequency. Competing contaminants are not considered in the models, and minimal credit (DF = 10) is assumed for removal of these organics within the carbon beds. This presents a more challenging case for the offgas systems and provides a bounding emissions estimate.

Assumption 4.3.1. Heavy organics are assumed to have minimal removal (DF = 10) in the carbon adsorption beds and their contribution as competing contaminants is not considered in the models

Pertinent design and operating parameters (Sections 4.3.3.10.1 through 4.3.3.10.5) include the following.

4.3.3.10.1 Design Data - Activated Carbon Adsorbers

(24590-HLW-MKC-HOP-00013, 24590-HLW-M4C-HOP-00011)

- Maximum mercury concentration in stack offgas: 45 μg/dscm
- Minimum mercury removal efficiency: 99.9 % (DF = 1000)
- The expected DFs for each component are in Table 4.3-2.
- Operating temperature: 79 °C (174 °F)
- Pressure differential: 3.4 in. WG
- Carbon changeout: maximum once per year

4.3.3.10.2 Operating Logic - Activated Carbon Adsorbers

- This is a passive unit that is in constant operation while the system is online. Loss of efficiency will eventually require shutdown and bed changeout.
- The adsorbers are in series and are used in a lead/lag formation, where the lag adsorber becomes the lead whenever the lead adsorber requires change out.

4.3.3.10.3 Energy Contributions - Activated Carbon Adsorbers

Heat is generated by the adsorption of the mercury, water, NO_x, and organics onto the activated carbon, thereby causing a slight temperature increase in the offgas outlet. This is a passive unit and requires no energy input from facilities.

4.3.3.10.4 Services - Activated Carbon Adsorbers

None

4.3.3.10.5 Chemistry - Activated Carbon Adsorbers

(24590-WTP-RPT-PR-01-011)

$Hg(g) + S(s) \rightarrow HgS(s)$

4.3.3.11 Silver Mordenite Preheater

The silver mordenite preheater (HOP-HX-00002 and HOP-HX-00004) is a recuperative heat exchanger used to minimize heat input to the system.

Pertinent design and operating parameters (Sections 4.3.3.11.1 through 4.3.3.11.5) include the following.

4.3.3.11.1 Design Data - Silver Mordenite Preheater

(24590-HLW-M4C-HOP-00011, 24590-HLW-MED-HOP-00031)

- Thermal transfer efficiency: 70 %
- Duty: 338,000 BTU/hr

- Pressure differential:
  - Hot side: 1.33 in. WG
  - Cold side: 2.22 in. WG

4.3.3.11.2 Operating Logic - Silver Mordenite Preheater

This heat exchanger is a passive unit that is continuously in operation. Failure of the unit is not expected to affect throughput.

4.3.3.11.3 Energy Contributions - Silver Mordenite Preheater

This countercurrent heat exchanger heats the incoming offgas with the heat of the offgas stream exiting the catalyst skid. This preheater is a passive unit with no external energy input.

4.3.3.11.4 Services - Silver Mordenite Preheater

None

4.3.3.11.5 Chemistry - Silver Mordenite Preheater

None

4.3.3.12 Silver Mordenite Column

The silver mordenite column (HOP-ABS-00002, HOP-ABS-00003) removes both elemental and organic iodine by adsorption. It will also remove other halogens such as chloride and fluoride. It will contain multiple silver mordenite cartridges for easy changeout. The unit provides the best ^{129}I removal efficiency when it is operated above 150 °C.

Pertinent design and operating parameters (Sections 4.3.3.12.1 through 4.3.3.12.4) include the following.

4.3.3.12.1 Design Data - Silver Mordenite Column

(24590-HLW-MKC-HOP-00002, 24590-HLW-3YD-HOP-00001, 24590-HLW-M4C-HOP-00011, 24590-HLW-3PS-MBT0-T00001)

- Removal efficiency: 99.9 % (DF = 1000) for ^{129}I, HCl, and HF
- The expected DFs for each component are in Table 4.3-2.
- Pressure drop: 9.2 in. WG
- Operating Temperature: 166 °C (330 °F)
- Cartridge Changeout: 9 years

4.3.3.12.2 Operating Logic - Silver Mordenite Column

(24590-HLW-3YD-HOP-00001)

This is a passive unit that is in constant operation while the system is online. Loss of efficiency will eventually require shutdown and bed changeout.

4.3.3.12.3 Chemistry - Silver Mordenite Column

(24590-HLW-MKC-HOP-00002)

$$Ag(s) + \tfrac{1}{2}I_2(g) \leftrightarrow AgI(s)$$
$$2Ag(s) + 2HCl(g) + \tfrac{1}{2}O_2(g) \leftrightarrow 2AgCl(s) + H_2O(g)$$
$$2Ag(s) + 2HF(g) + \tfrac{1}{2}O_2(g) \leftrightarrow 2AgF(s) + H_2O(g)$$

The silver mordenite flowsheet module, until recently, had only process inlet and outlet streams. Silver mordenite resin inlet and outlet streams were added. The only component in the resin inlet stream is Ag^+. The Ag^+ captures Cl^-, F^-, $^{129}I^-$, and O^{-2} from the column's inlet stream. Ag^+ is supplied at the rate necessary to capture the cited anions per the following equations. This simulates the rate of consumption of the silver mordenite resin.

Note that the equations are charge imbalanced. This is because the valance of the silver is actually Ag^0 in fresh silver mordenite resin, but the flowsheets do not track this constituent. The imbalance is only in the resin streams; it does not affect the rest of the flowsheet.

$$2Ag^+(s, \text{resin in}) + 2HCl(g, \text{supply}) + \tfrac{1}{2}O_2(g, \text{supply}) \rightarrow 2Ag^+(s, \text{resin out}) + 2Cl^-(s, \text{resin out}) + H_2O(g, \text{offgas})$$

$$2Ag^+(s, \text{resin in}) + 2HF(g, \text{supply}) + \tfrac{1}{2}O_2(g, \text{supply}) \rightarrow 2Ag^+(s, \text{resin out}) + 2F^-(s, \text{resin out}) + H_2O(g, \text{offgas})$$

$$Ag^+(s, \text{resin in}) + {}^{129}I^-(g, \text{supply}) + 1\tfrac{1}{2}O_2(g, \text{supply}) \rightarrow (Ag^+ + {}^{129}I^- + 3O^{-2})(s, \text{resin out})$$

where:

(s, resin in) is the solid resin stream entering the column.

(s, resin out) is the solid resin stream leaving the column

(g, supply) is the gaseous stream entering the column from the silver mordenite preheater

(g, offgas) is the gaseous stream leaving the column

$^{129}I^-$ is understood to be actually one-half of the $^{129}I_2$ gas

The silver mordenite will not capture all of the halides; the halides have to be in the forms described above. Solid compound forms are not attracted to silver mordenite. Consequently, the following reactions do not happen and will pass by the silver mordenite column unless captured by entrapment:

$$Ag(s) + Cl^-(s) \rightarrow AgCl(s)$$
$$Ag(s) + F^-(s) \rightarrow AgF(s)$$

It is true these reactions could happen when the constituents are dissolved in water, but the silver mordenite column is a dry system and Cl^- and F^- are bound in the dry system to other cations, e.g., Na^+.

4.3.3.12.4 Decontamination Factors and Reaction Extents

All constituents passing through the silver mordenite column should essentially be unaffected except for HCl, HF, and ^{129}I. The DF results for iodine from R&T (24590-101-TSA-W000-00009-144-01) are given below. No values are given for HCl and HF. These values should provide a reasonable estimate for chlorine and fluorine since they tend to be more reactive than iodine. The captured constituent shall follow the above listed reactions to completion.

R&T Silver Mordenite Column Results

Date	Iodine DF
01/28/03	> 1700
01/29/03	> 2040
02/25/03	> 1530
02/26/03	> 2151

$DF_{Iodine} = 4/(1/1700 + 1/2040 + 1/1530 + 1/2151) > 1820$

Until more definitive data for the DFs of iodine, HCl, and HF are available, WTP will continue to use the specified DF of 1000 (24590-HLW-3PS-MBT0-T0001) in the flowsheets.

4.3.3.13 Catalytic Skid Preheater (Heat Recovery)

As the gas enters the catalyst skid unit, it passes through the heat recovery unit heat exchanger (HOP-HX-00001 and HOP-HX-00003). The heating medium is the exhaust from the SCR beds.

Pertinent design and operating parameters (Sections 4.3.3.13.1 through 4.3.3.13.3) include the following.

4.3.3.13.1 Design Data - Catalytic Skid Preheater (Heat Recovery)

(24590-HLW-3YD-HOP-00001, 24590-HLW-DCA-PR-02-008, 24590-HLW-MKD-HOP-00019, 24590-HLW-M4C-HOP-00011)

- Thermal transfer efficiency: Various - efficiency is temperature dependent
- Duty: 774,750 BTU/hr
- Pressure differential:
  - 0.77 in. WG (cold side)
  - 0.59 in. WG (hot side)

4.3.3.13.2 Operating Logic - Catalytic Skid Preheater (Heat Recovery)

The heat exchanger is a passive unit that is continuously in operation. Failure of the unit is not expected to have major impacts on throughput.

4.3.3.13.3 Energy Contributions - Catalytic Skid Preheater (Heat Recovery)

This is a recuperative heat exchanger. There is no direct energy input from Facilities. The cold-side inlet temperature is the same as the silver mordenite column outlet. The hot side inlet temperature is the same as the one calculated as the exit temperature of the SCR.

4.3.3.14 Catalytic Skid Heater

After the heat recovery unit, the offgas passes through an electric heater (HOP-HTR-00001 and HOP-HTR-00007) to bring the temperature up to that desired for the VOC and NO_x SCR catalysts to operate.

Pertinent design and operating parameters (Sections 4.3.3.14.1 through 4.3.3.14.4) include the following.

4.3.3.14.1 Design Data - Catalytic Skid Heater

(24590-HLW-M4C-HOP-00011, 24590-HLW-MKD-HOP-00019)

- Provide enough power to raise the offgas temperature to 750 °F (399 °C)
- Pressure differential: 0.45 in. WG

4.3.3.14.2 Operating Logic - Catalytic Skid Heater

The heater is continuously operating while the catalyst unit is operational. The heater load is greatest during startup and when the NO_x feed concentration is low.

4.3.3.14.3 Energy Contributions - Catalytic Skid Heater

(24590-HLW-M4C-HOP-00011, 24590-HLW-MKD-HOP-00019)

Electrical power: enough power is provided to the heater to raise the temperature to the catalyst beds' operating temperature of 750 °F (399 °C). The amount of power supplied depends on the cold-side outlet temperature of the heat exchanger immediately upstream of the heater.

4.3.3.14.4 Services - Catalytic Skid Heater

Electrical power: enough power is provided to the heater to raise the catalyst beds' operating temperature to 750 °F (399 °C).

4.3.3.15 Thermal Catalytic Oxidizer

The VOC oxidation is the first step in the catalytic unit, after heating. The TCO column (HOP-SCO-00001, HOP-SCO-00004) is placed at the beginning of the unit. The VOC destruction reaction is exothermic. Through this catalyst, the organics are generally oxidized to carbon dioxide and water vapor.

Pertinent design and operating parameters (Sections 4.3.3.15.1 through 4.3.3.15.5) include the following.

4.3.3.15.1 Design Data - Thermal Catalytic Oxidizer

(24590-HLW-MKC-HOP-00010, 24590-HLW-MKD-HOP-00019)

- Organic removal efficiency: 95 %
- The expected DFs for each component are in Table 4.3-2
- Operating temperature: 399 °C (750 °F)
- Catalyst changeout: 1 year

4.3.3.15.2 Operating Logic - Thermal Catalytic Oxidizer

This is a passive unit that is in constant operation while the catalytic unit is online. Loss of efficiency will eventually require shutdown and catalyst changeout.

4.3.3.15.3 Energy Contributions - Thermal Catalytic Oxidizer

The VOC oxidation reactions are exothermic, producing a slight increase in the offgas temperature exiting the unit. There is no external energy input to this unit.

4.3.3.15.4 Services - Thermal Catalytic Oxidizer

None

4.3.3.15.5 Chemistry - Thermal Catalytic Oxidizer

(24590-HLW-3YD-HOP-00001, 24590-WTP-RPT-PO-03-008)

Reactions will depend on the VOCs in the offgas. In general, VOCs are oxidized to carbon dioxide and water vapor. Also the following reactions occur in this unit:

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$	CF = 0.95
$SO_2(g) + \frac{1}{2}O_2(g) \rightarrow SO_3^{-2}(s)$	CF = 0.20

Test Performance

An offline test of the TCO has been performed by the Vitreous State Laboratory at the Catholic University of America (VSL). The test used spikes of benzene, chlorobenzene, and trichloroethane (TCE). The results concluded that when the residence time is 0.3 to 0.4 sec, and the temperature is 380 to 410 °C, the destruction and removal efficiencies (DRE) will be 99 %. Therefore, the organic removal efficiency listed above (DF = 20) is sufficiently conservative. (24590-101-TSA-W000-0009-87-09)

Oxidation reactions for organic tracking compounds have been developed for use in the flowsheets. Each compound is representative of one of the tracking groups used in the emissions runs. These reactions represent complete oxidation, whether in the melter or the TCO. Any PICs resulting from partial oxidation of these compounds are not shown, and will be included as they are identified. Some of these compounds are themselves formed as PICs from the partial oxidation of waste feed organics, such as the complexants, in the melter plenum.

Tracking Compound Oxidation Reactions:

For oxidation reactions of the steady-state flowsheet tracking compounds, see **Error! Reference source not found.**.

PIC Oxidation Reactions:

Offgas constituent compounds, mostly PICs, have been identified in VSL and Duratek reports during processing of WTP Envelope A, B, or C waste simulants (24590-101-TSA-W000-0009-106-18, 24590-101-TSA-W000-0009-107-01, 24590-101-TSA-W000-0009-111-01, and 24590-101-TSA-W000-0009-111-02). The identified PICs are shown in Section 4.2.3.3.3 along with their corresponding Chemical Abstract Service (CAS) number and chemical formula. The reaction for complete oxidation of the compound is also shown. Due to the large number of these compounds and capacity of the flowsheets to handle additional constituents, they are presented for reference only.

4.3.3.16 Selective Catalytic Reducer

After the VOC catalyst, the offgas enters a chamber where anhydrous ammonia gas plus 200 scfm of dilution air (24590-HLW-MKD-HOP-00019) is injected through an atomized spray and allowed to mix with the offgas. Ammonia (NH_3) is added so that it can react with the NO_x and reduce it to nitrogen and water vapor. The offgas then goes through the NO_x catalyst module (HOP-SCR-00001, HOP-SCR-00002). NH_3 is added at stoichiometric ratio to NO_x to maintain the bed saturated with NH_3 and allow the reduction of NO_x.

Pertinent design and operating parameters (Section 4.3.3.16.1 through 4.3.3.16.5) include the following.

4.3.3.16.1 Design Data - Selective Catalytic Reducer

(24590-HLW-MKD-HOP-00019, 24590-HLW-M4C-HOP-00011)

- Completion factor for NO_x destruction in bed: CF = 0.95
- The expected DFs for each component are in Table 4.3-2
- Operating temperature: 399 °C (750 °F)
- Pressure differential: 2.9 in. WG
- Catalyst changeout: 1 year

4.3.3.16.2 Operating Logic - Selective Catalytic Reducer

This is a passive unit that is in constant operation while the catalytic unit is online. Loss of efficiency will eventually require shutdown and catalyst changeout.

4.3.3.16.3 Energy Contributions - Selective Catalytic Reducer

(24590-HLW-MKD-HOP-00019)

Mixing of the ammonia and offgas streams will lower the combined stream temperature because ammonia is added at 38 °C (100 °F) and the offgas stream at that point is above 399 °C (750 °F). NO_x reduction

reactions are highly exothermic, and therefore increase the outlet temperature. No external energy input to this unit is provided.

4.3.3.16.4 Services - Selective Catalytic Reducer

Ammonia is added above the stoichiometric ratio to ensure saturation of the catalyst with ammonia.

4.3.3.16.5 Chemistry - Selective Catalytic Reducer

(24590-HLW-3YD-HOP-00001)

Reactions in oxygen rich environment:

$$4NO(g) + 4NH_3(g) + O_2(g) \rightarrow 4N_2(g) + 6H_2O(g) \qquad CF = 0.95$$
$$2NO_2(g) + 4NH_3(g) + O_2(g) \rightarrow 3N_2(g) + 6H_2O(g) \qquad CF = 0.95$$

4.3.3.17 Stack Extraction Fan

Three variable-speed extraction fans (HOP-FAN-00008A/B/C, HOP-FAN-00010A/B/C) are downstream of the SCR and silver mordenite preheater. They, in conjunction with the booster extraction fans, provide motive force for air movement of the melter offgas and the vessel ventilation offgas.

Pertinent design and operating parameters (Sections 4.3.3.17.1 through 4.3.3.17.5) include the following.

4.3.3.17.1 Design Data - Stack Extraction Fan

(24590-HLW-3YN-HOP-00006, 24590-HLW-MAD-HOP-00038)

- Motor power: 30 hp
- Static pressure: 82 in. WG

4.3.3.17.2 Operating Logic - Stack Extraction Fan

(24590-HLW-3YD-HOP-00001, 24590-HLW-MAC-HOP-00001)

The fans operate continuously to prevent impacts to the HLW offgas system. A standby fan is provided to meet this requirement. The fans have variable frequency drives to allow adjustment of the flowrate to compensate for changes in the offgas.

4.3.3.17.3 Energy Contributions - Stack Extraction Fan

Electrical power supply to the fans is the only energy source provided. The fans themselves transfer some of the energy to the gas stream (heat of compression) causing a temperature rise in the stream.

4.3.3.17.4 Services - Stack Extraction Fan

Electrical power: varies depending on the speed of the fans.

4.3.3.17.5 Chemistry - Stack Extraction Fan

None

4.3.4 Semivolatiles and Combined Decontamination Factors

The halides (chlorine, fluorine, and iodine), sulfur, and boron are semivolatile elements in the melters. Some of their mass will leave with the molten glass and the remainder will leave with the offgas. However, that which leaves with the offgas leaves in two forms. This makes tracking these semivolatiles more difficult. One form that leaves is solid particulates entrained in the gas. The most common solid compounds are sodium salts (i.e., NaCl and NaF). The other form is gas (i.e., HCl or Cl_2). The most common gaseous compounds for the semivolatiles are HCl, HF, I_2, SO_2, and H_3BO_3 [or $B(OH)_3$]. Consequently, these semivolatiles have two DFs to describe their behavior. The pilot studies performed at VSL provided the two DFs -- one for solid particulate and the other for gas.

The following logic combines the two DFs into one. The logic maintains the appropriate total mass partitioning of the semivolatiles in the process equipment using a *combined* DF. The preferred compounds to use in the offgas are the gases HCl, HF, I_2, SO_2 (with minor amounts of SO_3), and simply B^{+3} or B_2O_3 for boron. Remember that these gases also contain and represent the mass of the solid particles released at the melters.

Figure 4.3-3 shows the offgas distribution of 100 kg of chlorine or fluorine feed to the LAW melters. These figures will be used to calculate the combined DFs. The individual DFs are listed in the equipment figure blocks. The individual melter DFs come from engineering calculation 24590-WTP-M4C-V37T-00008. The HLW offgas DFs were reconciled in Reference 6 and compiled in Section 4.2. Figure 4.3-1 through Figure 4.3-5 show the partitioning of iodine, boron, and sulfur in HLW and LAW off gas streams.

See Section 3.3.4 for details on the derivation of the combined DFs. The combined DFs for all the concerned volatiles are listed in Table Figure 4.3-3 under *references*.

Most of the semivolatiles and their mass will combine with sodium, which is one of the most populated cations in the offgas. This means the semivolatile compounds are soluble and will dissolve into the liquid phase when captured by the offgas removal equipment, for example, Table 4.5 in 24590-101-TSA-W000-0009-111-02 shows the semivolatiles as dissolved in SBS blow-downs.

4.3.5 Ongoing Work and Potential Changes

Testing of the prototypic offgas system at the VSL in Washington, DC, has been completed.

4.3.6 References

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24590-101-TSA-W000-0009-87-09, Rev 00B, *Final Report - Off-line Test of the DM 1200 Thermal Catalytic Oxidation (TCO) Unit* (VSL-02R8200-1, Rev 0).

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24590-101-TSA-W000-0009-106-18, Rev 00C, *RPP-WTP Pilot Melter Envelope C Melter Emissions Test Results Report* (TRR-PLT-077, Rev 1).

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24590-101-TSA-W000-0009-144-00005, Rev. 00A, *Final Report - DM1200 Tests with AZ-101 HLW Simulants* (VSL-03R3800-4, Rev 0).

24590-101-TSA-W000-0009-144-00006, Rev 00B, *Final Report - Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification* (VSL-05R5800-1, Rev 0).

24590-101-TSA-W000-0009-144-01, Rev 00B, *Final Report - Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers* (VSL-03R3800-1, Rev 0).

24590-101-TSA-W000-0009-144-02, Rev 00B, *Final Report - Integrated DM1200 Melter Testing of HLW AZ-102 Composition Using Bubblers* (VSL-03R3800-2, Rev 0).

24590-101-TSA-W000-0009-144-03, Rev 00B, *Final Report - Noble Metals Testing on the DM1200 Pilot Melter System with AZ-101 HLW Simulants* (VSL-03R3740-2, Rev. 0).

24590-101-TSA-W000-0009-158-00001, Rev 00A, *Final Report - Integrated Dm1200 Testing Of Bubbler Configurations Using Hlw Az-101 Simulants* (VSL-04R4800-4, Rev 0).

24590-101-TSA-W000-0009-166-00001, Rev 00B, *Final Report - Regulatory Off-Gas Emissions Testing on the DM1200 Melter System Using HLW and LAW Simulants* (VSL-05R5830-1, Rev 0).

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24590-HLW-3YD-HOP-00001, Rev 2, *Systems Description for HLW Melter Offgas Treatment Process and Process Vessel Vent Exhaust (HOP and PVV Systems).*

24590-HLW-3YD-PJV-00001, Rev 3, *System Description for the HLW Pulse Jet Ventilation System (System PJV).*

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24590-HLW-DCA-PR-02-008, Rev 0, *Increase in Thermal Efficiency for the Booster Fan Preheater (HOP-HX-00002).*

24590-HLW-ES-PR-04-0001, Rev 1, *HLW Melter Feed and Feed Preparation Vessel Utilization and Time Cycle Evaluation.*

24590-HLW-M4C-30-00003, Rev 0, *HLW Vitrification Facility Feed and Effluent Design Basis Flowsheets.*

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24590-HLW-MAC-C5V-00006, Rev B, *HLW C5V System Pressure Drop Calculation.*

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24590-HLW-MEC-HOP-00012, Rev 0, *Sizing of the HLW Offgas HEPA Electric Preheater.*

24590-HLW-MED-HOP-00030, Rev 0, *24590-HLW-ME-HOP-HTR-00003, 24590-HLW-ME-HOP-HTR-00006 WESP Bulge Inlet Air Heater.*

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24590-HLW-MKD-HOP-00013, Rev 2, *24590-HLW-HOP-SCB-00001 - Submerged Bed Scrubber (Melter 1).*

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Table 4.3-1 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HLW SBS DF	Source	Revised DF WESP Nominal Operational	Source	Revised DF HEME Nominal Operational	Source
Cations							
	Al3+	223	16	2.9	16	310	7
	Ag+	50	7	1000	7	310	7
	Am3+	50	7	1000	7	310	7
	As5+	5.3	16	25.4	16	330	7
	B3+	See Table 4.3-3	--	--	--	--	--
	Ba2+	10.7	16	1000	7	310	7
	Be2+	50	7	1000	7	310	7
	Bi3+	50	7	1000	7	310	7
	Ca2+	35.7	16	3.8	16	300	7
	Cd2+	11.1	16	4.8	16	320	7
	Ce4+	520	7	1000	7	300	7
	Co2+	8.7	7	1000	7	330	7
	Cr3+	5.5	16	8.4	16	340	7
	Cr6+	5.5	16	8.4	16	340	7
	Cr(OH)4-	5.5	16	8.4	16	340	7
	Cr(TOTAL)	5.5	16	8.4	16	340	7
	Cs+	3.3	16	18.4	16	320	7
	Cu2+	12.9	16	1.5	16	310	7
	Eu3+	50	7	1000	7	310	7
	Fe2+	294	16	8.6	16	310	7
	Fe3+	294	16	8.6	16	310	7
	H+	2000	8	1000	8	1000	8
	Hf4+	145.2	24	1.8	24	290	24
	Hg2+			1.000	9		
	Hg:Cl [1] < 0.1	6	24	N/A		3.5	26
	0.1 < Hg:Cl < 0.5	2.27	24	N/A		1.55	26
	Hg:Cl > 0.5	1.4	9	N/A		1	9
	K+	9	16	5.7	16	320	7
	La3+	1000	7	1000	7	300	7

		Revised DF HLW SBS DF	Source	Revised DF WESP Nominal Operational	Source	Revised DF HEME Nominal Operational	Source
	Li+	19.9	16	20	16	320	7
	Mg2+	106	16	1.4	16	300	7
	Mn4+	51.4	16	1.6	16	300	7
	MnO2	51.4	16	1.6	16	300	7
	MnO4-	51.4	16	1.6	16	300	7
	Mo6+	10	7	1000	7	330	7
	Na+	15.7	16	36.8	16	320	7
	Nd3+	850	7	1000	7	300	7
	Ni2+	95.9	16	1.4	16	300	7
	NH4+	10	11	1.110	11	1.110	11
	Pb2+	9.4	16	5.5	16	320	7
	Pd2+	50	7	1000	7	310	7
	Pr4+	50	7	1000	7	310	7
	Pu4+	50	7	1000	7	310	7
	Ra2+	50	7	1000	7	310	7
	Rb+	50	7	1000	7	310	7
	Rh3+	50	7	1000	7	310	7
	Ru4+	2.9	16	22.2	16	330	7
	S+6	3.9	16	59.6	16	320	7
	Sb3+	19.1	16	5.7	16	270	7
	Se4+	4.8	16	36.1	16	320	7
	Si4+	259.6	16	9.5	16	310	7
	Sr2+	34.6	16	1.8	16	300	7
	Ta5+	50	7	1000	7	310	7
	Tc4+	50	7	1000	7	310	7
	Te4+	3.6	16	139.8	16	320	7
	Th4+	50	7	1000	7	310	7
	Ti4+	32.8	16	1.5	16	290	7
	Tl5+	50	7	1000	7	310	7
	U4+	50	7	1000	7	310	7
	U(TOTAL)	50	7	1000	7	310	7

		Revised DF HLW SBS DF	Source	Revised DF WESP Nominal Operational	Source	Revised DF HEME Nominal Operational	Source
	V3+	5.3	7	1000	7	340	7
	W6+	50	7	1000	7	310	7
	Y3+	280	7	1000	7	310	7
	Zn2+	87	16	7.5	16	310	7
	Zr4+	145.2	16	1.8	16	290	7
Anions							
	Cl-	See Table 4.3-3	--	--	--	--	--
	CO32-	15.7	10	36.8	10	320	10
	HCO3-	15.7	10	36.8	10	320	10
	F-	See Table 4.3-3	--	--	--	--	--
	I-	See Table 4.3-3	--	--	--	--	--
	CN-	15.7	10	36.8	10	320	10
	NO2-	15.7	10	36.8	10	320	10
	NO3-	15.7	10	36.8	10	320	10
	O2-	NA	NA	NA	NA	NA	NA
	OH-(aq)	15.7	10	1000	7	320	7
	OH-(s)	15.7	10	1000	7	320	7
	PO43-	8.5	16	2.6	16	320	7
	SiO4-4	259.6	16	9.5	16	320	7
	SO42-	See Table 4.3-3	--	--	--	--	--
Organics							
	acetate	15.7	15	36.8	15	320	15
	oxalate	15.7	15	36.8	15	320	15
	citrate	15.7	15	36.8	15	320	15
	EDTA	15.7	15	36.8	15	320	15
	formate	15.7	15	36.8	15	320	15
	glycolate	15.7	15	36.8	15	320	15
	HEDTA	15.7	15	36.8	15	320	15
	IDA	15.7	15	36.8	15	320	15
	Sucrose	NA	NA	NA	NA	NA	NA
	PPG	1	25	1	25	1	25

		Revised DF HLW SBS DF	Source	Revised DF WESP Nominal Operational	Source	Revised DF HEME Nominal Operational	Source
	PDMS	1	25	1	25	1	25
	C12H4C16(1)	18	17, 18	250	17, 18	500	17, 18
	C2H3N(1)	18	17, 18	250	17, 18	500	17, 18
	C12H4C16(g)	4.5	17, 18	1.1	17, 18	500	17, 18
	C2H3N(g)	5.0	17, 18	1.0	17, 18	1.0	17, 18
Water							
	H2O	Calculated	NA	Calculated	NA	Calculated	NA
Gases							
	CO	1.000	7	1.000	7	1.000	7
	CO2	1.001	13	1.000	7	1.000	7
	HCl	See Table 4.3-3	--	--	--	--	--
	HF	See Table 4.3-3	--	--	--	--	--
	HI	See Table 4.3-3	--	--	--	--	--
	I2	See Table 4.3-3	--	--	--	--	--
	N2	1.000	7	1.000	7	1.000	7
	NH3	10	19	1.110	7	1.110	7
	NO	1.058	12	1.000	7	1.000	7
	NO2	1.002	12	1.050	7	1.050	7
	O2	1.000	7	1.000	7	1.000	7
	P2O5(s)	8.5	16	2.6	16	360	7
	SO2	See Table 4.3-3	--	--	--	--	--
Radionuclides							
	3H (1)	Follows Water	NA	Follows Water	NA	Follows Water	NA
	14C(2)	1.001	13	1.000	7	1.000	7
	59Ni	95.9	16	1.4	16	300	7
	60Co	8.7	7	1000	7	330	7
	63Ni	95.9	16	1.4	16	300	7
	79Se	4.8	16	36.1	16	320	7
	90Sr	34.6	16	1.8	16	300	7

		Revised DF		Revised DF		Revised DF	
		HLW SBS DF	Source	WESP Nominal Operational	Source	HEME Nominal Operational	Source
	90Y	429	8	1000	7	310	7
	93Zr	145.2	16	1.8	16	290	7
	93mNb	50	14	1000	14	310	14
	99Tc	50	7	1000	7	310	7
	103Ru	2.9	16	22.2	16	330	7
	106Ru	2.9	16	22.2	16	330	7
	113mCd	11.1	16	4.8	16	320	7
	125Sb	19.1	16	5.7	16	270	7
	126Sn	50	7	1000	7	310	7
	129I	See Table 4.3-3	--	--	--	--	--
	134Cs	3.3	16	18.4	16	320	7
	137Cs	3.3	16	18.4	16	320	7
	137mBa	3.3	23	18.4	23	310	7
	151Sm	50	14	1000	14	310	14
	152Eu	50	7	1000	7	310	7
	154Eu	50	7	1000	7	310	7
	155Eu	50	7	1000	7	310	7
	226Ra	50	7	1000	7	310	7
	227Ac	50	14	1000	14	310	14
	228Ra	50	7	1000	7	310	7
	229Th	50	7	1000	7	310	7
	231Pa	50	7	1000	7	310	7
	232Th	50	7	1000	7	310	7
	232U	50	7	1000	7	310	7
	233U	50	7	1000	7	310	7
	234U	50	7	1000	7	310	7
	235U	50	7	1000	7	310	7
	236U	50	7	1000	7	310	7
	237Np	50	7	1000	7	310	7
	238Pu	50	7	1000	7	310	7
	238U	50	7	1000	7	310	7

		Revised DF		Revised DF		Revised DF	
		HLW SBS DF	Source	WESP Nominal Operational	Source	HEME Nominal Operational	Source
	239Pu	50	7	1000	7	310	7
	240Pu	50	7	1000	7	310	7
	241Am	50	7	1000	7	310	7
	241Pu	50	7	1000	7	310	7
	242Cm	50	7	1000	7	310	7
	242Pu	50	7	1000	7	310	7
	243Am	50	7	1000	7	310	7
	243Cm	50	7	1000	7	310	7
	244Cm	50	7	1000	7	310	7

1. 24590-101-TSA-W000-0009-98-07, Rev 00C, *DM1200 Tests with C-104/AY-101 HLW Simulants Final Report.*
2. 24590-101-TSA-W000-0009-144-01, Rev 00B, *Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers.*
3. 24590-101-TSA-W000-0009-144-02, Rev 00B, *Integrated DM1200 Melter Testing of HLW AZ-102 Composition Using Bubblers.*
4. 24590-101-TSA-W000-0009-34-03, Rev 00C, *Final Report - Tests on the DuraMelter 1200 HLW Pilot Melter System Using AZ-101 HLW Simulants.*
5. 24590-101-TSA-W000-0009-158-00001, Rev 00A, *Final Report - Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants.*
6. Average DF from available R&T Data; calculated as: $DF_{avg} = n / (1/DF_1 + 1/DF_2 + ... + 1/DF_n)$.
7. 24590-WTP-M4C-V11T-00010, Rev 0, *Process Engineering Mass Balance for WTP.*
8. DF for H+ used only in the Dynamic Flowsheet (G2), round split to SBS condensate to 100 %.
9. 24590-101-TSA-W000-0004-125-00004, Rev 00A, *Test Summary: WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant*, Table 8.2.
10. Assumed the following anions are particulate primarily tied with sodium, so used the sodium DF: CO_3^{2-}, HCO_{3-}, CN-, NO_{2-}, NO_{3-}, and OH-.
11. DF for NH_4^+ assumed equal to DF for NH_3.
12. The DFs for NO and NO_2 are assumed the same as those for LAW.
13. The fraction of CO_2 fed to the SBS that is absorbed (0.001) is assumed based on an un-issued calculation by Process Engineering.
14. DF assumed the same as the average HLW DF from Attachment D of 24590-WTP-M4C-V11T-00010, Rev 0.
15. Organic ions are assumed bound to sodium; therefore, the sodium DF applies.
16. Letter Report AEM 068, Reconcile HLW and LAW Secondary Offgas (SBS and WESP) Decontamination Factors. This reconciliation effort included references 1 through 4, and 20 through 22.
17. 24590-101-TSA-W000-0009-106-18, Rev 00C, *RPP Pilot Melter Envelope C Melter Emissions Test Results Report.*
18. 24590-101-TSA-W000-0009-107-01, Rev 00C, *RPP Pilot Melter Envelope A Melter Emissions Test Results Report.*
19. Assumption based on unvalidated ASPEN PLUS/Environmental Simulation Program results.
20. 24590-101-TSA-W000-0009-144-00005, Rev. 00A, *Final Report - DM1200 Tests with AZ-101 HLW Simulants.*
21. 24590-101-TSA-W000-0009-144-00006, Rev 00A, *Final Report - Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification.*
22. 24590-101-TSA-W000-0009-118-00009, Rev 00A, *Final Report - Integrated DM1200 Melter Testing of Redox Effects Using HLW AZ-101 and C-106/AY-102 Simulants.*

23. DF for 137mBa assumed equal to DF for Cs.
24. Hafnium is a non-volatile constituent, and is given a DF equal to that of zirconium.
25. PPG and PDMS are semi-volatile organics with flash points below the temperatures in the melter, and negligible amounts are anticipated to pass into the offgas system. The minimum DF of 1 is assumed for these treatment units.
26. 24590-WTP-RPT-PR-01-011, Rev 0, *Mercury Pathway and Treatment Assessment for the WTP.*

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
Cations													
	Al3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ag+	3333	7	500	7	1	3	1	4	1	2	1	2
	Am3+	3333	7	500	7	1	3	1	4	1	2	1	2
	As5+	3333	7	500	7	1	3	1	4	1	2	1	2
	B3+	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1	2	1	2
	Ba2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Be2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Bi3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ca2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Cd2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ce4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Co2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Cr3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Cr6+	3333	7	500	7	1	3	1	4	1	2	1	2
	Cr(OH)4-	3333	7	500	7	1	3	1	4	1	2	1	2
	Cr(TOTAL)	3333	7	500	7	1	3	1	4	1	2	1	2
	Cs+	3333	7	500	7	1	3	1	4	1	2	1	2
	Cu2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Eu3+	3333	7	500	7	1	3	1	4	1	2	1	2

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
	Fe2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Fe3+	3333	7	500	7	1	3	1	4	1	2	1	2
	H+	3333	7	500	7	1	3	1	4	1	2	1	2
	Hf4+	3333	9	500	9	1	9	1	9	1	9	1	9
	Hg2+	1	7	1	7	1	3	1	4	1	2	1000	2
	K+	3333	7	500	7	1	3	1	4	1	2	1	2
	La3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Li+	3333	7	500	7	1	3	1	4	1	2	1	2
	Mg2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Mn4+	3333	7	500	7	1	3	1	4	1	2	1	2
	MnO2	3333	7	500	7	1	3	1	4	1	2	1	2
	MnO4-	3333	7	500	7	1	3	1	4	1	2	1	2
	Mo6+	3333	7	500	7	1	3	1	4	1	2	1	2
	Na+	3333	7	500	7	1	3	1	4	1	2	1	2
	Nd3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ni2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Pb2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Pd2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Pr4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Pu4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ra2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Rb+	3333	7	500	7	1	3	1	4	1	2	1	2

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
	Rh3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ru4+	3333	7	500	7	1	3	1	4	1	2	1	2
	S+6	1	7	1	7	1	3	1	4	1	2	1	2
	Sb3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Se4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Si4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Sr2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ta5+	3333	7	500	7	1	3	1	4	1	2	1	2
	Tc4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Te4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Th4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Ti4+	3333	7	500	7	1	3	1	4	1	2	1	2
	Tl5+	3333	7	500	7	1	3	1	4	1	2	1	2
	U4+	3333	7	500	7	1	3	1	4	1	2	1	2
	U(TOTAL)	3333	7	500	7	1	3	1	4	1	2	1	2
	V3+	3333	7	500	7	1	3	1	4	1	2	1	2
	W6+	3333	7	500	7	1	3	1	4	1	2	1	2
	Y3+	3333	7	500	7	1	3	1	4	1	2	1	2
	Zn2+	3333	7	500	7	1	3	1	4	1	2	1	2
	Zr4+	3333	7	500	7	1	3	1	4	1	2	1	2

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
Anions													
	Cl-	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1	2	1	2
	CO32-	3333	7	500	7	1	3	1	4	1	2	1	2
	HCO3-	3333	7	500	7	1	3	1	4	1	2	1	2
	F-	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1	2	1	2
	I-	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1	2	1	2
	CN-	3333	7	500	7	1	3	1	4	1	2	1	2
	NH4+	3333	7	500	7	1	3	1	4	1	2	1	2
	NO2-	3333	7	500	7	1	3	1	4	1	2	1	2
	NO3-	3333	7	500	7	1	3	1	4	1	2	1	2
	O2-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	OH-(aq)	3333	7	500	7	1	3	1	4	1	2	1	2
	OH-(s)	3333	7	500	7	1	3	1	4	1	2	1	2
	PO43-	3333	7	500	7	1	3	1	4	1	2	1	2
	SiO4-4	3333	7	500	7	1	3	1	4	1	2	1	2
	SO42-	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1	2	1	2
Organics													
	acetate	3333	7	500	7	20	3	1	4	1	6	1	6
	oxalate	3333	7	500	7	20	3	1	4	1	6	1	6
	citrate	3333	7	500	7	20	3	1	4	1	6	1	6
	EDTA	3333	7	500	7	20	3	1	4	1	6	1	6
	formate	3333	7	500	7	20	3	1	4	1	6	1	6

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
	glycolate	3333	7	500	7	20	3	1	4	1	6	1	6
	HEDTA	3333	7	500	7	20	3	1	4	1	6	1	6
	IDA	3333	7	500	7	20	3	1	4	1	6	1	6
	Sucrose	3333	7	500	7	20	3	1	4	1	2	1	2
	PPG	3333	10	500	10	20	3	1	4	1	6	1	6
	PDMS	3333	10	500	10	20	3	1	4	1	6	1	6
	C12H4Cl6(l)	3333	1	500	1	20	1	1	1	1	1	10	1
	C2H3N(l)	3333	1	500	1	20	1	1	1	1	1	10	1
	C12H4Cl6(g)	1	1	1	1	4.1	1	1	1	1	1	10	1
	C2H3N(g)	1	1	1	1	1	1	1	1	1	1	10	1
Water													
	H2O	1	7	1	7	1	3	1	4	1	2	1	2
Gases													
	CO	1	7	1	7	20	3	1	4	1	2	1	2
	CO2	1	7	1	7	1	3	1	4	1	2	1	2
	HCl	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1000	8	1	2
	HF	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1000	8	1	2
	HI	See Table	4.3-3	See Table	4.3-3	NA	NA	NA	NA	NA	NA	NA	NA
	I2	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1000	8	1	2
	N2	1	7	1	7	1	3	1(& Produced)	NA	1	2	1	2
	NH3	1	7	1	7	1	3	Consumed	NA	1	2	1	2
	NO	1	7	1	7	1	3	20	5	1	2	1	2

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
	NO2	1	7	1	7	1	3	20	5	1	2	1	2
	O2	1	7	1	7	1	3	1	4	1	2	1	2
	P2O5(s)	3333	7	500	7	1	3	1	4	1	2	1	2
	SO2	See Table	4.3-3	See Table	4.3-3	1.25	3	1	4	1	2	1	2
Radionuclides													
	3H (1)	1	7	1	7	1	3	1	4	1	2	1	2
	14C(2)	1	7	1	7	1	3	1	4	1	2	1	2
	59Ni	3333	7	500	7	1	3	1	4	1	2	1	2
	60Co	3333	7	500	7	1	3	1	4	1	2	1	2
	63Ni	3333	7	500	7	1	3	1	4	1	2	1	2
	79Se	3333	7	500	7	1	3	1	4	1	2	1	2
	90Sr	3333	7	500	7	1	3	1	4	1	2	1	2
	90Y	3333	7	500	7	1	3	1	4	1	2	1	2
	93Zr	3333	7	500	7	1	3	1	4	1	2	1	2
	93mNb	3333	7	500	7	1	3	1	4	1	6	1	6
	99Tc	3333	7	500	7	1	3	1	4	1	2	1	2
	103Ru	3333	7	500	7	1	3	1	4	1	2	1	2
	106Ru	3333	7	500	7	1	3	1	4	1	2	1	2
	113mCd	3333	7	500	7	1	3	1	4	1	2	1	2
	125Sb	3333	7	500	7	1	3	1	4	1	2	1	2
	126Sn	3333	7	500	7	1	3	1	4	1	2	1	2
	129I	See Table	4.3-3	See Table	4.3-3	1	3	1	4	1000	8	1	2

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
	134Cs	3333	7	500	7	1	3	1	4	1	2	1	2
	137Cs	3333	7	500	7	1	3	1	4	1	2	1	2
	137mBa	3333	7	500	7	1	3	1	4	1	2	1	2
	151Sm	3333	7	500	7	1	3	1	4	1	6	1	6
	152Eu	3333	7	500	7	1	3	1	4	1	2	1	2
	154Eu	3333	7	500	7	1	3	1	4	1	2	1	2
	155Eu	3333	7	500	7	1	3	1	4	1	2	1	2
	226Ra	3333	7	500	7	1	3	1	4	1	6	1	6
	227Ac	3333	7	500	7	1	3	1	4	1	6	1	6
	228Ra	3333	7	500	7	1	3	1	4	1	6	1	6
	229Th	3333	7	500	7	1	3	1	4	1	6	1	6
	231Pa	3333	7	500	7	1	3	1	4	1	6	1	6
	232Th	3333	7	500	7	1	3	1	4	1	6	1	6
	232U	3333	7	500	7	1	3	1	4	1	2	1	2
	233U	3333	7	500	7	1	3	1	4	1	2	1	2
	234U	3333	7	500	7	1	3	1	4	1	2	1	2
	235U	3333	7	500	7	1	3	1	4	1	2	1	2
	236U	3333	7	500	7	1	3	1	4	1	2	1	2
	237Np	3333	7	500	7	1	3	1	4	1	2	1	2
	238Pu	3333	7	500	7	1	3	1	4	1	2	1	2
	238U	3333	7	500	7	1	3	1	4	1	2	1	2
	239Pu	3333	7	500	7	1	3	1	4	1	2	1	2

Table 4.3-2 HLW Vitrification Material Flow Decontamination Factors by Component

		Revised DF HEPA (First) Nominal	Source	Revised DF HEPA (Second) Nominal	Source	Revised DF Thermal Oxidizer	Source	Revised DF NO_x SCR	Source	Revised DF Silver Mordenite Column	Source	Revised DF Carbon Adsorption Column	Source
	240Pu	3333	7	500	7	1	3	1	4	1	2	1	2
	241Am	3333	7	500	7	1	3	1	4	1	2	1	2
	241Pu	3333	7	500	7	1	3	1	4	1	2	1	2
	242Cm	3333	7	500	7	1	3	1	4	1	2	1	2
	242Pu	3333	7	500	7	1	3	1	4	1	2	1	2
	243Am	3333	7	500	7	1	3	1	4	1	2	1	2
	243Cm	3333	7	500	7	1	3	1	4	1	2	1	2
	244Cm	3333	7	500	7	1	3	1	4	1	2	1	2

1. 24590-WTP-MCR-PO-04-0055, Rev 0, *LAW & HLW Miscellaneous Updates for the Dynamic (G2) Flowsheet.*
2. 24590-WTP-M4C-V11T-00010, Rev 0, *Process Engineering Mass Balance for WTP.*
3. Only organics, CO, and SO_2 are oxidized in the TCO. CO is assumed to oxidize at the same efficiency as the organics (See 24590-MKD-HOP-00019, Rev 5). SO_2 is assumed to oxidize at an efficiency of 20 % (See 24590-WTP-RPT-PO-03-008, Rev 2).
4. Only NO and NO_2 are reduced in the SCR.
5. Per 24590-HLW-MKD-HOP-00019, Rev 8, *HLW Catalytic Oxidizer/Selective Catalytic Reducer Data Sheet.*
6. By analogy with 24590-WTP-M4C-V11T-00010, Rev 0, *Process Engineering Mass Balance for WTP.*
7. Per 24590-WTP-MKC-50-00002, Rev 1, *Process Engineering Decontamination Factor Curves.* All tracked organics are below their melting points at HEPA operating temperatures. Note that this reference applies to particulates; gases will have a DF of 1.000.
8. Per 24590-HLW-3PS-MBT0-T0001, Rev 5, *Engineering Specification for Silver Mordenite Column Design and Fabrication,* iodine, HCl and HF DFs in the silver mordenite column are 1000.
9. Hafnium is a non-volatile constituent, and is given a DF equal to that of zirconium.
10. PPG and PDMS are below their melting points at the HEPA operating temperatures, and will be removed as particulates.

Table 4.3-3 Combined Solids and Gas Halide Decontamination Factors, DFs

Equipment	Fluorine - HLW	Chlorine - HLW
Melter	1.24	1.36
SBS	57.0	4.10
WESP	2.00	9.50
HEME	7.60	7.60
HEPAs - 1st Stage	1.00	1.00
HEPAs - 2nd Stage	1.00	1.00

Equipment	Iodine - HLW	Boron - HLW
Melter	1.30	49.3
SBS	3.20	95.5
WESP	1.70	12.5
HEME	1.00	310
HEPAs - 1st Stage	1.00	3333
HEPAs - 2nd Stage	1.00	1.00

Equipment	Sulfur - HLW
Melter	1.72
SBS	6.82
WESP	1.20
HEME	64.50
HEPAs - 1st Stage	1.00
HEPAs - 2nd Stage	1.00

Sources:

1. 24590-WTP-M4C-V37T-00008, Rev 0, *Reconciliation of HLW and LAW Melter Decontamination Factors.*
2. 24590-101-TSA-W000-0009-111-02, Rev 00B, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope A1 Simulants*, Table 6.3
3. 24590-101-TSA-W000-0009-143-01, Rev 00B, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants*, Table 6.3.
4. 24590-101-TSA-W000-0009-111-01, Rev 0, *Final Report - Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sun-Envelope C1 Simulants*, Table 6.3.
5. 24590-WTP-RPT-PT-02-005, Rev 5, *Flowsheet Bases, Assumptions, and Requirement*, Tables 3.3-1 and 3.3-2.
6. Letter Report AEM 068, Reconcile HLW and LAW Secondary Offgas (SBS and WESP) Decontamination Factors. This reconciliation effort included references 1 through 4, and 20 through 22.
7. 24590-101-TSA-W000-0009-98-07, Rev 00C, *DM1200 Tests with C-104/AY-101 HLW Simulants Final Report.*
8. 24590-101-TSA-W000-0009-144-01, Rev 00B, *Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers.*
9. 24590-101-TSA-W000-0009-144-02, Rev 00B, *Integrated DM1200 Melter Testing of HLW AZ-102 Composition Using Bubblers.*
10. 24590-101-TSA-W000-0009-34-03, Rev 00C, *Final Report - Tests on the DuraMelter 1200 HLW Pilot Melter System Using AZ-101 HLW Simulants.*

11. 24590-101-TSA-W000-0009-144-00005, Rev. 00A, *Final Report - DM1200 Tests with AZ-101 HLW Simulants.*
12. 24590-101-TSA-W000-0009-144-00006, Rev 00A, *Final Report - Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification.*
13. 24590-101-TSA-W000-0009-144-00006, Rev 00A, *Final Report - Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification.*
14. 24590-WTP-RPT-PT-02-005, Rev 5, *Flowsheet Bases, Assumptions, and Requirement*, Tables 4.3-1 and 4.3-2.

Figure 4.3-1 HLW Primary Offgas Treatment System

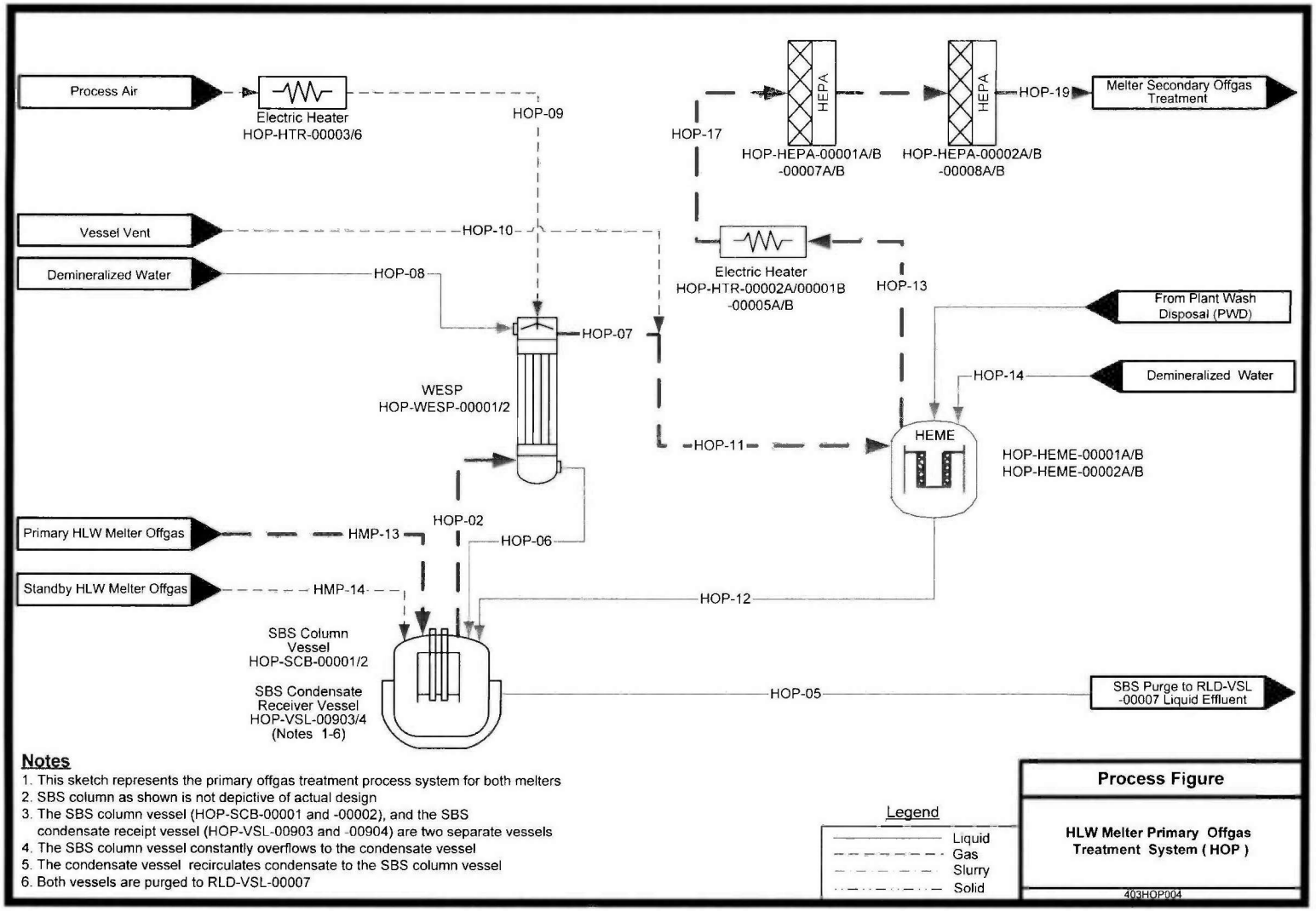


Figure 4.3-2 HLW Secondary Offgas Treatment System

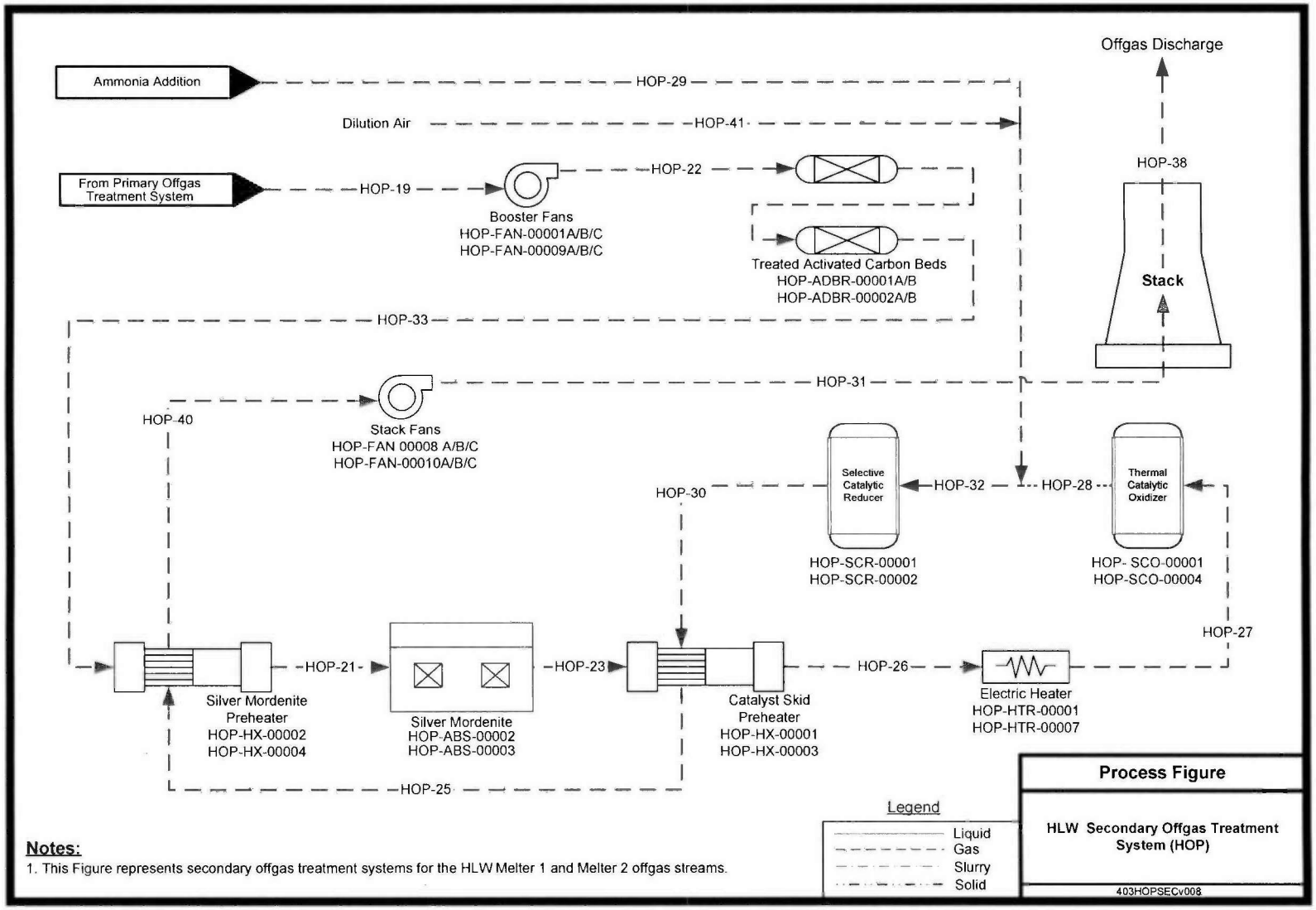


Figure 4.3-3 HLW Partitioning of the Halides

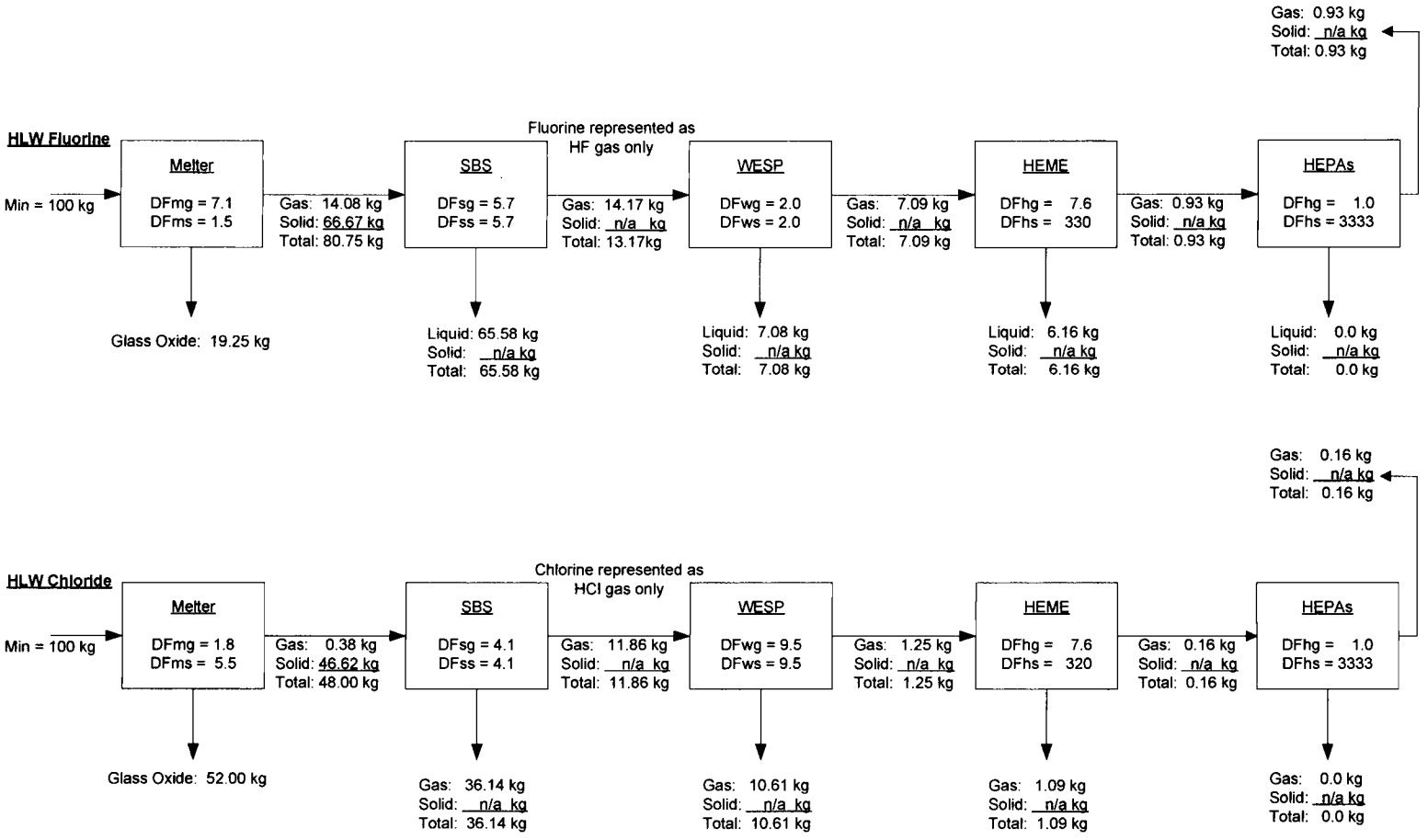


Figure 4.3-4 HLW Partitioning of Iodine and Boron

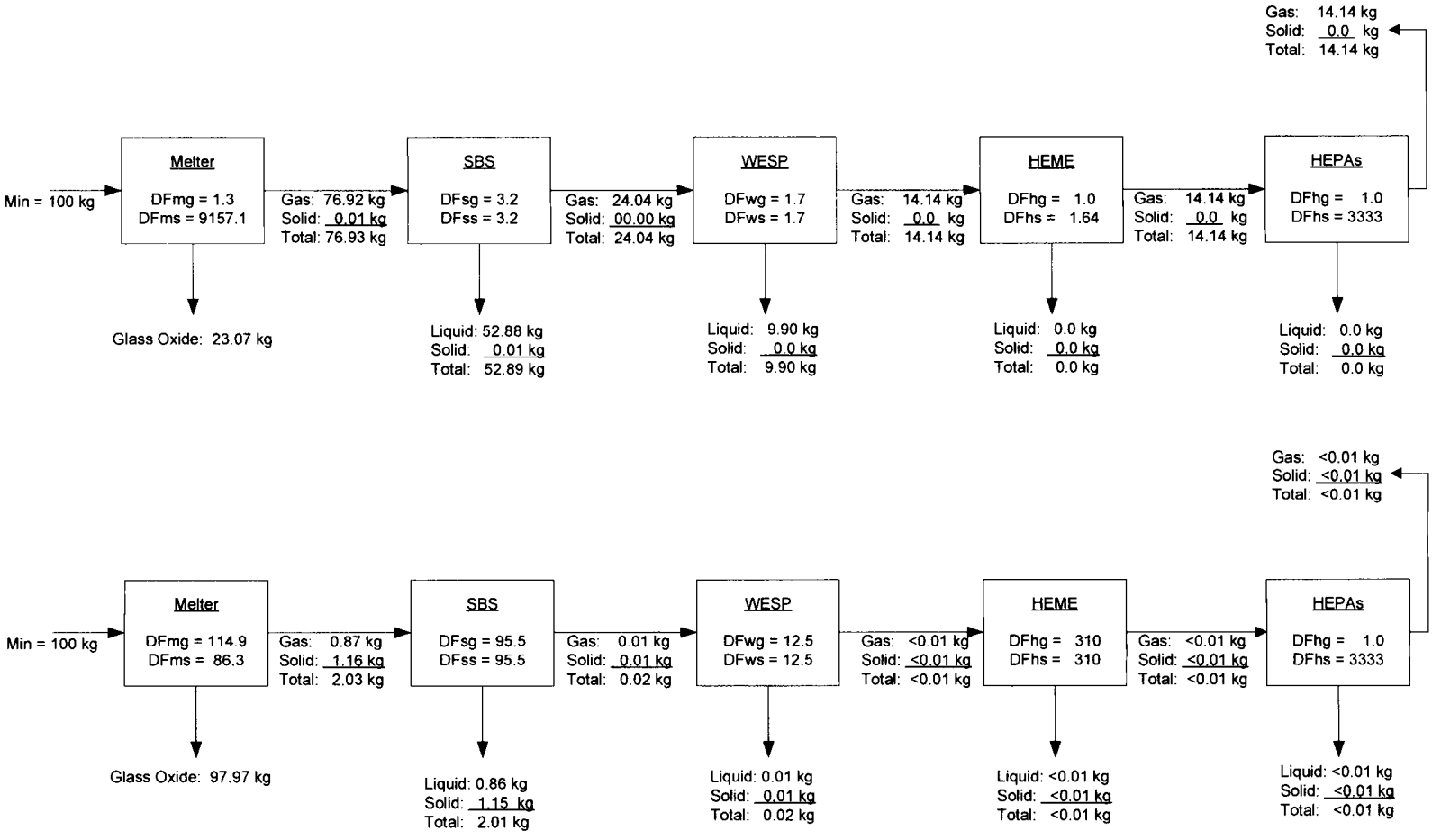
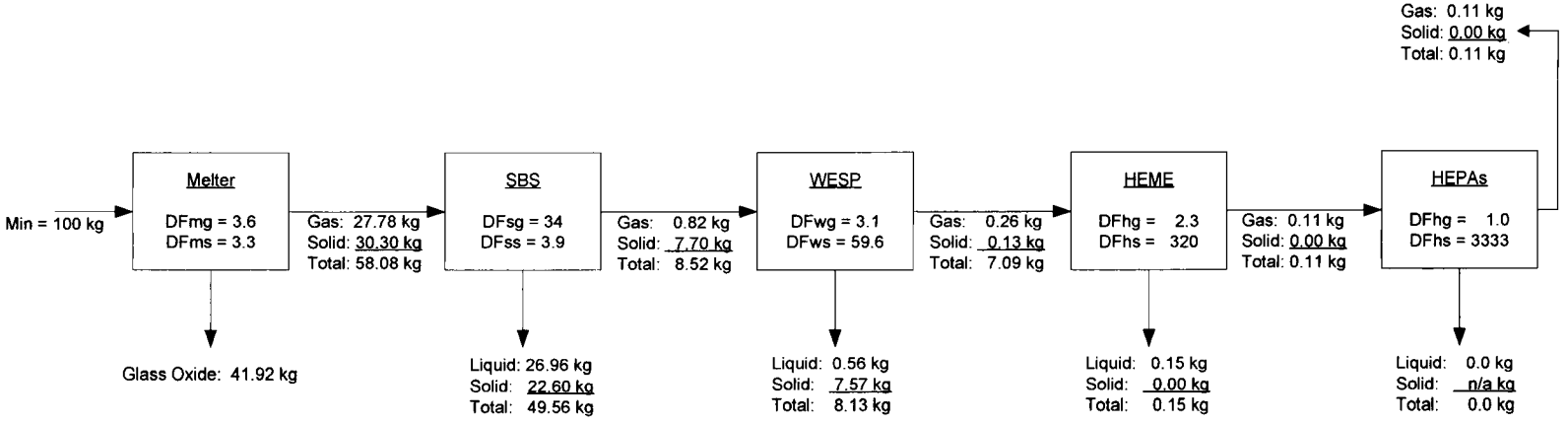


Figure 4.3-5 HLW Partitioning of Sulfur



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4.4 System PJV: HLW Pulse Jet Ventilation

4.4.1 Functions and Requirements

The function of the high-level waste (HLW) pulse jet ventilation system (PJV) is to collect, contain, treat, and discharge emissions produced by the HLW fluidic devices (pulse jet mixers [PJM] and reverse flow diverters [RFD]). This allows environmentally compliant gas releases to the atmosphere. Treatment of the gas involves filtration through high-efficiency particulate air (HEPA) filters (24590-HLW-3YD-PJV-00001).

The main requirements of the system include the following:

- Ensuring as low as reasonably achievable (ALARA) principles are considered
- Designing the system for a 40-year operation life
- Maintaining radionuclide emissions within limits specified in 40 CFR 61 Subpart H, WAC 246-247, WAC 173-401, the Hanford Site air operating permit, and associated notices of construction
- Making provisions to allow for removal, replacement, calibration, periodic functional testing, in-place maintenance, and inspection of plant items while the plant is in normal operation

According to the WTP *Statement of Work* (DE-AC27-01RV14136) Facility Specification, Section C.7(a)(12):

> *Comply with applicable Federal, State and local requirements, including environmental permits and other regulatory approvals and authorizations. The WTP shall be designed and operated to ensure that exposure to the maximally exposed off-site individual (non-acute) is ALARA but not more than 1.5 mrem per year and hazardous organic emissions are ALARA but not more than 0.375 tons per year from components regulated under 40 CFR 265, Subpart AA.*

System requirements are specified primarily in 24590-WTP-DB-ENG-01-001, *Basis of Design*, and 24590-HLW-3YD-PJV-00001, *System Description for the HLW Pulse Ventilation System (System PJV).*

4.4.2 Process Description

Operation of the HLW Facility fluidic devices generates significant emissions that require treatment before release to the environment. The HLW fluidic devices include the PJMs, used to mix and suspend vessel contents; and RFDs, used to transfer the vessel contents out of the vessels and for sampling. The PJV system also receives ventilation from HDH-VSL-00002/4. Both the PJM and RFD use compressed air as the motive force. PJMs use compressed air to push out liquid from their charge vessels and create a vacuum to refill their charge vessels with fluid. RFDs use compressed air to pressurize the RFD vessel, moving the process stream through a transfer pipeline. The use of compressed air to pressurize and evacuate the PJM and RFD charge vessels results in air emissions.

As the PJM and RFDs vents are released, they are collected in a common main header and passed through an electric heater (PJV-HTR-00002) to raise the temperature. Increasing the temperature prevents condensation in the HEPA filters downstream. The gas then goes through either of two parallel pairs of HEPA filter banks in series (PJV-HEPA-00004A/B and PJV-HEPA-00005A/B) to remove particulates. These filter banks are arranged such that one pair is in operation while the other is in standby mode. Extraction fans (PJV-FAN-00002A/B) are downstream of the HEPA filters. These variable speed fans

provide the motive force for the gas to pass through the system to the stack and maintain a negative pressure in the PJV system. After the fans, the gas is released to the atmosphere through the stack. The PJV system is illustrated in Figure 4.4-1. The system description, 24590-HLW-3YD-PJV-00001, provides details.

4.4.3 Basis

Treatment of the fluidics vent includes heating through an electric heater and filtration through HEPA filters. Removal efficiency of the filters allows environmental discharge. Fans provide the motive force for the gas to travel from the vessels to the stack.

4.4.3.1 Emissions Generation

The PJV system begins at the exhausts from fluidics equipment from several HLW vessels. The exhausts from all fluidics equipment in each vessel join at a header near the jet pump pairs for each vessel. The combined offgas from each vessel is routed to ventilation pipes that consolidate the offgas into a single stream. The offgas from canister decontamination vessels ventilation and from fluidic equipment in the radioactive liquid waste disposal (RLD) and HLW melter offgas treatment process (HOP) systems is contained and treated in the PJV system in accordance with 24590-HLW-MAC-PJV-00001, *HLW Pulse Jet Ventilation System Design Basis Flowsheets*. The RLD system includes fluidics equipment that will be used to mix, sample, and transfer wastes. The HOP system includes jet pumps that will be used for the submerged bed scrubber (SBS) vessels (HOP-SCB-00001, HOP-SCB-00002), and the fluidics equipment that will be used for the SBS condensate receiver vessels (HOP-VSL-00903, HOP-VSL-00904).

4.4.3.1.1 Design Data - Emissions Generation

(24590-HLW-MAC-PJV-00001, 24590-HLW-MKD-PJV-00001, 24590-WTP-M4C-V11T-00010)

- Maximum flow rate limit for the HLW PJV HEPAs is 7500 acfm
- Calculation 24590-HLW-MAC-PJV-00001 provides design basis flowrates for minimum, nominal, and maximum flow scenarios. Only the nominal scenario will be described herein with operating assumptions described below.

  Assumption 4.4.3 The contamination release fraction per constituent in the emissions stream of the HLW PJV system is assumed 1.0E-10
- Vessels at upper operating limit (PJMs use slightly less air, but vessels will normally be full).
  - PJMs are operating in all vessels except RLD-VSL-00008. RLD-VSL-00008 only receives intermittent waste streams and will normally be empty except for a water heel.
  - The HLW canister decontamination handling system (HDH) vessel (HDH-VSL-00002/4) lids are closed and only inleakage and HDH air sparging are venting into the PJV system. (Although the HDH canister decontamination vessel lids will be opened numerous times during the day, they will be closed most of the time.)
  - Two recirculation RFDs are operating each HOP-VSL-00903 and -00904 vessels (normal operations; the other two RFDs are spares and are not connected to the SBS).
  - No sampler RFDs are operating (S-RFDs are operated only once per day in RLD-VSL-00007).
- No SBS condensate transfers are occurring (SBS condensate is transferred only once per day).
  - The nominal generation sources from the PJMs are in the table listed below:

Table 4.4-1 Emissions From PJMs

Vessel Number	No. of Transfer PJMs	PJM Cycle Time (s)	Peak Vent Flow Rate per PJM (SCFM)	Average Vent Flow Rates per PJM (SCFM)
RLD-VSL-00007	4	33	316	132
RLD-VSL-00008	4	31	272	140
HOP-VSL-00903	4	23	257	131
HOP-VSL-00904	4	23	257	131

Reference: 24590-HLW-3YD-PJV-00001, Table 6-2.

The PJMs contribute most of the offgas to the PJV system. However, the offgas flow rates from transfer RFDs, recirculation RFDs, and sample RFDs will also contribute to the total offgas flow rate. Their respective flow rates are as follows.

Table 4.4-2 Emissions From Transfer RFDs and Siphon Ejectors

Vessel Number	No. of Transfer RFDs	Average Flow Rates Total (SCFM)	No. of Sampling RFDs	Average Flow Rates Total (SCFM)
RLD-VSL-00007	0	NA	2	18 (9 each)
RLD-VSL-00008	0	NA	2	18 (9 each)
HOP-VSL-00903	4	328 (82 each)	0	NA
HOP-VSL-00904	4	288 (72 each)	0	NA
HOP-SCB-00001[a]	2	224 (112 each)	0	NA
HOP-SCB-00002[a]	2	224 (112 each)	0	NA
Total	12	1064	4	36

[a] Note the fluidics equipment in these vessels are siphon air ejectors rather than RFDs.

Reference: 24590-HLW-3YD-PJV-00001, Tables 6-3 and 6-4.

Sparge air from vessels HDH-VSL-00002/4 is supplied to the PJV header (24590-HLW-3YD-HDH-00002).

Vessel Number	Flow Type	Average Flow Rate (scfm)
HDH-VSL-00002	Sparge	5
HDH-VSL-00004	Sparge	5

4.4.3.2 HEPA Preheater

After the fluidics offgas emissions are collected in a common header, the offgas is heated (PJV-HTR-00002) to prevent condensation in the HEPA filters. The heater reduces the humidity and

liquid aerosols in the fluidics emissions stream and reduces the possibility that humidity may damage the HEPA filters.

Design and operational parameters for this unit include the following.

4.4.3.2.1 Design Data - HEPA Preheater

(24590-HLW-MAC-PJV-00001, 24590-HLW-3YD-PJV-00001)

ΔT across the heater = 5 °C (9 °F)

4.4.3.2.2 Operating Logic - HEPA Preheater

(24590-HLW-3YD-PJV-00001)

Heater is used as long as the system is operational.

4.4.3.2.3 Energy Contributions - HEPA Preheater

(24590-HLW-MAC-PJV-00001, 24590-HLW-3YD-PJV-00001)

Electrical power: enough power is added to the heater to raise the offgas temperature by 5 °C.

4.4.3.2.4 Services - HEPA Preheater

Electrical power: enough power is added to the heater to raise the offgas temperature by 5 °C.

4.4.3.2.5 Chemistry - HEPA Preheater

None

4.4.3.3 HEPA Filter

The HEPA filters (PJV-HEPA-00004A/B and PJV-HEPA-00005A/B) remove particulate contamination in order to comply with environmental release limits.

Pertinent design and operational parameters for this unit include:

4.4.3.3.1 Design Data - HEPA Filter

(24590-HLW-3YD-PJV-00001, 24590-HLW-MAC-PJV-00001)

- Decontamination factors for each component for the HEPAs are in Table 4.4-3.
- Pressure differential: 2.0 in. WG (0.072 psi, nominal)
- Maximum flowrate: 2000 scfm per filter (for 5 filters, 10,000 scfm)

4.4.3.3.2 Operating Logic - HEPA Filter

(24590-HLW-MAC-PJV-00002)

Two sets of cylindrical HEPA filter banks (each bank containing five HEPA filters), one operational and one in standby mode, are used for each train. Excessive high or low pressure drop in a HEPA bank triggers a switch to the standby line. Due to redundancy, no impact to throughput is expected.

4.4.3.3.3 Energy Contributions - HEPA Filter

None

4.4.3.3.4 Services - HEPA Filter

None

4.4.3.3.5 Chemistry - HEPA Filter

None

4.4.3.4 Extraction Fans

The pulse vent extraction fans (PJV-FAN-00002A/B) are variable speed fans downstream of the PJV HEPAs, one operational and one on standby. The fan provides motive force to move the fluidics equipment emissions through the HEPA filters, maintain a vacuum in the PJV system, and discharge treated emissions through a dedicated exhaust stack. The fan will operate continuously to prevent impact on HLW operations.

4.4.3.4.1 Design Data - Extraction Fans

(24590-HLW-M4C-PJV-00001)

- Suction pressure: -34.5 in. WG
- Discharge pressure: 3.6 in. WG

4.4.3.4.2 Energy Contributions - Extraction Fans

(24590-HLW-3YD-PJV-00001)

Power to the fans is the only energy source provided. The fans themselves transfer some of the energy to the gas stream (heat of compression), causing a temperature rise in the stream.

4.4.3.4.3 Operating Logic - Extraction Fans

(24590-HLW-M4C-PJV-00001)

Two 100 % exhaust fans are provided (one operating and one on standby) to prevent HLW Facility operations from being affected. Fans have variable frequency drives to allow adjustment of the fan speed to compensate for changes in flowrate.

4.4.4 Ongoing Work and Potential Changes

Adjustments to the design of the HLW PJV system are possible, but unlikely. Finalized dimensions and characteristics from vendor documentation are pending. Confirmation of the constituent release factor from Section 4.4.3.1 is required via testing.

4.4.5 References

24590-HLW-3YD-HDH-00002, Rev 3, *System Description for the HLW System HDH Canister Decontamination Handling.*

24590-HLW-3YD-PJV-00001, Rev 3, *System Description for the HLW Pulse Ventilation System (System PJV).*

24590-HLW-M4C-PJV-00001, Rev 00A, *Process Information for the Pulse Jet Ventilation (PJV) System Equipment.*

24590-HLW-M5-V17T-00005, Rev 4, *Process Flow Diagram HLW Vitrification Pulse Jet Ventilation Treatment (System PJV).*

24590-HLW-M6-PJV-00001, Rev 4, *P&ID - HLW Pulse Jet Ventilation System Collection & Conditioning.*

24590-HLW-M6-PJV-00002, Rev 4, *P&ID - HLW Pulse Jet Ventilation System Filtration & Monitoring.*

24590-HLW-MAC-PJV-00001, Rev 00B, *HLW Pulse Vent System Design Basis Flowsheets.*

24590-HLW-MAC-PJV-00002, Rev 00B, *HLW Pulse Jet Ventilation System Filter Sizing.*

24590-HLW-MKD-PJV-00001, Rev 1, *24590-HLW-MK-PJV-HEPA-00004-A - PJV System HEPA Filters.*

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

24590-WTP-M4C-V11T-00010, Rev 0, *Process Engineering Mass Balance for WTP.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

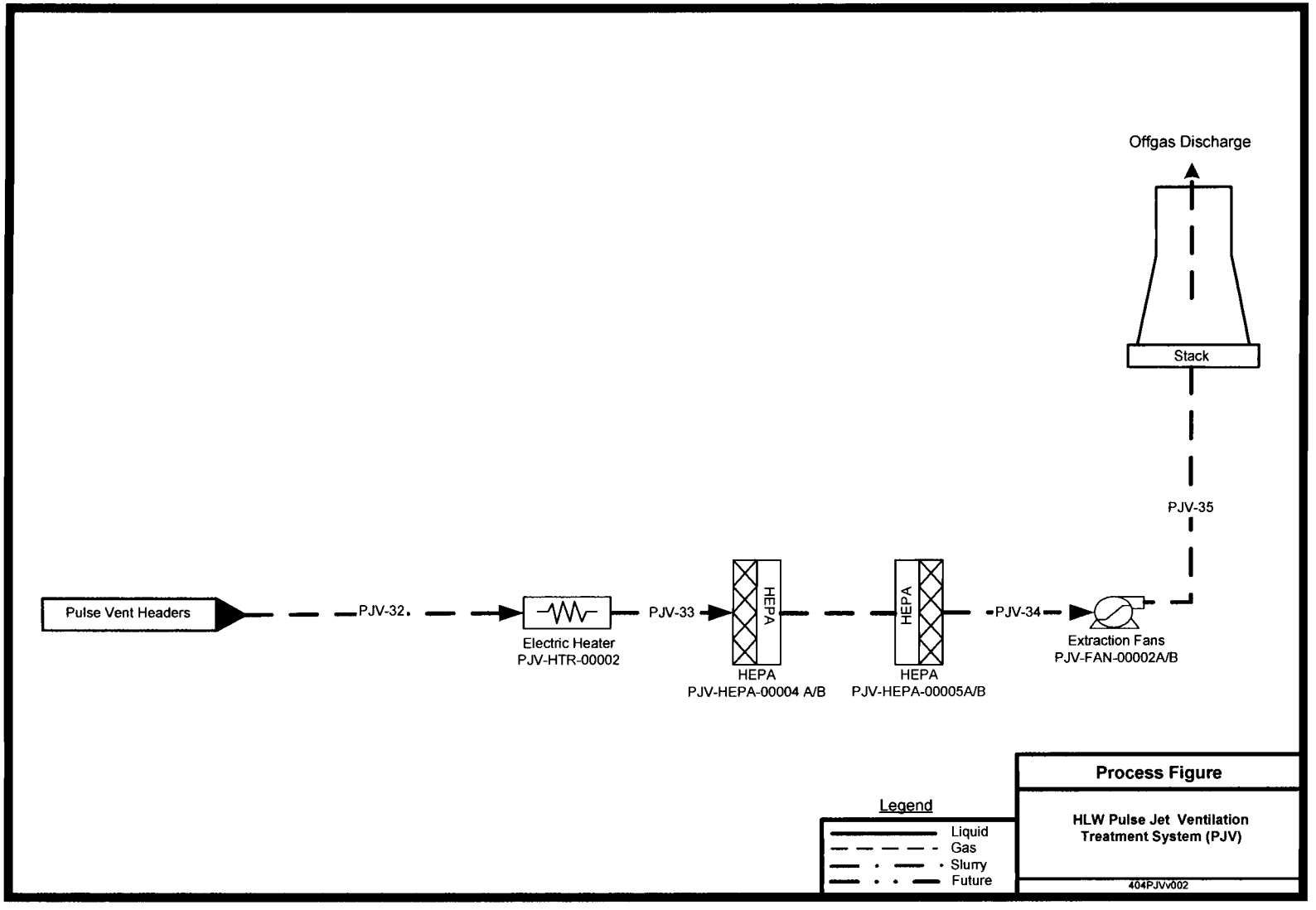
Table 4.4-3 PJV Vitrification Material Flow Decontamination Factors by Component

Components	HEPA (First)	HEPA (Second)	Components	HEPA (First)	HEPA (Second)
Cations			Pr^{+3}	3333	500
Ag^{+}	3333	500	Pu^{+4}	3333	500
Al^{+3}	3333	500	Rb^{+}	3333	500
As^{+5}	3333	500	Rh^{+3}	3333	500
B^{+3}	3333	500	Ru^{+3}	3333	500
Ba^{+2}	3333	500	Sb^{+5}	3333	500
Be^{+2}	3333	500	Se^{+6}	3333	500
Bi^{+3}	3333	500	Si^{+4}	3333	500
Ca^{+2}	3333	500	Sr^{2+}	3333	500
Cd^{+2}	3333	500	Ta^{+5}	3333	500
Ce^{+3}	3333	500	Tc^{+7}	3333	500
Co^{+3}	3333	500	Te^{+6}	3333	500
Cr (Total)	3333	500	Th^{+4}	3333	500
Cs^{+}	3333	500	Ti^{4+}	3333	100
Cu^{+2}	3333	500	Tl^{+3}	3333	500
Fe^{+3}	3333	500	V^{+5}	3333	500
Hg^{2+}	1	1	W^{+6}	3333	500
K^{+}	3333	500	Y^{+3}	3333	500
La^{+3}	3333	500	Zn^{2+}	3333	500
Li^{+}	3333	500	Zr^{4+}	3333	500
Mg^{+2}	3333	500	**Anions**		
Mn^{+4}	3333	500	Cl^{-}	3333	500
Mo^{+6}	3333	500	CN^{-}	3333	500
Na^{+}	3333	500	CO_3^{-2}	3333	500
Nd^{+3}	3333	500	F^{-}	3333	500
Ni^{+2}	3333	500	NO_2^{-}	3333	500
Pb^{+2}	3333	500	NO^{-3}	3333	500
Pd^{+2}	3333	500	O^{-2}	3333	500
OH^{-}	3333	500	^{154}Eu	3333	500
PO_4^{-3}	3333	500	^{155}Eu	3333	500
SO_3^{-}(s)	3333	500	$^{3}H^{(1)}$	1	1
SO_4^{-2}	3333	500	^{129}I	1	1

Table 4.4-3 PJV Vitrification Material Flow Decontamination Factors by Component

Components	HEPA (First)	HEPA (Second)	Components	HEPA (First)	HEPA (Second)
Water			^{237}Np	3333	500
H_2O	1	1	^{238}Pu	3333	500
Gases			^{239}Pu	3333	500
CO	1	1	^{240}Pu	3333	500
CO_2	1	1	^{241}Pu	3333	500
NO	1	1	^{242}Pu	3333	500
NO_2	1	1	^{125}Sb	3333	500
N_2	1	1	^{126}Sn	3333	500
O_2	1	1	^{90}Sr	3333	500
SO_2	1	1	^{99}Tc	3333	500
NH_3	1	1	^{232}U	3333	500
HCl	1	1	^{233}U	3333	500
HF	1	1	^{235}U	3333	500
Radionuclides			^{236}U	3333	500
^{241}Am	3333	500	U (Total)	3333	500
^{243}Am	3333	500	^{90}Y	3333	500
^{137m}Ba	3333	500			
$^{14}C^{(2)}$	1	1			
^{60}Co	3333	500			
^{243}Cm	3333	500			
^{244}Cm	3333	500			
^{134}Cs	3333	500			
^{137}Cs	3333	500			
^{152}Eu	3333	500			

Figure 4.4-1 Pulse Jet Ventilation Treatment System



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4.5 System RLD-30/NLD-30: HLW Liquid Waste Disposal Process

4.5.1 Function and Requirements

There are two effluent collection systems in the High-Level Waste (HLW) Facility: the Radioactive Liquid Waste Disposal System (RLD) and the Nonradioactive Liquid Waste Disposal System (NLD). System RLD receives wastes from the following functional areas: HLW primary and secondary offgas treatment system, HLW Canister Decontamination Handling System (HDH), vessel washes, offgas drains, and C3/C5 floor drains and sumps system. System NLD receives drain, sump, and wash wastes from the C2 areas and steam condensate from the steam racks. The general purpose of the systems is to receive effluents for interim storage and then transfer the wastes to the Balance of Facilities (BOF) or the Pretreatment (PT) Facility.

Requirements are found in the WTP *Statement of Work* (SOW) (DE-AC27-01RV14136) Facility Specification, Section C.7 (a)(5)

> *Disposition all secondary wastes in accordance with ICD requirements; secondary wastes are identified in Section C.9, Interface Control Documents and Standard 6, Product Qualification, Characterization Certification.*

ICD 05 -Interface Control Document for Nonradioactive, Nondangerous Liquid Effluents (24590-WTP-ICD-MG-01-005) has been developed to govern nonradioactive, nondangerous liquid effluent systems and operations, including transfer to the Tank Farm Contractor. *ICD 06 - Interface Control Document for Radioactive, Dangerous Liquid Effluents* (24590-WTP-ICD-MG-01-006) has been developed to govern radioactive, dangerous liquid effluent systems and operation.

WTP SOW Facility Specification, Section C.7 (d)(1)(vi)

> *Liquid Effluent Treatment: This operation collects the WTP effluent and provides for the discharge to the Hanford Site 200 East Area Effluent Treatment Facility (ETF) or allows for the re-use of liquid effluent as process water with the WTP. Treated effluent will be transferred to the Hanford Site ETF as required.*

4.5.2 Process Description

HLW Liquid Effluents

The HLW liquid effluents disposal process system consists of four vessels that will receive, store, mix, sample, and transfer radioactive and nonradioactive secondary effluents from the HLW Facility (see Figure 4.5-1).

Radioactive, low pH condensate purge from the submerged bed scrubber (SBS) condensate receiver vessels (HOP-VSL-00903, HOP-VSL-00904), purge from the SBSs (HOP-SCB-00001, HOP-SCB-00002), decontamination effluent from HDH-VSL-00003 and sodium hydroxide addition are sent to the HLW acid waste storage vessel (RLD-VSL-00007) for mixing, sampling, and up to 1 day of storage. Normally, the HLW acid waste storage vessel will discharge to the HLW effluent transfer vessel (PWD-VSL-00043) in the PT Facility (system 10-PWD). In the unlikely event that the HLW effluent transfer vessel (PWD-VSL-00043) is unavailable to receive the discharge, and the HLW acid waste storage vessel has insufficient remaining capacity, the vessel can be manually directed to discharge its contents to the plant wash and drains vessel (RLD-VSL-00008) for additional storage capacity. The

contents of the plant wash and drains vessel are then discharged to the HLW effluent transfer vessel (PWD-VSL-00043) in pretreatment. Subsequent transfers are discussed in the Plant Wash and Disposal System (PWD) section. The HLW acid waste storage vessel is described in Section 4.5.3.1.1.

Offgas drainage from the ductwork located between the high-efficiency mist eliminators (HEME) and the high-efficiency particulate air (HEPA) filters is directed to the offgas drains collection vessel (RLD-VSL-00002). The offgas drains collection vessel provides a seal for 100 in. WG negative pressure in the ductwork and collects condensation that forms during system startup and shutdown. The vessel operating level is controlled by level detectors to maintain an adequate depth for the seal. Whenever there is condensation drainage from the primary offgas system, the design liquid level in the vessel is maintained by discharging the excess to the plant wash drains vessel (RLD-VSL-00008). The offgas drainage is added to the contents of the plant wash drains vessel and mixed. The plant wash drains vessel discharges the effluent to the HLW effluent transfer vessel (PWD-VSL-00043) in the PT Facility. Subsequent transfers are discussed in the PWD system section. The offgas drains collection vessel is described in Section 4.5.3.1.5.

Neutral pH waste drainage from vessel and sump washings, acidic waste transferred (non-routinely) from vessel RLD-VSL-00007, and offgas system drainage transferred from vessel RLD-VSL-00002 are directed to the plant wash and drains vessel (RLD-VSL-00008). The plant wash and drains vessel receives, stores for up to 2 days, mixes, and samples the effluent before it discharges to the HLW effluent transfer vessel (PWD-VSL-00043). In the unlikely event that the HLW effluent transfer vessel is unavailable to accept the transfer, discharge can be directed to the PT Facility vessel (PWD-VSL-00033). Subsequent transfers are discussed in the PWD system. The plant wash and drains vessel is described in Section 4.5.3.1.2.

The C2 drains collection tank (NLD-TK-00006) receives C2 area drains, sumps, washes effluent, and steam condensate from steam racks. The effluent is mixed and sampled. If the effluent meets Treated Effluent Disposal Facility (TEDF) discharge limits (below), the waste is transferred by a centrifugal discharge pump (NLD-PMP-00001) to the BOF nonradioactive effluent tank (NLD-TK-00001). If the effluents are radioactive, and do not comply with TEDF limits, they will not be discharged to the nonradioactive effluent tank. Instead they will be sent to the plant wash drains vessel (RLD-VSL-00008). From there the active effluents will be transferred to pretreatment (system 10-PWD), where they will be processed in the evaporator (system 10-FEP). The C2 drains collection tank is described in Section 4.5.3.2.1.

4.5.3 Basis

The two systems provide staging/transfer vessels for incidental wastes collected during operation of the HLW Facility (24590-HLW-3YD-RLD-00001).

4.5.3.1 System RLD

System RLD consists of three vessels that receive unique influent streams. They are the acid waste storage vessel (RLD-VSL-00007), the plant wash and drains vessel (RLD-VSL-00008), and the offgas drains collection vessel (RLD-VSL-00002). Descriptions of each vessel follow. See process flow diagrams 24590-HLW-M5-V17T-00007001 and 24590-HLW-M5-V17T-00007002.

4.5.3.1.1 HLW Acid Waste Storage Vessel

The HLW acid waste storage vessel (RLD-VSL-00007) receives, stores, mixes, samples, and transfers waste from the offgas SBS (HOP-SCB-00001, HOP-SCB-00002), the SBS condensate receiver vessels (HOP-VSL-00903, HOP-VSL-00904), and the decontamination effluent from waste neutralization vessel (HDH-VSL-00003). The waste is received in batches. The HLW acid waste storage vessel is in the wet process cell. The vessel has four pulse jet mixers (PJM). The vessel is piped and valved to operate in an influent/effluent mode. The vessel is designed to have the capability to receive sodium hydroxide addition, which will be used to raise the effluent pH when required by pretreatment. The vessel is equipped with dual redundant steam ejectors for waste discharge. Normal discharge, as well as a line and breakpot flush with 1 line volume (405 gal) after transfer using plant wash water, is routed to the PT Facility HLW effluent transfer vessel (PWD-VSL-00043). The HLW acid waste storage vessel is equipped with an additional steam ejector to send vessel wash to the plant wash and drains vessel (RLD-VSL-00008). The vessel has level, pressure, and temperature indicators, neutralization capability, and a sampling system (via reverse flow diverters). The vessel is pumped down upon receipt of a setpoint signal from the level detector. The vessel is connected to the vent header and the plant wash water system. Overflow is directed to RLD-VSL-00008. Waste transfers to the vessel at various flowrates, and from the vessel at 48 gpm.

4.5.3.1.1.1 Design Data - HLW Acid Waste Storage Vessel

RLD-VSL-00007 (24590-HLW-M6C-RLD-00002)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

4.5.3.1.1.2 Operating Logic - HLW Acid Waste Storage Vessel

(24590-HLW-3YD-RLD-00001, 24590-HLW-M6C-HDH-00001, 24590-HLW-M6C-RLD-00002)

- Collect effluent from HOP-VSL-00903 at 48 gpm
- Collect effluent from HOP-VSL-00904 at 48 gpm
- Collect effluent from HOP-SCB-00001 at 48 gpm
- Collect effluent from HOP-SCB-00002 at 48 gpm
- Receive transfer from HDH-VSL-00003 at 58 gpm
- After transfers, sample waste, analyze samples, and neutralize waste to pH 8 if necessary
- Mix waste
- Transfer vessel RLD-VSL-00007 contents to PWD-VSL-00043 at 48 gpm

4.5.3.1.1.3 Services - HLW Acid Waste Storage Vessel

- High-pressure steam system for waste transfer
- Instrument service air for PJMs

4.5.3.1.2 Plant Wash and Drains Vessel

The plant wash and drains vessel (RLD-VSL-00008) receives, stores, mixes, samples, and transfers drain, sump, and vessel wash wastes, and offgas drainage from the offgas drains collection vessel (RLD-VSL-00002) and elsewhere. The vessel is equipped with four PJMs. The tank is piped and valved to operate in an influent/effluent mode. The vessel is designed to have the capability to receive sodium hydroxide addition. The vessel has dual, redundant steam ejectors for waste discharge. Normal discharge is to pretreatment vessel PWD-VSL-00043. The vessel has level, pressure, and temperature indicators, neutralization capability, and a sampling system. The vessel is pumped down upon receipt of a setpoint signal from the level detector. The vessel is connected to the Demineralized Water System (DIW) and vented through the overflows. Overflow is directed to a sump. Waste transfer rate from vessel is 38 gpm.

4.5.3.1.3 Design Data - Plant Wash and Drains Vessel

RLD-VSL-00008 (24590-HLW-M6C-RLD-00005)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

4.5.3.1.3.1 Operating Logic - Plant Wash and Drains Vessel

(24590-HLW-3YD-RLD-00001, 24590-HLW-M4C-30-00003, 24590-HLW-M6C-RLD-00005)

- Collect effluent from RLD-VSL-00002 at 23 gpm
- After transfers, sample waste, analyze samples, and neutralize waste to pH 8 if necessary
- Mix waste
- Discharge effluent to PWD-VSL-00043 at 48 gpm

4.5.3.1.3.2 Energy Contributions - Plant Wash and Drains Vessel

BOF Related:

- High-pressure steam: 1660 Btu/hr

4.5.3.1.3.3 Fluidics - Plant Wash and Drains Vessel

- Flow rates and quantities are given in vessel Operating Logic, above
- PJMs: 565 scfm

4.5.3.1.3.4 Services - Plant Wash and Drains Vessel

- High-pressure steam for waste transfer
- Plant service air for PJM operation

4.5.3.1.4 Chemistry - Plant Wash and Drains Vessel

None

4.5.3.1.5 Offgas Drains Collection Vessel

The offgas drains collection vessel (RLD-VSL-00002) receives, stores, and transfers offgas duct drain condensate from low points in the HEME-to-HEPA offgas system ductwork, which is part of the offgas treatment system. The tank is piped and valved to operate in an influent/effluent mode. The vessel has a steam ejector for waste discharge to the plant wash and drains vessel (RLD-VSL-00008). The vessel has level, pressure, and temperature indicators. The vessel is pumped down upon receipt of a setpoint signal from the level detector. The vessel vents through the overflow. Overflow is directed to a sump.

The vessel is designed to maintain a minimum negative 100 in. WG pressure to provide a hydraulic seal to maintain offgas system vacuum.

4.5.3.1.6 Design Data - Offgas Drains Collection Vessel

RLD-VSL-00002 (24590-HLW-M6C-RLD-00004)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

4.5.3.1.7 Operating Logic - Offgas Drains Collection Vessel

(24590-HLW-3YD-RLD-00001)

The primary purpose of vessel is to maintain a water seal for offgas ducts. Vessel maintains batch volume level to maintain water seal. Excess is pumped down as needed.

4.5.3.1.7.1 Energy Contributions - Offgas Drains Collection Vessel

BOF related:

- High-pressure steam: 1660 Btu/hr

4.5.3.1.7.2 Fluidics - Offgas Drains Collection Vessel

Flow rates and quantities are given in vessel Operating Logic, above

4.5.3.1.7.3 Services - Offgas Drains Collection Vessel

High-pressure steam for waste transfer

4.5.3.1.7.4 Chemistry - Offgas Drains Collection Vessel

None

4.5.3.2 System NLD

This system consists of one tank, the C2 drains collection vessel (NLD-TK-00006). This tank receives waste from the drains, sumps, and washes in the C2 areas of the plant, and fire protection discharge. See process flow diagram 24590-HLW-M5-V17T-00009.

4.5.3.2.1 C2 Drains Collection Tank

The C2 drains collection vessel (NLD-TK-00006) receives stores, mixes, samples, and transfers C2 area drains, sumps, and washes wastewater. This tank is partitioned into two identical sides. Each side of the tank can receive flows from all of the incoming sources. To ensure the sample is representative of the effluent being transferred, the side of the tank not receiving flow will be isolated during sampling, analysis, and transfer. Influents are subjected to analysis for pH and percentage of solids as well as alpha and beta/gamma radiation detection before collection. The tank has mixing eductors and a centrifugal discharge pump. The tank is piped and valved to operate in discharge and recirculation mode (normal mode). Discharge is to the plant wash and drains vessel (RLD-VSL-00008) or BOF tank NLD-TK-00001, depending on analysis results. The vessel has level and temperature indicators, and the recirculation line has a sampling system. The vessel is pumped down upon receipt of a setpoint signal from the level detector. The vessel is vented to the room and connected to the process water system. The vessel overflows to the firewater collection area.

Sampling and analysis will be used to determine disposition. If the effluent meets all TEDF criteria, the contents are pumped to BOF tank NLD-TK-00001. If found to be active, contents are sent to the plant wash and drains vessel (RLD-VSL-00008).

4.5.3.2.1.1 Design Data - C2 Drains Collection Tank

NLD-TK-00006 (24590-HLW-M6C-NLD-00002)

See Appendix B for design data such as overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate.

4.5.3.2.1.2 Operating Logic - C2 Drains Collection Tank

(24590-HLW-M6C-NLD-00002, 24590-WTP-3YD-NLD-00001)

- Collect clean effluent from HLW Facility
- Sample contents as needed
- Discharge batch to NLD-TK-00001 at 30 gpm

4.5.3.2.1.3 Energy Contributions - C2 Drains Collection Tank

BOF related:

- None: vessels are neither heated nor cooled

Non-BOF related:

(24590-HLW-MPD-NLD-00001)

- Pump: 1.5 hp

4.5.3.2.1.4 Fluidics - C2 Drains Collection Tank

Flow rates and quantities are given in vessel Operating Logic, above.

4.5.3.2.1.5 Services - C2 Drains Collection Tank

Provide plant service water for vessel washing.

4.5.3.2.1.6 Chemistry - C2 Drains Collection Tank

None

4.5.4 Ongoing Work and Potential Changes

None identified.

4.5.5 References

24590-HLW-3YD-RLD-00001, Rev 3, *System Description for HLW Radioactive Liquid Waste Disposal System RLD.*

24590-HLW-M4C-30-00003, Rev 0, *HLW Vitrification Facility Feed and Effluent Design Basis Flowsheets.*

24590-HLW-M5-V17T-00007001, Rev 5, *Process Flow Diagram-HLW Vitrification Liquid Waste Effluent (System RLD) (Sheet 1).*

24590-HLW-M5-V17T-00007002, Rev 5, *Process Flow Diagram-HLW Vitrification Liquid Waste Effluent (System RLD) (Sheet 2).*

24590-HLW-M5-V17T-00009, Rev 5, *Process Flow Diagram HLW C2 Drains Collection (System NLD).*

24590-HLW-M6C-HDH-00001, Rev 00C, *HLW Canister Decontamination Waste Neutralization Vessel Sizing HDH-VSL-00003.*

24590-HLW-M6C-NLD-00002, Rev 00D, *C2 Drains Collection Tank.*

24590-HLW-M6C-RLD-00002, Rev 00C, *HLW Acidic Waste Vessel RLD-VSL-00007 Sizing Calculation.*

24590-HLW-M6C-RLD-00004, Rev 00C, *HLW Offgas Drains Collection Vessel RLD-VSL-00002 Sizing Calculation.*

24590-HLW-M6C-RLD-00005, Rev 00C, *HLW Plant Wash and Drain Vessel RLD-VSL-00008 Sizing Calculation.*

24590-HLW-MPD-NLD-00001, Rev 4, *NLD-PMP-00001 - C2 Drains Collection Transfer Pump.*

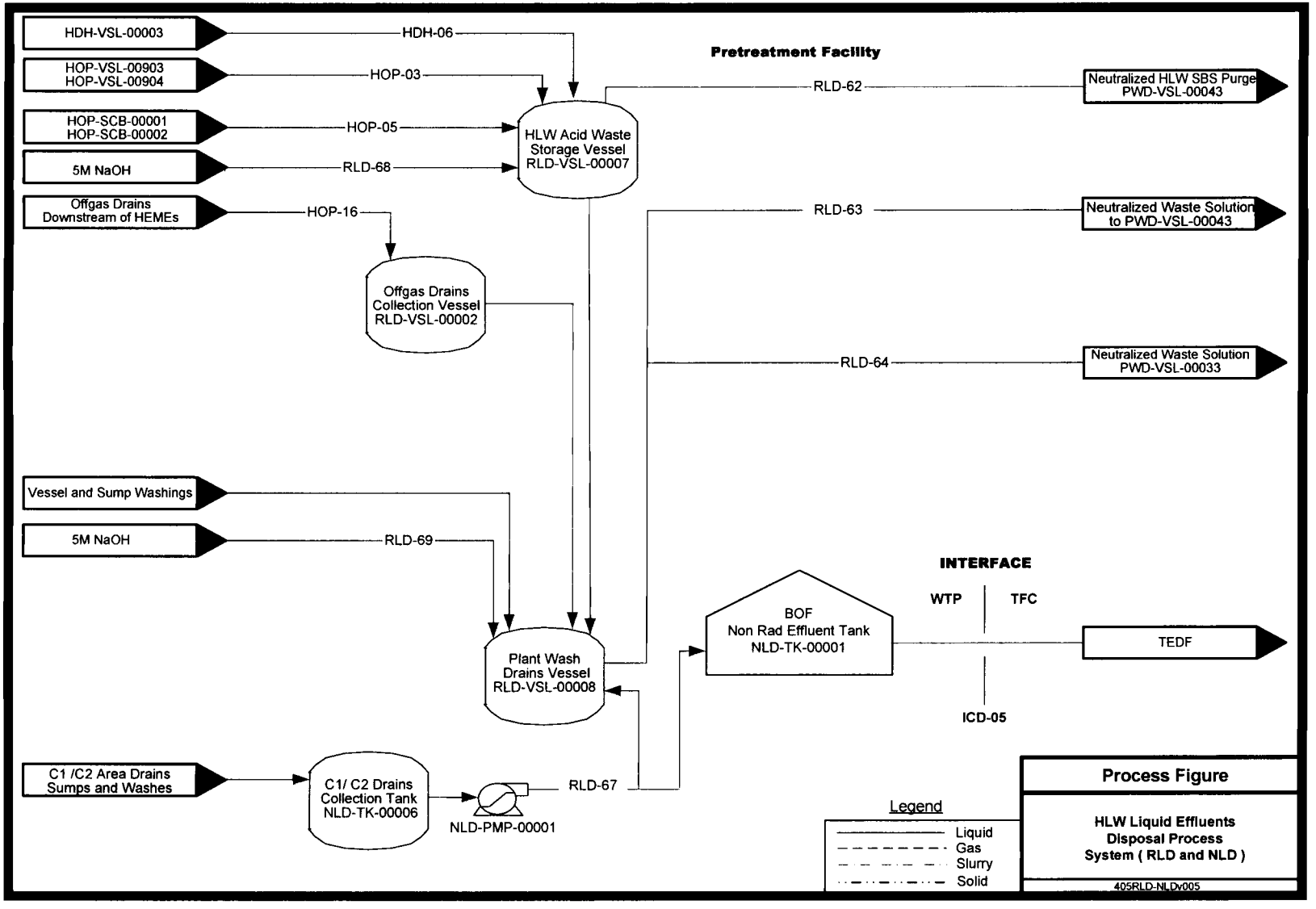
24590-WTP-3YD-NLD-00001, Rev 1, *System Description for the Waste Treatment Plant Non-Radioactive Liquid Waste Disposal (NLD) System.*

24590-WTP-ICD-MG-01-005, Rev 4, *ICD-05 - Interface Control Document for Nonradioactive, Nondangerous Liquid Effluents.*

24590-WTP-ICD-MG-01-006, Rev 4, *ICD-06 - Interface Control Document for Radioactive, Dangerous Liquid Effluents.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

Figure 4.5-1 HLW Liquid Effluents Disposal Process System



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4.6 System HDH: HLW Canister Decontamination Handling System

4.6.1 Function and Requirements

The function of the high-level waste (HLW) canister decontamination handling system (HDH) is to remove smearable radioactive contamination from the filled and sealed HLW canister surface, and to recycle removed contamination to the Pretreatment (PT) Facility for reprocessing. The immobilized high-level waste (IHLW) product canisters are constructed of type 304 L stainless steel (an alloy of iron, nickel, and chromium), and are cylindrical, 14.75 ft (4.5 m) long, with a diameter of 2 ft (0.61 m).

Requirements are found in the WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Operational Specification, Section C.8, Specification 1.2.2.1.1:

> *Product and Disposal Requirements: The IHLW product shall meet the requirements established in the Waste Acceptance Product Specifications (WAPS) and the supporting documents Waste Acceptance Systems Requirements Document (WASRD), and Integrated Interface Control Document (IICD).*

WASRD 4.8.12 HLW Canister Surface Contamination:

> *The Producer shall inspect the canistered waste form and remove visible waste glass from the exterior surface of the canister prior to shipment.*

WASRD 4.8.3 Dimensional Envelope for HLW Canisters:

> *At time of delivery, the canistered HLW form shall stand upright without support on a flat horizontal surface and fit without forcing into a right-circular, cylindrical cavity (64 cm [25 in] diameter and 3.01 m [9.88 ft] length or alternatively 64 cm [25 in] diameter and 4.51 m [14.8 ft] length).*

WTP SOW Facility Specification, Section C.7 (d)(2)(iv):

> *High-Level Waste Canister Closure, Decontamination, and Inspection: The HLW canister is sealed via welding. The canister is decontaminated using a chemical etching process that uses [cerium] Ce (IV) as the chemical reagent.* **(M047)**

Basis of Design (24590-WTP-DB-ENG-01-001, Rev 1P) Section 6.4:

> *The following process services and reagents are required by one or more of the various facilities within the WTP. Specific numerical values below are not criteria. Except as noted, the values cited below are representative values at the facility user and are confirmed or otherwise altered as the design of the systems develop. The cited values are not to be used as the basis for confirmed design media.*
>
> *HP and LP Steam - High-pressure (HP) steam is supplied to the main steam header at a pressure of 135 lb/in^2 gage, saturated (358 °F). Low-pressure (LP) steam is supplied from the HP steam system.*

Condensate return - Condensate recovery for both HP and LP (low pressure) steam systems is provided for economic reasons. The steam/condensate system is a closed loop for contamination control (for steam equipment in contact with radioactive material).

Cooling water - Primary loop cooling water is provided to user plants and facilities at a temperature ranging from 57 °F to 77 °F. Secondary loop cooling water is provided to equipment in contact with radioactive material at temperatures ranging from 68 °F to 84 °F. Primary loops are open recirculating loops with evaporative cooling towers. Secondary loops are closed recirculating loops cooled by primary loops. Primary loops shall operate at a higher pressure than the secondary loops at equipment interfaces. Secondary loops shall operate at a higher pressure than the process at equipment interfaces.

Demineralized water - Demineralized water is provided to the main demineralized water header at ambient temperature and at a pressure of 80 lb/in^2 gage at 686 ft elevation (MSL). Design selection will avoid the generation of dangerous waste. Demineralized water is used within the process unit operations where it is decided on a case-by-case basis that process water is unsuitable for process operations.

Nitric acid - This reagent will be supplied as a 12 molar solution (approximately) and is diluted for a number of duties including ^{137}Cs resin bed elution.

4.6.2 Process Description

HLW canister decontamination begins after the canister has been filled, its lid welded on, and any adhering glass has been removed from the canister surface. The canister is initially washed with 45 psig plant wash water to remove any loose contamination that may be spread into the C3 decontamination/swabbing cave from the C5 handling cave. The water wash is performed in the canister rinse bogie vessel, HDH-VSL-00001 (mounted on a bogie), which travels from below the handling cave to below the decontamination cave. After the water wash, the canister is placed in one of two canister decontamination vessels (HDH-VSL-00002/4). The HLW canister is further decontaminated by chemically milling about 0.00039 in. (10 μm) of stainless steel from the canister surface using a heated cerium (IV) nitrate bath, a 6-hr process. Following the cerium nitrate milling process, the canister is rinsed with nitric acid and then with demineralized water. The process is shown in *Process Flow Diagram HLW Vitrification HLW Canister Decon (System HDH)* (24590-HLW-M5-V17T-00006, Rev 6). After drying, the canister is swabbed to verify that its smearable contamination level meets the requirements of IHLW. It is then transferred to the canister storage racks. The decontamination vessel waste solution batches (from the milling, nitric acid rinse, and water rinse) are transferred to the waste neutralization vessel, HDH-VSL-00003. The wastewater from the canister rinse bogie vessel is also transferred to the waste neutralization vessel. A small amount of hydrogen peroxide is added to the waste neutralization vessel to reduce any remaining cerium nitrate to a non-reactive form. Then the entire contents of the waste neutralization vessel are transferred to the acidic waste vessel, RLD-VSL-00007 (24590-HLW-3YD-HDH-00002, Rev 3). A schematic of system HDH is depicted in Figure 4.6-1.

The primary system consists of the following.

Table 4.6-1 HLW Canister Decontamination System

HLW Canister Decontamination System	Purpose
canister decontamination rinse bogie vessel (HDH-VSL-00001) / canister rinse bogie (HDH-TRLY-00003)	The bogie transfers the canister from under the canister handling cave (HLW canister pour handling system [HPH]) to under the canister decontamination cave. The rinse vessel provides an initial plant wash water wash of the canister to remove loose contamination before transferring it to the decontamination vessel.
cerium^{+4} addition tank (HDH-TK-00002)	Ce^{+4} solution is provided from this tank to the canister decontamination vessels for canister decontamination solution makeup.
canister decontamination vessels (HDH-VSL-00002) (HDH-VSL-00004)	Canister decontamination is performed in this titanium vessel using a chemical milling process. The vessel contents are heated to 149 °F to promote the chemical milling reaction and maintained at that temperature for 6 hr. After completion of the process, the contents are transferred to the waste neutralization vessel and the canister is washed with nitric acid. Finally, the canister is washed with demineralized water. All waste solutions are transferred to the waste neutralization vessel.
hydrogen peroxide addition tank (HDH-TK-00003)	Hydrogen peroxide is provided from this tank to the waste neutralization vessel to neutralize any residual Ce^{+4} solution remaining from the chemical milling process performed in the canister decontamination vessel.
waste neutralization vessel (HDH-VSL-00003)	All waste solutions from the canister decontamination process are accumulated in this vessel. Neutralization of any Ce^{+4} solution remaining from the canister decontamination occurs in this vessel. The contents that have accumulated after two canister decontaminations, and neutralized with NaOH, are transferred to the RLD-VSL-00007 acidic waste vessel.

4.6.3 Basis

The HLW canister decontamination process uses a heated Ce^{+4} cerium nitrate bath to chemically mill approximately 10 μm of canister material from the canister surface. Any smearable contamination is removed with the canister material. The design for the WTP canister decontamination process is based on the West Valley Nuclear Services (WVNS) system. As described in the *WVNS Waste Form Qualification Report* (WVDP-186, Section 3.7), WVNS performed both coupon testing and full-scale canister tests to prove the efficacy of the Ce^{+4} solution chemical milling process. These tests determined that a milling depth of 10 μm was optimal, and that a cerium nitrate solution at 149 °F using a soak time of approximately 6 hr achieved optimal results.

4.6.3.1 Canister Rinse Bogie Vessel HDH-VSL-00001

The canister rinse bogie vessel, HDH-VSL-00001, receives the filled, welded canister from the handling cave overhead crane. The rinse vessel is designed to direct plant wash water sprays at all external surfaces of the canister to dislodge and flush away loose contamination and glass shards.

4.6.3.1.1 Design Data - Canister Rinse Bogie Vessel HDH-VSL-00001

(24590-HLW-3YD-HDH-00002, 24590-HLW-MVC-HDH-00005, 24590-HLW-M5-V17T-00006)

See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

4.6.3.1.2 Operating Logic - Canister Rinse Bogie Vessel HDH-VSL-00001

- After lid closure by welding, the filled canister is lowered into the rinse bogie vessel.
- The canister rinse bogie vessel moves to a central position in the canister rinse tunnel.
- An inflatable seal is made against the spool piece.
- The canister water wash cycle is started. The canister is spray washed with 45 psig plant wash water within the canister decontamination rinse bogie vessel (HDH-VSL-00001).
- The rinse water is continuously pumped to the waste neutralization vessel (HDH-VSL-00003) during the wash cycle.
- The canister decontamination rinse bogie vessel (HDH-VSL-00001) moves to a position below the decontamination import cave hatch.
- The canister is lifted and positioned over the canister decontamination vessel (HDH-VSL-00002/4).

4.6.3.1.3 Energy Contributions - Canister Rinse Bogie Vessel HDH-VSL-00001

The canister is placed in the canister decontamination rinse bogie at a temperature of 100 °F. The canister is washed with 360 gal of demineralized water at room temperature to remove loose contamination. The wastewater is transferred to the waste neutralization vessel using a centrifugal pump at 80 gpm.

4.6.3.2 Canister Decontamination Vessel HDH-VSL-00002/4

Two canister decontamination vessels are provided to maintain 6 metric tons of glass per day production. Each canister decontamination vessel, HDH-VSL-00002/4, receives the canister from the canister rinse bogie vessel by means of the decontamination area overhead crane. Each is a titanium vessel that holds the filled canister and the Ce^{+4} solution during the decontamination process. Each canister decontamination vessel has service piping for demineralized water, high-pressure steam, cooling water supply, cooling water return, and process air for sparging. The vessel also has two spray rings for nitric acid and demineralized water rinses, dual steam ejectors, an overflow line, and a combined hot water/Plant Cooling Water (PCW) coil for heating and cooling of the cerium nitrate solution.

4.6.3.2.1 Design Data - Canister Decontamination Vessel HDH-VSL-00002/4

(24590-HLW-3YD-HDH-00002, 24590-HLW-MVC-HDH-00005, 24590-HLW-M5-V17T-00006)

See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

4.6.3.2.2 Operating Logic - Canister Decontamination Vessel HDH-VSL-00002/4

- The lid on the canister decontamination vessel (HDH-VSL-00002/4) is opened, the canister is lowered into the empty vessel, and the lid is closed.
- Establish sparge airflow in the canister decontamination vessel (HDH-VSL-00002/4) and accept transfer of 194 gal of 1 M nitric acid from the nitric acid tank (NAR-TK-00001) and 20 gal of 0.5 M ceric nitrate from and the Ce^{+4} addition tank (HDH-TK-00002).
- Adjust the temperature of the canister decontamination solution to 149 ± 10 °F using a hot water-heated coil and maintain this temperature for 6 hr.
- Cool the solution to 104 °F.
- Transfer spent decontamination solution to the waste neutralization vessel (HDH-VSL-00003) using the steam ejector.
- Initiate 1 M nitric acid spray for 10 sec to wash the top of the canister at 50 psig.
- Open lid on canister decontamination vessel (HDH-VSL-00002/4) and lift canister.
- Initiate 1 M nitric acid spray wash flow at 50 psig to remove solution residue from the canister as the canister is being lifted.
- Transfer the 200 gal of acid rinse to the waste neutralization vessel (HDH-VSL-00003).
- Lower the canister back into the decontamination vessel.
- Repeat the spray wash procedure using water at 50 psig. The 200 gal of low-activity wash water is transferred to the waste neutralization vessel (HDH-VSL-00003).
- Upon completion of rinse, lower canister back into the decontamination vessel.
- Allow the canister to dry while in canister decontamination vessel (HDH-VSL-00002/4) with lid open.

4.6.3.2.3 Energy Contributions - Canister Decontamination Vessel HDH-VSL-00002/4

- Energy contribution from the chemical milling process includes hot water heating of the 214 gal of solution to 149 °F, maintaining temperature for 6 hr, before steam jet transferring the solution to HDH-VSL-00003. Acid wash and water wash solutions are also jet transferred to HDH-VSL-00003.
- Chemical reactions. The HLW canisters are decontaminated by removing a thin layer of metal from the canister surface using Ce^{+4}in a nitric acid solution. This reaction takes place when the canister is soaked in the decontamination solution at 149 °F for 6 hr while gentle air sparging agitates the solution. The Ce^{+4} solution etches stainless steel; therefore, the thickness of the layer removed is controlled by the amount of ceric nitrate available. This factor limits the thickness of the layer removed to 10 μm. The chemical reactions that take place to allow for the dissolution of the thin layer of stainless steel are:
  - $Fe + 3\ Ce^{+4} \rightarrow Fe^{+3} + 3\ Ce^{+3}$
  - $Ni + 2\ Ce^{+4} \rightarrow Ni^{+2} + 2\ Ce^{+3}$
  - $Cr + 6\ Ce^{+4} \rightarrow Cr^{+6} + 6\ Ce^{+3}$

4.6.3.3 Waste Neutralization Vessel HDH-VSL-00003

4.6.3.3.1 Design Data - Waste Neutralization Vessel HDH-VSL-00003

(24590-HLW-3YD-HDH-00002, 24590-HLW-MVD-HDH-00003, 24590-HLW-M6C-HDH-00001, 24590-HLW-M5-V17T-00006)

See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

4.6.3.3.2 Operating Logic - Waste Neutralization Vessel HDH-VSL-00003

- Receive vessel rinse solids and effluent from the canister rinse bogie vessel (HDH-VSL-00001)
- Receive steam condensate and decontamination effluent from one of the canister decontamination vessels (HDH-VSL-00002/4)
- Add hydrogen peroxide from the hydrogen peroxide addition tank/funnel (HDH-TK-00003) to the waste neutralization vessel (HDH-VSL-00003) to deactivate any remaining Ce^{+4} in the spent decontamination and wash solutions following each receipt of effluent
- Repeat process for the other melter line
- After two canisters have been decontaminated 5 M NaOH is added to neutralize the waste before it is transferred to the Acidic Waste Vessel (RLD-VSL-00007)
- Transfer vessel washings and solids (e.g., glass shards) to the Plant Wash and Drains Vessel (RLD-VSL-00008)

4.6.3.3.3 Energy Contributions - Waste Neutralization Vessel HDH-VSL-00003

This vessel receives steam condensate, steam-jet transferred spent decontamination solution, acid and water rinse, and hydrogen peroxide.

4.6.3.3.4 Chemical Reactions - Waste Neutralization Vessel HDH-VSL-00003

- Any unreacted Ce^{+4} remaining after the canister has been decontaminated is reduced to Ce^{+3} by hydrogen peroxide in the waste neutralization vessel. This neutralizes the reactivity of the Ce^{+4} so that the decontamination solution will not etch any of the stainless steel in the waste neutralization vessel, or in any of the vessels or instruments downstream from the waste neutralization vessel. The reduction reaction is:

$$2\ Ce^{+4} + H_2O_2 \rightarrow 2\ Ce^{+3} + 2\ H^{+} + O_2$$

- The nitric acid remaining from the canister decontamination process will be reacted with 5 M NaOH before the waste is sent to the PT Facility.

$$HNO_3 + NaOH \rightarrow H_2O + NaNO_3$$

4.6.3.4 Cerium^{+4} Addition Tank HDH-TK-00002

4.6.3.4.1 Design Data - Cerium^{+4} Addition Tank HDH-TK-00002

(24590-HLW-3YD-HDH-00002, 24590-HLW-M5-V17T-00006)

See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

- Manually transfer 20 gal of ceric nitrate solution from the shipping containers into the Ce^{+4} addition tank (HDH-TK-00002) using a drum pump
- Confirm that the canister decontamination vessel (HDH-VSL-00002/4) is empty (check level indicator on the vessel) and ready to accept a 214 gal batch volume of decontamination solution
- Open the nitric acid addition line and immediately open the ceric nitrate addition line so that the ceric nitrate will mix with the nitric acid in the line during the transfer
- When the cerium addition tank (HDH-TK-00002) is empty, close the cerium addition line

4.6.3.4.2 Energy Contributions - Cerium^{+4} Addition Tank HDH-TK-00002

- Ceric acid (20 gal) at room temperature is added to this tank for transfer to the canister decontamination vessel.

4.6.3.5 Hydrogen Peroxide Addition Tank HDH-TK-00003

4.6.3.5.1 Design Data - Hydrogen Peroxide Addition Tank HDH-TK-00003

(24590-HLW-3YD-HDH-00002, 24590-HLW-M5-V17T-00006)

See Appendix B for design data (i.e., overflow volume, filled volume, batch volume, heel volume, and maximum effluent rate).

- Manually add 0.5 gal of hydrogen peroxide to the hydrogen peroxide addition tank/funnel (HDH-TK-00003)
- Ensure that the lid is closed to prevent decomposition of the hydrogen peroxide
- After the decontamination solution is transferred to HDH-VSL-00003, open hydrogen peroxide addition line to receive 0.5 gal of hydrogen peroxide from the hydrogen peroxide addition tank (HDH-TK-00003) into the waste neutralization vessel (HDH-VSL-00003) to reduce residual Ce^{+4} to Ce^{+3}
- Close addition line after transfer is complete

4.6.3.5.2 Energy Contributions - Hydrogen Peroxide Addition Tank HDH-TK-00003

Hydrogen peroxide (0.5 gal) is added to this tank for transfer to the waste neutralization vessel.

4.6.4 References

24590-HLW-3YD-HDH-00002, Rev 3, *System Description for HLW System HDH Canister Decontamination Handling.*

24590-HLW-M5-V17T-00006, Rev 6, *Process Flow Diagram HLW Vitrification HLW Canister Decon (System HDH).*

24590-HLW-M6C-HDH-00001, Rev 0, *HLW Canister Decontamination Waste Neutralization Vessel HDH-VSL-00003 Sizing Calculation.*

24590-HLW-MVC-HDH-00005, Rev A, *HDH Vessel and Tank Process Data Calculation.*

24590-HLW-MVD-HDH-00003, Rev 4, *24590-HLW-MV-HDH-VSL-00003 - Waste Neutralization Vessel.*

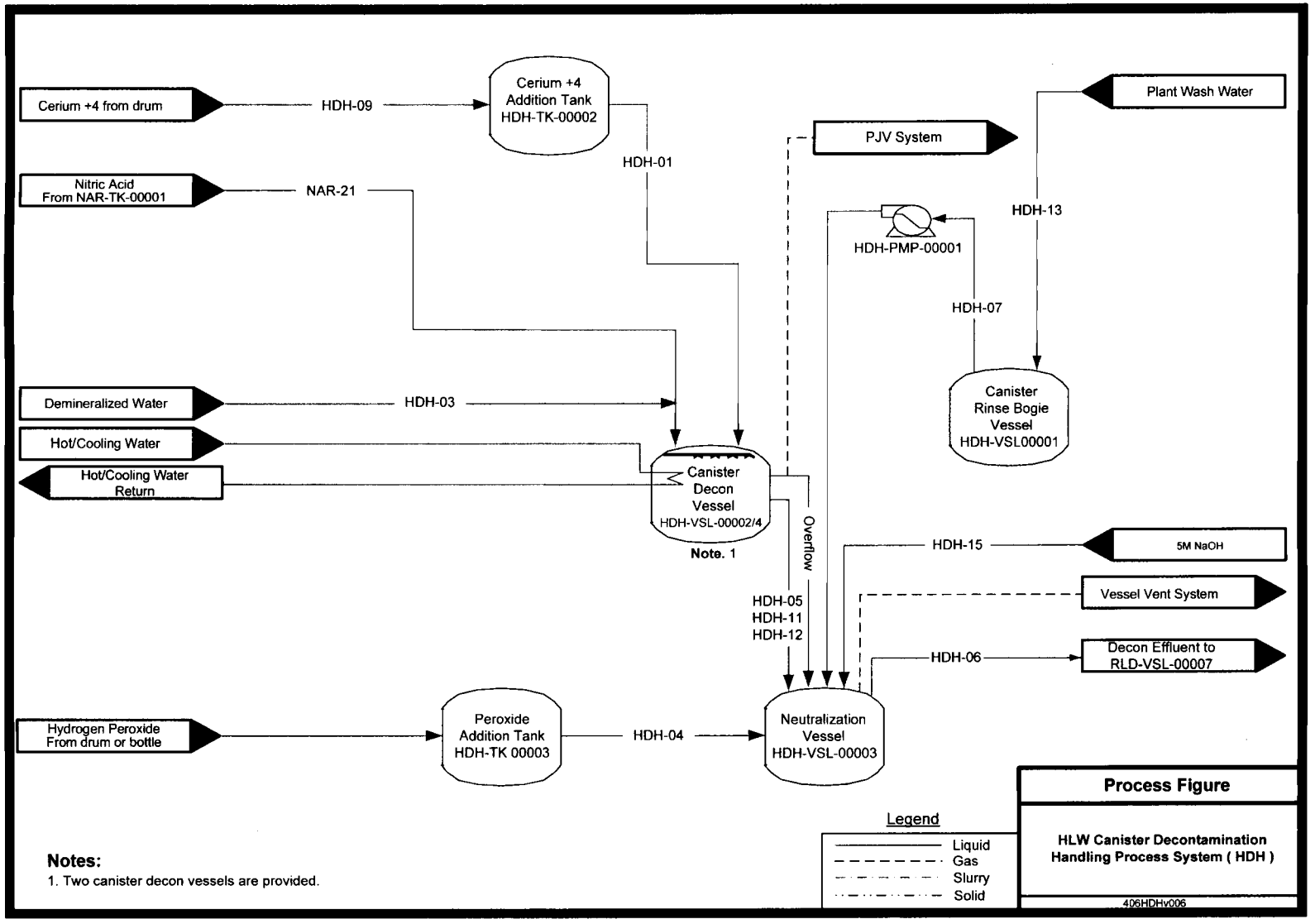
24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

OCRWM-WASRD. *Waste Acceptance System Requirements Document*, Rev 5. US Department of Energy, Office of Civilian Radioactive Waste Management, Washington, DC.

WVDP-186. *WVNS Waste Form Qualification Report*, Rev 2. West Valley Nuclear Services Co., Inc., West Valley, NY.

Figure 4.6-1 HLW Canister Decontamination Handling Process System



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4.7 HLW Interfaces with WTP Reagents, Ammonia Reagent, and Demineralized Water System (NAR, SHR, AMR, and DIW)

4.7.1 Introduction

The WTP reagent system receives, stores, and distributes chemical reagents for use within the WTP. The Balance of Facilities (BOF) Chemical Storage Facility distributes nitric acid (HNO_3, designated as NAR), and sodium hydroxide (NaOH, designated as SHR) to the High-Level Waste (HLW) Facility (24590-WTP-3YD-SHR-00001).

The Ammonia Reagent System (AMR) transfers gaseous anhydrous ammonia to the HLW Facility (24590-WTP-3YD-AMR-00001).

The Demineralized Water System (DIW) receives, stores, and distributes reverse osmosis quality water for use within the HLW Facility. The primary uses of DIW are for process operations, line flushes, vessel washes, and make-up water for reagent dilutions

4.7.2 Process Description

Below is a summary for each of the above systems. For a more detailed explanation of the WTP reagent system, refer to Section 6.2, BOF Process Reagents (NAR, STR, SPR, SNR, AMR, SHR). For a more detailed explanation of the DIW delivery system, refer to Section 6.7, Process Service and Demineralized Water (PSW, DIW).

4.7.2.1 Nitric Acid

The HLW nitric acid dilution and distribution tank and distribution system perform three overall functions. The first is to provide receiving and interim storage capability for nitric acid usage in the HLW vitrification facility. HNO_3 at 2 M concentration is transferred to the HLW nitric acid tank (NAR-TK-00001) from the wet chemical storage facility on a routine basis, as required. The second function is to dilute the nitric acid with DIW to 1 M for normal use by the HDH vessels (HDH-VSL-00002/4). The third function is to distribute nitric acid, as required, to the canister decontamination vessels (HDH-VSL-00002/4). NAR-TK-00001 also distributes 0.5 to 2 M nitric acid to the HLW plant wash racks, as required (24590-WTP-3YD-SHR-00001).

4.7.2.2 Sodium Hydroxide

NaOH at 5 M is supplied by the wet chemical storage facility to the HLW 5 M SHR Tank (SHR-TK-00002), then transferred to the following vessels in the HLW Facility:

- Acidic waste effluent vessels (RLD-VSL-00007/8)
- Waste neutralization vessel (HDH-VSL-00003)

4.7.2.3 Ammonia

Anhydrous ammonia is unloaded from a tanker truck to two ammonia holding vessels (AMR-VSL-00003/4) as a liquid. Gaseous ammonia from the vessel head space is supplied to the selective catalytic reduction units in the HLW and LAW Facilities to reduce NO_x in the offgas to nitrogen and water. Liquid

ammonia from the vessels is routed to vaporizers and heated as needed in order to maintain adequate supply pressure of gaseous ammonia (24590-WTP-3YD-AMR-00001).

4.7.2.4 Demineralized Water System

The demineralized water storage tank (DIW-TK-00002) receives and stores DIW for use in the HLW Facility. DIW from the storage tank is pumped to the canister decontamination vessels (HDH-VSL-00002/4). DIW is also pumped to the high-efficiency mist eliminators (HOP-HEME-00001/2) and wet electrostatic precipitators (HOP-WESP-00001/2) in the HLW Melter Offgas Treatment Process System (HOP) (24590-HLW-M6-DIW-00001001, -00001002, -00001003, -00001004, Rev 0,).

4.7.3 Potential Changes

None identified.

4.7.4 References

24590-HLW-M6-DIW-00001001, Rev 0, *P&ID - HLW Demineralized Water System, Demineralized Water Distribution.*

24590-HLW-M6-DIW-00001002, Rev 0, *P&ID - HLW Demineralized Water System, Demineralized Water Distribution.*

24590-HLW-M6-DIW-00001003, Rev 0, *P&ID - HLW Demineralized Water System, Demineralized Water Distribution.*

24590-HLW-M6-DIW-00001004, Rev 0, *P&ID - HLW Demineralized Water System, Demineralized Water Distribution.*

24590-WTP-3YD-AMR-00001, Rev 2, *System Description for the Ammonia Reagent System (AMR).*

24590-WTP-3YD-SHR-00001, Rev 2, *System Description for the WTP Reagents (SHR, NAR, AFR, SPR, STR).*

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4.8 System HRH, HPH, HDH, and HEH: HLW Mechanical Handling

4.8.1 Functions and Requirements

The high-level waste (HLW) canister mechanical handling system performs the following functions: empty canisters are imported into the HLW Facility and filled with glass. The canisters are then sealed, decontaminated, and exported to storage where they await pickup by the customer.

The HLW canister mechanical handling system includes these four systems:

- System HRH: HLW canister receipt handling
- System HPH: HLW canister pour handling
- System HDH: HLW canister decontamination handling
- System HEH: HLW canister export handling

The primary function of the HRH system is to introduce clean immobilized high-level waste (IHLW) canisters into the facility and import canisters into the canister handling cave (HPH system). The system will also provide buffer storage for staging canisters awaiting import into the canister handling cave (24590-HLW-3YD-HRH-00001).

The HPH system performs several functions. It transfers canisters to and from a pour spout beneath a melter cave, where they are filled with HLW glass. The HPH system also welds the closure lid on an IHLW canister after it has been filled with glass and allowed to cool. This system will also be used to take glass samples for analysis, perform canister inspections, and provide any necessary rework. Finally, the HPH system is used to transport IHLW canisters to interfacing process systems, provide cooling/buffer storage before welding, and provide lag storage before decontamination (24590-HLW-3YD-HPH-00001).

The function of the HDH system (24590-HLW-3YD-HDH-00002) is to move the canister through the decontamination process to remove smearable radionuclide contamination from the filled canister surface to meet the IHLW waste acceptance criteria. The HDH system includes the process and equipment to perform the ceric nitrate (Ce^{+4}) canister decontamination process.

The function of the HEH system is to provide temporary storage and a means to load and ship filled canisters via supplied shipping casks (24590-HLW-3YD-HEH-00001).

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136) Operational Specification, Section C.8, states the following:

Specification 1.2.2.1.2

> *Canister System: The reference canister system used to contain the IHLW product shall be a 4.5-meter long by 0.61-meter diameter canister system with a neck and flange design similar to that used at the West Valley Demonstration Project.*

Specification 1.2.2.1.2 (cont.)

1. *"Fill Height: Fill height shall be equivalent to at least 87 percent of the volume of the empty canister. The average fill height over all the canisters shall be at least 95 percent of the volume of the empty canister."*
2. *"Maximum Heat Generation Rate: The maximum heat generation rate for any single canister shall not exceed 1500 watts per canister when delivered to DOE."*
3. *"Surface Contamination Limitations: Removable contamination on the external surfaces of the package shall not exceed 3,670 Bq/m^2 for alpha and 36,700 Bq/m^2 for beta-gamma. (M047)."*

Specification 1.2.2.1.3

Condition at Delivery: At time of delivery to DOE, the HLW form shall stand upright without support on a flat horizontal surface and properly fit into a right-circular, cylindrical cavity (64-cm diameter and 4.51-m length).

Specification 1.2.3.1

Product Handling: The canister shall have a point of connection that allows vertical upward, vertical downward, and horizontal motion while attached to a hoist and grapple.

WTP SOW Facility Specification, Section C.7(d)(2)(iv):

High-Level Waste Canister Closure, Decontamination, and Inspection: The HLW canister is sealed via welding. The canister is decontaminated using a chemical etching process that uses [cerium] Ce (IV) as the chemical reagent. **(M047)**

The following information from the *Basis of Design*, Section 11.8.3.1, Mechanical Handling System Design Requirements (24590-WTP-DB-ENG-01-001) Section 11.8.3.1:

Cranes

Cranes are designed to lift the heaviest item in the cave during the design life of the facility. The rated capacity, code/standard, and basis of rated capacity will be developed as the design progresses.

The preferred geometry of in-cave cranes is a 3-axis top running configuration based on a twin-beamed bridge with end carriages for long travel, carrying a carriage unit for cross travel. These cranes contain a rope hoisting system for lifting and lowering the payload. Where possible, standard designs and components are utilized.

These items are designed to be of modular construction and orientated to facilitate quick removal and replacement of failed components. These modules have quick connectors on flying leads to allow rapid reconnection of cabling or other services. Areas where contamination can be trapped are minimized.

These items will typically have no on-board logic.

Maintenance cranes are designed and installed so there is no interference with normal operations of the process cranes.

Cranes are designed so that in the park position in the crane maintenance area, inspections can be performed in low radiation/contamination areas and without unsafe interferences occurring during the inspections.

The mechanical handling equipment shall be designed to be removable to dedicated maintenance areas for replacement of mechanical equipment, controls, and other components. These maintenance areas shall be shielded and maintained accessible for operator access.

Where crane decontamination is required, provisions must be made for use of CO_2, pressurized warm water, detergent solution, and steam. Normally this would be for isolated areas on the crane to minimize damage to electrical gear on the crane; however, the design would cover the entire crane. A location for the decontamination must be provided, including disposal of the waste liquid. Rotating hooks shall not be degraded because of crane decontamination, therefore, sealed bearings and motor shall be used.

Crane lubrication points shall be centralized and accessible to personnel. Brakes on all crane drive functions are to be set when power is off. Lights are to be mounted on the crane to illuminate the working area below (except on single girder cranes with adequate lighting below). Crane and hoist components shall be interchangeable to the maximum extent possible.

High reliability, mechanical sequencing grapples are to be used for crane handling of product containers.

Bogies

Bogies provide a means of transferring the product containers, on a pair of parallel rails from one location to another during process activities. The bogies are of modular design to facilitate quick removal and replacement of failed components, and are designed to minimize contamination traps. Bogies are primarily of carbon steel construction, with the exception of materials contacting the product containers, which are stainless steel. Bogies located in an environment with a high level of contamination are primarily of stainless steel construction.

Power manipulators (gantry mounted)

These machines combine the roving capability of a crane with the dexterity of a manipulator.

The preferred geometry of these machines utilizes a 3-axis top running configuration based on a twin-beamed bridge with end carriages for long travel, carrying a carriage unit for cross travel. The machines contain a rope or chain hoisting system for lifting and lowering a telescopic mast. A power manipulator arm will be deployed on the

bottom of the mast. A hook may also be provided at the shoulder of this manipulator arm to allow the mast to lift heavy items.

To reduce fatigue on the power manipulator arm and increase the functionality of the machine, an auxiliary hoist may be utilized. This hoist may be attached to the carriage or may rotate around the fixed tube of the mast above the manipulator arm.

In general, all the other features pertinent to in-cave cranes also apply to these machines.

4.8.2 Process Description

The HLW canister mechanical handling systems provide the ability to bring an empty canister into the HLW Facility, fill it with HLW glass, seal and decontaminate it, and export it for offsite storage. Empty canisters are brought to the facility by truck, inspected, and then brought through intermediate airspace and into a handling cave. From there they may be placed in temporary storage or immediately moved to a pour tunnel, filled with glass, and allowed to cool. Next, the glass fill level is measured, any necessary glass samples are obtained, and the canister is sealed. The canister is then decontaminated and subsequently checked for smearable contamination. When verified to be satisfactorily decontaminated, the canister is placed in temporary storage awaiting DOE shipment approval. Once the canister has received approval for shipment, the canister is loaded into a shielded shipping cask that is placed on a transporter and moved out of the HLW Facility. These processes are separated into four systems, described below. A schematic of the HLW mechanical handling systems and how they interface in the HLW Facility is depicted in Figure 4.8-1.

4.8.2.1 HRH -Canister Receipt Handling System

The HRH system picks up the new, empty canister from the truck and brings it into the import area, where it is inspected, turned upright, and transferred into the handling cave or placed in the canister import rack. This system includes the following.

Table 4.8-1 HRH System

System Component	Purpose
Import bay overhead crane (HRH-CRN-00002)	Transfers empty HLW canisters from the truck to the inspection/rotation table (HRH-TTBL-00001).
Inspection/rotation table (HRH-TTBL-00001)	Used to visually inspect canisters and then rotate from horizontal to vertical orientation in a location where the import monorail crane (HRH-HST-00001) can lift them.
Import monorail hoist (HRH-HST-00001)	Moves canisters from the inspection/rotation table (HRH-TTBL-00001) to either the import bogie (HRH-TRLY-00002) or to the import rack (HRH-MHAN-00002), and also from the import rack (HRH-MHAN-00002) to the import bogie (HRH-TRLY-00002).
Import bogie (HRH-TRLY-00002)	Transports canisters from the import area to the handling cave.
Import rack (HRH-MHAN-00002)	Stores empty canisters until they are needed in the handling cave.

4.8.2.2 HPH - Canister Pour Handling System

The HPH system performs numerous tasks. In the canister handling cave, it provides locations for storage of empty and full canisters, as well as for cooling of recently filled canisters. Additionally, this system provides the two overhead cranes, which perform all canister transport operations in the handling cave. Also in the handling cave, this system verifies glass fill level, obtains samples if required, and welds the canister lid in place. There is one pour tunnel for each of the two melters, with two pour tunnel bogies per pour tunnel for a total of four pour tunnel bogies. A canister will be placed in an available pour tunnel bogie by the canister handling overhead crane. The canister is then filled with glass, cooled, and removed from the pour tunnel by the canister handling overhead crane, which places it into the cooling rack. This system includes the following.

Table 4.8-2 HPH System

System Component	Purpose
Upper canister handling cave overhead cranes (HPH-CRN-00002)	Transport the canisters to and from the import bogie (HRH-TRLY-00002), the pour tunnels, the cooling racks (HPH-MHAN-00014), the handling cave buffer rack (HPH-MHAN-00017), the weld station (HPH-BENCH-00004), and the canister rinse vessel/bogie (HDH-VSL-00001/HDH-TRLY-00003).
Lower canister handling cave overhead cranes (HPH-CRN-00001)	These cranes serve as a redundant backup.
Cooling rack (HPH-MHAN-00014)	Used to store canisters after filling and allow them to cool to a temperature that will allow the lid to be welded on.
Handling cave buffer rack (HPH-MHAN-00017)	Used to store empty and full canisters.
Pour tunnel 1 bogies HPH-TRLY-00001 (east) and HPH-TRLY-00004 (west)	Move the canister from beneath pour tunnel 1 hatch (HPH-HTCH-00001) providing access between the pour tunnel and the handling cave to the melter pour spout.
Pour tunnel 2 bogies HPH-TRLY-00010 (east) and HPH-TRLY-00011 (west)	Move the canister from beneath pour tunnel 2 hatch (HPH-HTCH-00002) providing access between the pour tunnel and the handling cave to the melter pour spout.
Pour station	The indexed position below the melter pour spout.
Glass sampling equipment (HPH-SMPLR-00001, HPH-SMPLR-00002, HPH-SMPLR-00003, and HPH-SMPLR-00004)	Retrieves shard glass samples.
Level measurement equipment (HPH-MHAN-00022 and HPH-MHAN-00037)	Measures canister fill height.
Canister inspection equipment	Verifies canister temperature and weight.
Canister lid welder (east) (HPH-WELD-00004)	Welds the canister lid in place.
Canister lid welder (west) (HPH-WELD-00010)	Welds the canister lid in place.

4.8.2.3 HDH - Canister Decontamination System

The HDH system performs the task of decontaminating filled and sealed canisters. The canister is initially rinsed with demineralized water in the canister rinse bogie vessel. The canister is then placed into one of the two available canister decontamination vessels by the decontamination area overhead crane. The canister decontamination vessel then chemically etches 10 microns of material off the canister exterior (using ceric nitrate) to remove sufficient smearable contamination. After this process, the canister is rinsed, first with nitric acid to remove leftover ceric nitrate, then with demineralized water to remove the left over nitric acid. The canister is swabbed to verify acceptable levels of smearable contamination, then placed in the canister transfer bogie by the decontamination area overhead crane for export to the canister storage rack. The decontamination process equipment is discussed in detail in Section 4.6. This system includes the following.

Table 4.8-3 HDH System

System Component	Purpose
Canister rinse bogie vessel (HDH-VSL-00001/ HDH-TRLY-00003)	Transports canisters from the handling cave to the decontamination area and rinse canisters with demineralized water.
Decontamination area overhead crane (HDH-CRN-00005)	Transfers canisters into and out of the decontamination area, and transfers canisters to and from the canister decontamination vessel (HDH-VSL-00002) and the swabbing turntable (HDH-TTBL-00001).
Canister decontamination vessel (HDH-VSL-00002)	Used to chemically etch 10 microns of material from a canister's exterior surface.
Canister decontamination vessel (HDH-VSL-00004)	Used to chemically etch 10 microns of material from a canister's exterior surface.
Swabbing turntable (HDH-TTBL-00001)	Used to allow access to the entire canister by the swabbing manipulator (HDH-MANIP-00001).
Swabbing manipulator (HDH-MANIP-00001)	Swabs the surface of the canister for smearable contamination.
Canister transfer bogie (HDH-TRLY-00004)	Transfers canisters from the decontamination area to the canister storage area.

4.8.2.4 HEH - Canister Export Handling System

The HEH system provides for canister storage following decontamination. It also provides the ability to import an empty transport cask from a truck in the export bay, unbolt and remove the cask lid, place a full canister in the cask, replace the lid, and export the cask to the waiting truck. This system includes the following.

Table 4.8-4 HEH System

System Component	Purpose
Canister storage crane (HEH-CRN-00003)	Moves canisters from the canister transfer bogie (HDH-TRLY-00004) to the canister storage rack (HEH-MHAN-00002) and from the canister storage rack (HEH-MHAN-00002) into an empty cask in the cask handling bogie (HEH-TRLY-00005).
Canister storage rack (HEH-MHAN-00002)	Stores canisters following decontamination, until they can be shipped for offsite storage.
Cask handling overhead crane (HEH-CRN-00001)	Moves an empty cask from a transport trailer in the export bay to the cask handling bogie (HEH-TRLY-00005), and moves a full cask from the cask handling bogie (HEH-TRLY-00005) to a transport trailer in the export bay.
Cask handling bogie (HEH-TRLY-00005)	Transfers an empty cask from the export bay to the cask lidding machine (HEH-LID-00001) (where the cask lid is removed) and from there to the area where a full HLW canister is placed into the cask. Then the cask handling bogie (HEH-TRLY-00005) transfers the full cask back to the cask lidding machine (HEH-LID-00001) (where the cask lid is replaced) and then to the export bay.
Cask lidding machine (HEH-LID-00001)	Removes and replaces the cask lid.

4.8.3 Basis

The mechanical handling steps required to move a canister through the HLW process were identified as part of the HLW Facility design. These steps were coupled with the specific cell and equipment configuration to develop step times for each activity as listed below. Operations time is not considered. For mechanical handling systems there are no energy contributions. The steps are identified in the HLW vitrification mechanical flow diagrams located in the following system descriptions:

- 24590-HLW-3YD-HRH-00001, Rev 4
- 24590-HLW-3YD-HPH-00001, Rev 3
- 24590-HLW-3YD-HDH-00002, Rev 3
- 24590-HLW-3YD-HEH-00001, Rev 2

4.8.3.1 Mechanical Handling Steps and Times

The HLW mechanical handling process steps and times are shown in Table 4.8-5.

4.8.4 References

Project Documents

24590-101-TSA-W000-0009-101-00007, Rev 00A, *Report -RPP Pilot Melter Prototypic LAW Container and HLW Canister Glass Fill Test Results.* (TRR-PLT-0800, Rev 0)

24590-101-TSA-W000-0010-407-566, *90 % Design-HLW Melter System Description.* (REP-WTP-21002, Rev 0)

24590-HLW-3YD-HDH-00002, Rev 3, *System Description for the HLW System HDH Canister Decontamination Handling.*

24590-HLW-3YD-HEH-00001, Rev 2, *System Description for the HLW System HEH Canister Export Handling.*

24590-HLW-3YD-HPH-00001, Rev 3, *System Description for HLW System HPH Canister Pour Handling.*

24590-HLW-3YD-HRH-00001, Rev 4, *System Description for HLW System HRH Canister Receipt Handling.*

24590-HLW-DCA-M-02-019, Rev 0, *HLW Elimination of Pour Tunnel Lid Stations.*

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

CCN 232088, *HLW Mechanical Handling Step Times for WTP Operations Research Model.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

Table 4.8-5 HLW Mechanical Handling Process Steps and Times

No.	HLW Mechanical Handling Process	Time (min)
Note	Canisters are brought to the WTP by a transport truck and are unloaded by the import bay overhead crane (HRH-CRN-00002) to the staging area. Each truck can deliver nine containers per load. The staging area can hold 18 containers.	
Note	Each grapple engagement, hatch operation, or transport movement of each container.	10
HRH		
1	The canister is picked up in the staging area by the import bay overhead crane (HRH-CRN-00002) and placed on the inspection/rotation table (HRH-TTBL-00001).	30
2	Each canister is unwrapped and inspected.	25
3	The inspection/rotation table (HRH-TTBL-00001) rotates the canister to a vertical position, and the import monorail crane (HRH-HST-00001) picks the canister up from the rotation table and places it in the import bogie (HRH-TRLY-00002).	60
4	If the import bogie (HRH-TRLY-00002) is in use, the import monorail crane (HRH-HST-00001) takes the canister to the import rack (HRH-MHAN-00002) which has 16 spaces available for storage.	30
5	When the import bogie (HRH-TRLY-00002) is ready to accept a canister, the import monorail crane (HRH-HST-00001) transports a canister from the import rack (HRH-MHAN-00002) to the import bogie (HRH-TRLY-00002). Time for hatch operations is included.	40
6	The import bogie (HRH-TRLY-00002) travels through the import tunnel to the handling cave import hatch (HRH-HTCH-00001).	10
HPH		
7	Handling cave overhead crane (HPH-CRN-00001) lifts the canister from the import bogie (HRH-TRLY-00002) and transfers it to an available pour tunnel bogie.	40
8	If all of the pour tunnel bogies are in use, the canister is put into the handling cave buffer rack (HPH-MHAN-00017). There are 24 spaces available for storage.	30
9	The handling cave overhead crane (HPH-CRN-00001) moves a canister from the handling cave buffer rack (HPH-MHAN-00017) to the pour tunnel bogie that is ready to receive a new one.	30
10	The pour tunnel bogie moves to the pour station.	20
11	The canister is filled with glass.	1350
Note:	The time for this step is derived from a canister throughput of 6.0 metric tons of glass (MTG) per day. A pour will occur every 2 hr and last for 30 min (24590-101-TSA-W000-0010-407-566). The melter recovery time between pours is therefore 90 min. The time from the start of a fill to the end of the last pour is 24 hours less 90 minutes, or 1350 minutes. When targeting a throughput of 7.5 MTG, the canister fill time will be adjusted to 19.2 hours less 90 minutes, or 1062 minutes.	
12	The canister cools under the pour spout for 1 hour, then moves (10 minuets) to a cooling position a few feet away where the filled canister continues to cool for up to 8 hours	550

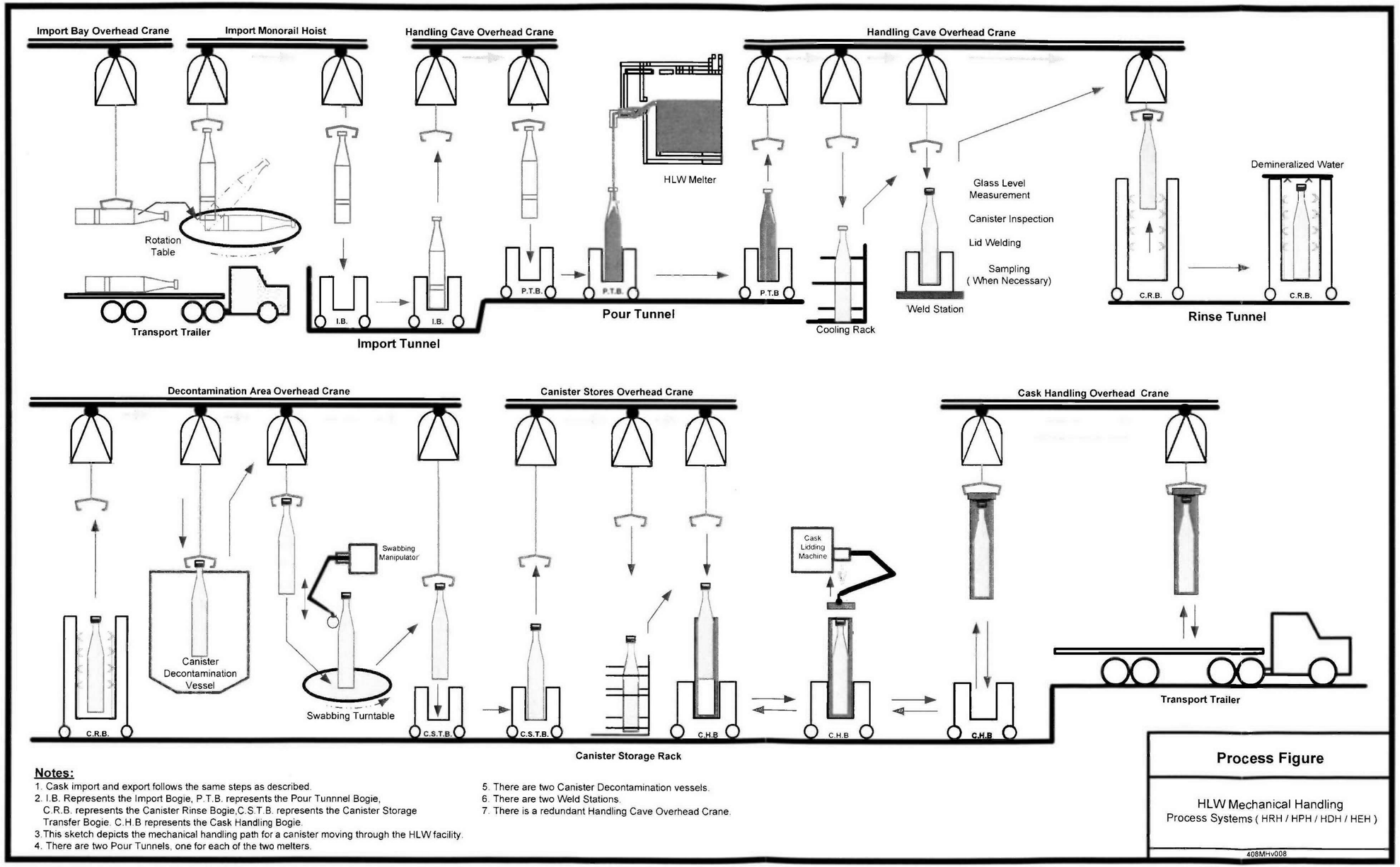
Table 4.8-5 HLW Mechanical Handling Process Steps and Times

No.	HLW Mechanical Handling Process	Time (min)
13	The canister is picked up by handling cave overhead crane (HPH-CRN-00001) and is placed into one of the cooling racks (HPH-MHAN-00014). There are 24 spaces available for storage in the cooling racks. The time includes open and close hatches and two grapple action.	40
14	When the canister has cooled, it is moved by the handling cave overhead crane to one of the two weld stations. The time includes two grapple action.	20
15	The glass level is measured, samples are taken when required, and the lid is welded on.	180
HDH		
16	The handling cave overhead crane (HPH-CRN-00001) transports the canister to the canister rinse bogie vessel (HDH-VSL-00001/HDH-TRLY-00003). The time includes two grapples and one hatch action.	30
17	The canister rinse bogie vessel (HDH-VSL-00001/HDH-TRLY-00003) moves the canister to the rinse station. The canister is rinsed and moved to the decontamination cave import hatch.	62
18	The decontamination area overhead crane (HDH-CRN-00005) moves the canister into one of the two decontamination vessels. The time includes canister movement, two grapples, and one hatch action.	40
19	The canister is decontaminated by soaking in a cerium IV bath.	566
20	The decontamination area overhead crane (HDH-CRN-00005) lifts the canister through a nitric acid spray, then lowers it back into the decon vessel. The overhead crane lifts the canister again through a water spray, then lowers it back into the decon vessel to dry.	100
21	The canister dries.	30
22	The decontamination area overhead crane (HDH-CRN-00005) transfers the canister from either of the decontamination vessels over to the swabbing station (HDH-TTBL-00001), and the bottom of the canister is swabbed to check for contamination.	90
23	The canister is lowered into the swabbing station and the rest of the canister is swabbed to check for contamination.	98
24	The decontamination area overhead crane (HDH-CRN-00005) moves the canister from the swabbing station (HDH-TTBL-00001) to the canister transfer bogie (HDH-TRLY-00004).	30
25	The canister transfer bogie (HDH-TRLY-00004) moves the canister to the canister store import hatch (HEH-HTCH-00004).	10
HEH		
26	The canister storage crane (HEH-CRN-00003) removes the canister from the canister transfer bogie (HDH-TRLY-00004) and places it in the canister storage rack (HEH-MHAN-00002). The storage capacity is 46 canisters. This step involves two grapples and one hatch action.	30
27	The canister remains in the storage rack until it is accepted by the contracting officer as stated in interface control document 14. Two days are added for both the time it will take for the proper documentation to reach the contracting officer, and from the time the controlling officer accepts the canister until a transport truck is made available.	

Table 4.8-5 HLW Mechanical Handling Process Steps and Times

No.	HLW Mechanical Handling Process	Time (min)
28	A cask is brought in on a flatbed trailer to the export bay via a supply tractor.	
29	The cask handling overhead crane (HEH-CRN-00001) removes the cask from the flatbed trailer and places it in the cask handling bogie (HEH-TRLY-00005). This step involves a cask pickup, an open and close door, an open product cask export hatch, and a bogie placement.	60
30	The lid is unbolted, the cask export hatch closes, and the cask handling bogie (HEH-TRLY-00005) moves to cask lidding machine (HEH-LID-00001). The cask lidding machine lifts the lid from the cask, and the cask handling bogie (HEH-TRLY-00005) moves it into position to receive a canister.	60
31	When the cask handling bogie (HEH-TRLY-00005) is ready to accept a canister, the 5-ton canister storage crane (HEH-CRN-00003) removes the canister from the canister store rack (HEH-MHAN-00002). It is then placed into the awaiting cask in the cask handling bogie (HEH-TRLY-00005). This step involves two grapples and one hatch action.	30
32	The cask handling bogie (HEH-TRLY-00005) moves to the cask lidding machine (HEH-LID-00001). The lid is lowered on the cask. The cask handling bogie (HEH-TRLY-00005) then moves to a position where the lid is bolted on. The cask can then be picked up by the cask handling overhead crane (HEH-CRN-00001).	90
33	The cask handling overhead crane (HEH-CRN-00001) lifts the cask and places it on the awaiting transport trailer. This step includes a rad survey.	120
34	The transport trailer leaves the facility.	30

Figure 4.8-1 HLW Mechanical Handling Process System



Notes:

1. Cask import and export follows the same steps as described.
2. I.B. Represents the Import Bogie, P.T.B. represents the Pour Tunnnel Bogie, C.R.B. represents the Canister Rinse Bogie,C.S.T.B. represents the Canister Storage Transfer Bogie. C.H.B represents the Cask Handling Bogie.
3. This sketch depicts the mechanical handling path for a canister moving through the HLW facility.
4. There are two Pour Tunnels, one for each of the two melters.
5. There are two Canister Decontamination vessels.
6. There are two Weld Stations.
7. There is a redundant Handling Cave Overhead Crane.

5 Analytical Laboratory

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5.1 Analytical Laboratory

5.1.1 Functions and Requirements

The WTP Analytical Laboratory (Lab) performs the analytical functions specified in the WTP *Statement of Work* (DE-AC27-01RV14136), under the C.7 Facility Specification section. The Lab functions support process control, perform waste form qualification testing, conduct environmental analysis, and provide limited technology testing. The Lab has the ability to receive, prepare, analyze, and record data for samples having moderate to high levels of radioactivity. If turnaround time permits, samples having zero to low levels of radioactivity will be outsourced to a supporting laboratory.

5.1.2 Process Description

Samples are taken from the Hanford Tank Farms, Pretreatment (PT), High-Level Waste (HLW), and Low-Activity Waste (LAW) Facilities. Several samples are also taken from the Balance of Facilities. Hanford Tank Farm grab samples are manually transferred to an outside laboratory. PT and HLW samples are pneumatically transferred to the hot cell receipt cell. LAW samples are pneumatically transferred to the radiological laboratory receipt station. From these receipt locations, the samples are transported to the hot cells and radiological laboratories for preparation, division into sub-samples, and performing analytical activities. Samples requiring preparation in the hot cells, followed by analysis in the radiochemical laboratories, are transferred manually from the hot cells to the radiochemical laboratories. The sample path for each individual sample is outlined in the revised transmittal of input for Operations Research (OR) Model (CCN 211832).

Before, during, and after analysis completion for each sample, data is recorded in the Laboratory Information Management System (LIMS). System descriptions for the analytical hot cell series (24590-LAB-3YD-AHL-00001) and the analytical radiochemical laboratories (24590-LAB-3YD-ARL-00001) provide further information on the hot cells and radiological labs. After each sample has been analyzed, the residual solid waste will be dispositioned to the hot cell waste collection cell. Liquid waste will be sent to the liquid waste collection system, and will later be pumped back to the PT Facility.

5.1.3 Bases

The bases of the Lab flowsheet are discussed in the following sections.

5.1.3.1 Sample Bases

The number of sample vials transferred to the Lab from the Hanford Tank Farms, and PT, HLW, and LAW Facilities is stated in the *Integrated Sampling and Requirements Document (ISARD)* (24590-WTP-PL-PR-04-0001).

Each sample has an analytical time available (ATA) value listed in the ISARD. There are 13 "hold point" samples (PT2, PT2a, PT4, PT 13, PT 17, PT17a, PT17b, PT28, PT 31b, PT35, LAW1a, HLW2a, and HLW2b) that will delay plant production if their turnaround time exceeds the ATA; therefore, these sample points have been assigned a higher processing priority for analysis than all other sample points. The WTP OR Model performed a laboratory assessment and confirmed that the Laboratory completed most of the sample analyses within the ATAs (24590-WTP-RPT-PET-10-024, *2010 WTP Operations Research Assessment*). The assessment also confirmed that the Laboratory configuration adequately

supports the WTP sampling needs. The relationship between sample arrivals, the LIMS, and the effect on production is summarized in Figure 5.1-1.

5.1.3.2 Hot Cell Series (AHL)

The Analytical Hot Cell Laboratory (AHL) has 14 hot cells in the Laboratory configuration. The hot cells are used primarily for preparation and dilution of PT and HLW samples. Activities performed in each hot cell are described below.

Hot cell one - is used to receive samples from the PT Facility and HLW Facility. It is also used for exporting diluted samples to the radiological laboratories for analysis and counting.

Hot cells two and three - are used for sample preparation. All equipment in these two cells are duplicates. Activities performed in these hot cells include mass and density measurements, dilutions, drying of solids, separation of liquids and solids, determination of liquid volumes, homogenizing samples, and splitting samples.

Hot cell four - is used for limited process technology testing and to study abnormalities in the processing facilities. Hot cell four is not utilized in the OR model.

Hot cell five - is used to process technology support and provide physical property measurements of the samples, including rheological, turbidity, and particle size measurements.

Hot cells six and seven - are used for dissolution and dilution of samples. All equipment in these two cells are duplicates and include fusion furnaces and microwave ovens. Activities performed in these hot cells include mixing samples, splitting samples, dissolution, digestion, and dilution of samples.

Hot cells eight and nine - are used for radionuclide preparation. All equipment in these two cells are duplicates. Activities performed in these hot cells include preparation of samples for radionuclide quantitation, loading samples onto ion exchange columns, and eluting sample fractions that have been separated from the radiation contributed by cesium-137.

Hot cell ten - is used for anion analyses, and total organic and total inorganic analyses. Activities performed in this hot cell include leaching, filtering, dilution, and preparation.

Hot cell eleven - is used to determine the volume reduction of sample material achievable before solids form and to test the compatibility of different waste types. The hot cell is also used to develop analytical methods. Hot cell eleven is not utilized in the OR model.

Hot cells twelve and thirteen - are used to analyze conventional non-dilute samples with an inductively coupled plasma (ICP) - atomic emission spectrometry (AES) and an ICP-mass spectrometry (ICP/MS).

Hot cell fourteen - is used for the size-reduction, accumulation, and export of waste.

A complete description of the hot cell series can be found in *System Description for the Analytical Hotcell Laboratory (AHL)* (24590-LAB-3YD-AHL-00001).

5.1.3.3 Radiological Laboratories (ARL)

The Analytical Radiological Laboratory Equipment System (ARL) has 13 radiological laboratories within the Lab. The radiological laboratories are used primarily for analysis of LAW, prepared PT, and HLW samples. Activities performed in each radiological laboratory are shown below:

RL-1 - Radiological Laboratory 1 directly receives samples from the LAW Facility and receives prepared and diluted PT and HLW samples. Temporary staging of samples is provided in shielded sample cabinets.

RL-2 - Radiological Laboratory 2 is used for the dissolution and dilution of samples. Activities performed in this rad lab include microwave-assisted acid dissolution and alkali fusion dissolution, initial dilutions, filtering, drying, and decontamination.

RL-3 - Radiological Laboratory 3 is used for the distillation and titration of samples. Activities performed in this rad lab include preparation and analysis for cyanide and ammonia, as well as acid/base titration.

RL-4 - Radiological Laboratory 4 is the standard and reagent preparation lab and includes specific-gravity measurements of samples. Activities performed in this rad lab include the dilution of purchased standards and the preparation of reagents.

RL-5 - Radiological Laboratory 5 is an X-ray laboratory. This laboratory is used mainly for process technology analyses, or non-routine measurements. However, it also contains two X-ray fluorescence analyzers for routine LAW sample analyses. The non-routine instrumentation includes two optical microscopes.

RL-6 - Radiological Laboratory 6 is for limited process technology use (no routine analyses). This lab is equipped with a Fourier transform infrared instrument (FT-IR) and a UV-visible spectrophotometer. There is also space provided for the set up of test beds for evaluation of ion exchange resins and laboratory-scale filtration units. Radiological Laboratory 6 is not utilized in the OR model.

RL-7 - Radiological Laboratory 7 is for limited process technology use (no routine analyses). This lab will provide support for physical / chemical characteristic measurements of non-routine process samples including process technology and method development testing for process support. The lab is equipped with particle size analyzer, rheometer, differential scanning calorimeter, and thermal gravimetric analyzer. Radiological Laboratory 7 is not utilized in the OR model.

RL-8 - Radiological Laboratory 8 is used for analytical methods development and verification. This lab will support laboratory scale testing under process conditions for determining processability. Radiological Laboratory 8 is not utilized in the OR model.

RL-9 - Radiological Laboratory 9 is used for the preparation and analysis of low-level radioactive samples by ICP/MS, and ICP/AES. A second elemental analysis laboratory, Radiological Laboratory 9A (RL9A), is for backup to systems in RL-9.

RL-10 - Radiological Laboratory 10 is the General Chemistry Laboratory. Activities performed in this lab include preparation and analysis of low and medium level radioactive samples for selected anions, organic acids, total inorganic carbon (TIC), and total organic carbon (TOC). This rad lab contains several different types of equipment including ion chromatography (IC), and carbon analyzers.

RL-11/12 - Radiological Laboratories 11 and 12 are used for performing separation and preparation of radionuclides for quantitation. Activities performed in this lab include weighing, evaporating, purifying, and preparing fractions of samples for appropriate spectroscopic and counting methodologies.

RL-13 - Radiological Laboratory 13 is a radionuclide counting laboratory for quantitation of specific radionuclides. Methods of quantitation include automated gamma spectroscopy (GS), gas proportional counting (GPC), gas proportional counting alpha/beta single detector counting system (GPC single detector), alpha spectrometry (AS), and liquid scintillation counting (LSC).

A complete description of the radiological laboratories can be found in System Description for the *Analytical Radiological Laboratory (ARL)* (24590-LAB-3YD-ARL-00001).

5.1.3.4 Duration and Frequency of Equipment Calibration

The following equipment calibration durations are based on values listed in CCN 211832. The frequency and logic for these calibrations are conservative assumptions based on operator logic, and are listed below:

There are three TIC/TOC furnace and gas trains and one TIC/TOC persulfate oxidation located in RL-10 (two each in two separate Radiological Lab 10 work stations). In the flowsheet they are all equivalent. The units are calibrated independently. This means that there will be four calibration cycles, in parallel, with each cycle lasting for 87 min. The frequency of calibration will be once per day.

There are four ICP/AES machines. One of two ICP/AES located in RL-9 can be calibrated in parallel with one unit from hot cell 12 or 13. This means that there will be two calibration cycles, in parallel, with each cycle lasting for 217 min. The frequency of calibration will be once per week.

There are four ICP/MS. One of two ICP/MS from RL-9 can be calibrated in parallel with one unit from hot cell 12 or 13. This means that there will be two calibration cycles, in parallel, with each cycle lasting for 217 min. The frequency of calibration will be once per week.

There are three IC analyzers located in RL-10. One unit is calibrated at a time. This means that there will be three calibration cycles, in parallel, with each cycle lasting for 90 min. The frequency of calibration will be once per day.

There are two LSC analyzers in RL-13, which are calibrated independently. This means that there will be two calibration cycles, in parallel, with each cycle lasting for 102 min. The frequency of calibration will be once per day.

There are two GPC counting systems with 16 detectors each in RL-13. Each of the 16 detector units is calibrated simultaneously with its counterpart on the other machine. This means that there will be two calibration cycles, in parallel, with each cycle lasting for 112 min. The frequency of calibration will be twice per day (every 12 hr). There is also one GPC (single detector) counting system. This equipment will be calibrated for 152 min twice per day (every 12 hr).

There are two AS counting systems with 24 detectors each in RL-13. Each of the 24 detector units are calibrated simultaneously. This means that there will be two calibration cycles, in parallel, with each cycle lasting for 130 min. The frequency of calibration will be once per day.

There are two GS systems located in RL-13 which are calibrated in parallel. This means that there will be two calibration cycles lasting for 102 min per cycle. The frequency of calibration will be once per day.

5.1.3.5 Mechanical Handling (LIH) in the Hot Cells

The scope of the Analytical Laboratory In-Cell Handling System (LIH) is to provide the capability to manipulate, operate, handle, repair, move or remove the analytical equipment and material located inside each of the hot cells.

5.1.3.5.1 Hot Cell Trolleys

The two hot cell rows are each serviced by an individual trolley dedicated to that row. The trolleys will be propelled by linear induction motors. Each trolley will move through a shielded tunnel and will have the ability to stop at each hot cell to transport samples, supplies, and waste between the hot cells within the row.

The minimum trolley velocity provided to the vendors of 30 ft/min is the basis for the trolley velocity in the Lab OR flowsheet module. The path of the trolley depends on the samples that are being processed.

5.1.3.5.2 Master-Slave Manipulators

Manipulation of samples within the hot cells requires the usage of master-slave manipulators (MSM). The analytical hot cells will include 22 pairs of heavy duty MSMs, for a total of 44 MSMs. There are 2 MSM pairs in the following hot cells and hot cell sections: 1, 1 egress, 8, 9, 14 East, and 14 West. There is 1 MSM pair in the following hot cells: 2, 3, 4, 5, 6, 7, 10, 11, 12, and 13.

5.1.3.6 Failure Data for ARL, AHL, and LIH

First-order failure data has been collected and implemented with respect to important equipment in the ARL, AHL, and LIH systems. Mean time between failure (MTBF) and mean time to repair (MTTR) data were incorporated for equipment that was deemed to have a major impact on production. MTBF and MTTR values for the analytical equipment, trolleys, and MSMs are provided in *OEE Sheets for Analytical Laboratory* (CCN 047010).

If an instrument or any piece of equipment fails in a particular hot cell workstation, then the trolley will transport samples to the equivalent workstation containing that equipment on the opposite hot cell series. If an equivalent piece of equipment does not exist or is not available, then the sample will wait for completion of the MTTR cycle before resuming processing. If an MSM fails, then all activities within the corresponding hot cell will be disabled until the MTTR cycle is completed. If a trolley breaks down, all incoming samples will be sent down the opposite hot cell series, until failure mitigation has been completed. If an analytical instrument fails in the radiological laboratories and a redundant instrument is available, then the incoming sample will be sent there. If a redundant piece of equipment is not available then the sample will wait for the instrument to be repaired, and the turnaround time will be affected. Maintenance data has not been included in the flowsheet at this time.

5.1.3.7 Sample Rework

Operator experience says that a significant portion of analyses within an analytical laboratory constitute rework of samples for a variety of reasons, including but not limited to sample contamination and

operator error. The ISARD (24590-WTP-PL-PR-04-0001) assumes that 15 % of samples are reworked. Sample rework has been incorporated as a random "failure" of 15 % of all sampling steps.

5.1.4 Labor Utilization and Solids Waste Handling

The OR Laboratory flowsheet assumes the conventional non-dilution case design in the hot cells, since this is conservative. Based on the *Analytical Laboratory Operations Research Model Requirements* (CCN 106633), labor sensitivity inputs may be made (varying total chem-techs in the Lab per shift, and fractional manpower needed for each task). The utilization of each "cross-trained" chem-tech worker in the workstations is determined in the Lab module. The percentage of time will be reported that each chem-tech worker spends on the four individual labor task categories. These categories are: "processing plant samples," "QL/calibrations," "solids waste handling," and "idle." The overall percent busy and overall percent idle experienced by the entire group of "cross-trained" chem-tech workers will also be reported.

As specified in CCN 106633, solids waste-handling labor for removing solid waste from the radiological laboratories and the hot cells to hot cell 14 near the end of each 12-hr shift is accounted for in the Lab module. While the solid waste is being removed, samples shall be prevented from entering an affected workstation.

5.1.5 ASX System

The autosampling system (ASX) consists of autosamplers connected to vessels within the PT, HLW, and LAW Facilities to sample vessel contents on demand and a pneumatic transfer system that transports samples to the Laboratory. There are a total of 9 autosamplers, each with up to six ISOLOK units. The ISOLOK units are the actual sampling mechanisms within the autosampler, and each ISOLOK unit is connected to a vessel (or a number of vessels) from which samples can be drawn.

Each sampling event consists of drawing a certain number of bottles, as specified in the *ISARD*. Times associated with sampling and transportation are based on Table 5-1 of 24590-QL-HC4-HAHH-00001-12-00001. The following logic is used for each bottle collected within each sampling event:

- Sample carriers are stored in ASX-SMPLR-00047 for the hot cells and ASX-SMPLR-00034 for the Radiological Lab.
- Each sample carrier can hold one bottle.
- Upon sample initialization, an empty carrier travels through the pneumatic transfer system (PTS) from the appropriate receipt station in the Laboratory to the proper autosampler. This takes 3 minutes.
- Only one carrier can be in the LAW PTS at a time.
- Only a total of one carrier can be in the PTF and HLW PTS at a time.
- Drawing a sample takes 14 minutes.
- Only one carrier can be in each autosampler at a time.
- It takes 2 minutes for the sample to fly back to a laboratory receipt station.
- Once a sample arrives in a Laboratory receipt station, 8 minutes elapses before it is available to enter the Laboratory. The carrier is put back in queue in ASX-SMPLR-00047 or ASX-SMPLR-00034.
- The number of carriers stored in queue should not be a constraint.

- Once all of the bottles for a sampling event have arrived and are available to enter the Lab, the sequence as specified in the flat file can commence.

Samples can come in as they are available, meaning that all bottles from one sampling event do not need to arrive before bottles from another sampling event can arrive. Sampling is performed utilizing the same priority that samples are given in the Lab (i.e., sample hold points have a higher priority). All samples processed in the Laboratory, except for equipment calibration samples, utilize the ASX system.

5.1.6 RAM Data

The reliability, availability, and maintainability (RAM) data used in the Laboratory OR Model are displayed in Appendix D for Section 5.1.

5.1.7 Future Work

The BARD and any affected models will be updated upon the release of the ISARD, Rev 3.

5.1.8 References

24590-LAB-3YD-AHL-00001, Rev 2, *System Description for the Analytical Hotcell Laboratory Equipment (AHL).*

24590-LAB-3YD-ARL-00001, Rev 2, *System Description for the Analytical Radiological Laboratory Equipment (ARL).*

24590-WTP-3YD-ASX-00001, Rev 1, *System Description for the Autosampling System (ASX).*

24590-QL-HC4-HAHH-00001-12-00001, Rev G, *Assessment - WTP Autosampling System Reliability Assessment.*

24590-WTP-PL-PR-01-004, Rev 3, *Analytical Laboratory Design Requirements: WTP Sampling and Analysis Plan.*

24590-WTP-PL-PR-04-0001, Rev 2, *Integrated Sampling and Analysis Requirements Document.*

24590-WTP-RPT-PET-10-024, *2010 WTP Operations Research Assessment.*

24590-WTP-RPT-PR-01-004, Rev 3, *Operations Research Model Requirements.*

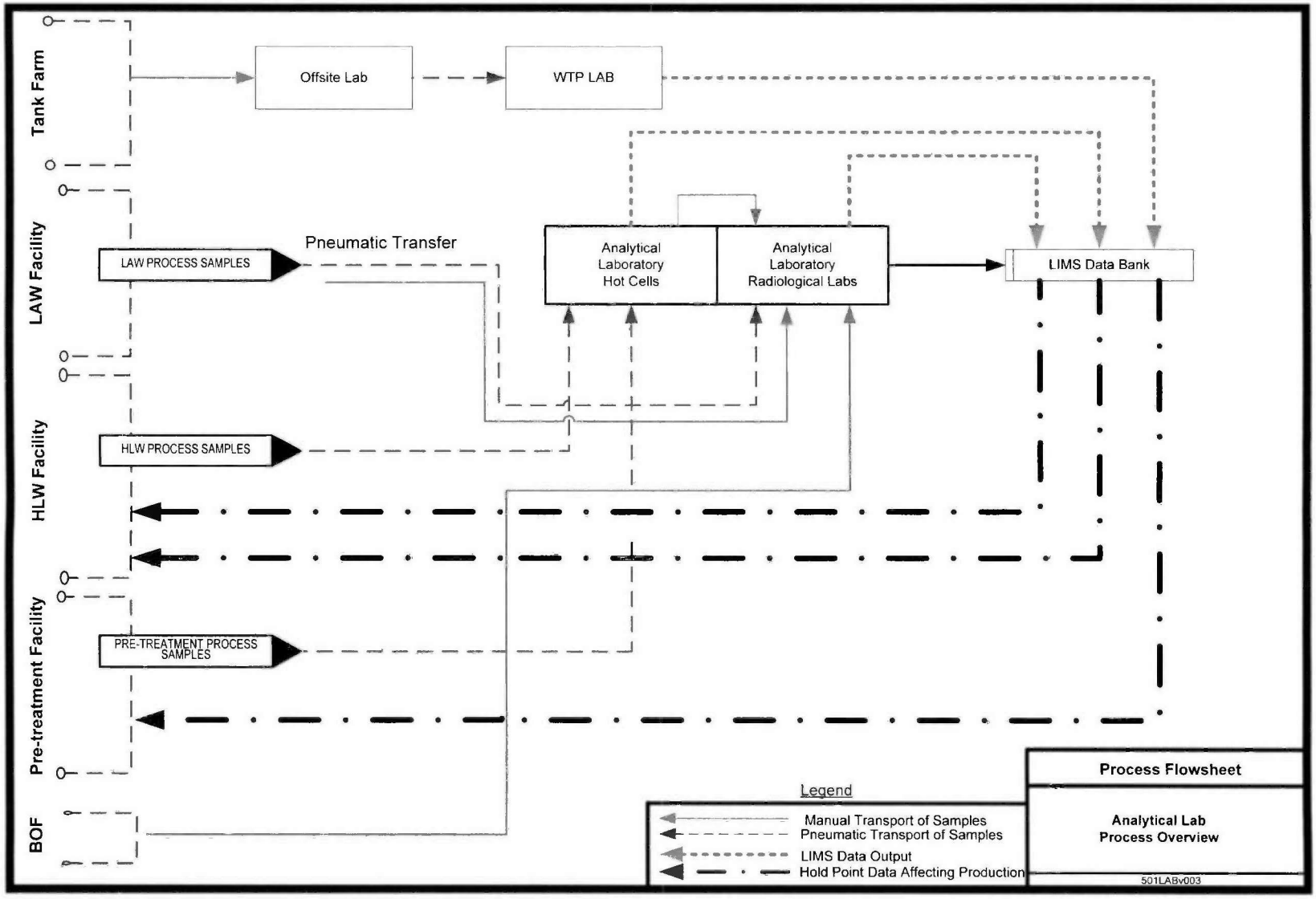
CCN 047010, *OEE Sheets For Analytical Laboratory*. 3 March 2003.

CCN 106633, *Analytical Laboratory Operations Research Model Requirements*. 7 January 2005.

CCN 211832, *Supersedes CCN 208986 - Final Version of the Lab Flat File for OR v6.0 Flowsheet Model.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

Figure 5.1-1 Analytical Laboratory Sample and Information Flowchart



6 Balance of Facilities

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6.1 System GFR: Glass Formers Reagent System

6.1.1 Function and Requirements

The Glass Formers Reagent System (GFR) is designed to store and process bulk glass forming chemicals (GFC) from offsite suppliers. Large quantities of glass forming chemicals are consumed in the process of vitrification to immobilize low-activity waste (LAW) and high-level waste (HLW), and the GFR system will supply glass formers to both the HLW and LAW Facilities. The GFR system consists of storage silos for all the GFCs, weigh hoppers, blending silos, mixers, and transporters. The glass former equipment vendor is required to design the GFR system to provide a system availability of 90 % (24590-BOF-3PS-G000-T0007, *Engineering Specification for the Glass Former Storage Facility*). The vendor-submitted glass former equipment reliability, availability, and maintainability data are documented in 24590-CM-POA-MH00-00001-07-00001, *List - System Failure Values RAM Data.*

The basic functions of the GFR system include receipt and handling of glass forming minerals, lag storage, weighing, blending, and transportation of glass former batches to the vitrification facilities. Additionally, the GFR system is responsible for transporting silica to the LAW inert fill hoppers, and supplying individual glass formers to the HLW mix using the trim hopper.

6.1.2 Process Description

The GFR system is responsible for receiving, storing, blending, and transporting GFCs to the vitrification facilities. There are 13 different GFCs that may be used to create a batch, which include silica, zinc oxide, titanium oxide, ferric oxide, zirconium silicate sand, lithium carbonate, boric acid, aluminum silicate, magnesium silicate, calcium silicate, sodium carbonate, borax, and sucrose. The handling and processing of GFR minerals are described in 24590-WTP-3YD-GFR-00001, *System Description for the WTP Glass Formers Reagent System (GFR)*, and depicted in 24590-CM-POA-MH00-00001-08-00005, *Drawing - Process Flow Diagram.*

Formulation of glass former batches is determined through sampling of the treated LAW or HLW waste to be vitrified. An algorithm optimizes the expected glass product based on concentrations of compounds in the waste.

Each glass former is stored in its own silo. All 13 silos are arranged into five systems, systems 100-500, where each system shares a weigh hopper and transporter. When a batch is requested, the silo will start filling the weigh hopper. The weigh hopper confirms that the correct amount of material has been transferred and delivers its contents into the transporter. After the inlet and vent valves on the transporter are closed, the vessel is pressurized, and the contents are pneumatically conveyed to the blending silo.

There are two blending silos in the GFR system. One is dedicated to blending the LAW glass former batch, and the other is for HLW glass former batch. The blending silos receive GFCs from all the system transporters, and blend the glass formers. After blending, the batch is dropped into the LAW or HLW transporter. The inlet and vent valves are closed, and the contents are pneumatically conveyed to the appropriate mixer.

There are a total of four mixers; two are located in the HLW Facility, and two are located in the LAW Facility. During the mixing, deionized water is added for dust control. When mixing is complete, the batch is transferred into the respective melter feed preparation vessel (MFPV) at a controlled rate using a screw conveyor and a rotary valve.

In the case of HLW, after GFCs have been mixed with the waste in the MFPV, another sample is taken to ensure the correct glass formers have been added. If the batch is out of specification, then it may be trimmed using the HLW trim hopper to add glass formers to the batch. This process is only available to the HLW Facility.

The inert fill day hoppers, located in the LAW Facility, receive silica from the GFR system. Silica provides the inert fill material required to fill void space in the ILAW containers. This process is only available to the LAW Facility.

6.1.3 Glass Former Storage Facility

The basis for the GFR system is to receive and store glass formers, and deliver GFC blends based on recipes generated from samplings of the treated waste. From one sample of waste, four batches of glass formers for the LAW Facility may be made, but only one batch may be made from a sample of HLW. Glass former batch preparation time must be small enough so there is no hold up in the melter feed process.

6.1.3.1 Glass Former Reagent System Storage Silos

All the glass formers are stored in 13 storage silos, and the silos are sized to hold a 10-day supply of the GFCs. Glass formers are delivered from an offsite supplier in trucks with onboard truck compressors. Sets of silos are grouped into five systems based on similar maximum batch sizes, and each system of silos share weigh hoppers and transporters. The only silo that does not share a weigh hopper and transporter is the silica silo. Each silo has filters mounted on top for dust control and a conveyor at the bottom to transfer material into one of five weigh hoppers.

Plant Item Number	System	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-TK-00001	100	Silica silo	8500 ft^3	5.7
GFR-TK-00008	200	Aluminum silicate silo	2175 ft^3	5.88
GFR-TK-00007	200	Boric acid silo	3000 ft^3	10.2
GFR-TK-00010	200	Calcium silicate silo	3000 ft^3	9
GFR-TK-00011	200	Sucrose silo	1800 ft^3	7.2
GFR-TK-00006	300	Lithium carbonate silo	2500 ft^3	6
GFR-TK-00002	300	Zinc oxide silo	2500 ft^3	2.88
GFR-TK-00012	400	Sodium carbonate silo	1500 ft^3	7.62
GFR-TK-00028	400	Borax silo	2150 ft^3	9.18
GFR-TK-00004	500	Ferric oxide silo	1000 ft^3	0.72
GFR-TK-00003	500	Titanium dioxide silo	1000 ft^3	0.78
GFR-TK-00009	500	Magnesium silicate silo	1000 ft^3	3
GFR-TK-00005	500	Zirconium silicate sand silo	1000 ft^3	4.68

6.1.3.2 Glass Former Reagent System Weigh Hoppers

The weigh hoppers weigh GFCs for each batch and are sized based on the demand for batches from the silos and to optimize air usage. Load cells measure the weight of the glass former in the hopper. After the weight is confirmed, the material is transferred by gravity into the hopper's dedicated transporter. Weigh hoppers and transporters are not sized to weigh and transport the entire quantity of glass former required for the batch. Several transfers are required from the silo into the hopper and then into the transporter.

Plant Item Number	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-TK-00013	System 100 weigh hopper	10 ft^3	163.8
GFR-TK-00016	System 200 weigh hopper	10 ft^3	129
GFR-TK-00015	System 300 weigh hopper	10 ft^3	51.6
GFR-TK-00018	System 400 weigh hopper	10 ft^3	136.8
GFR-TK-00014	System 500 weigh hopper	3 ft^3	61.2

6.1.3.3 Glass Former Reagent System Transporters

Transporters are sized in the same manner as the weigh hoppers, so all the corresponding weigh hoppers and transporters have the same volume. After the material is gravity-fed into the transporter, the inlet and vent valves are closed. The transporter is compressed with air and the contents are pneumatically transferred to the blending silo. Transporters are sized to efficiently use compressed air, so several transfers from the transporter to the blender may be necessary to convey the entire amount of material required for the batch.

Plant Item Number	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-VSL-00002	System 100 transporter	10 ft^3	2.5
GFR-VSL-00003	System 200 transporter	10 ft^3	2.9
GFR-VSL-00004	System 300 transporter	10 ft^3	2.5
GFR-VSL-00005	System 400 transporter	10 ft^3	2.5
GFR-VSL-00006	System 500 transporter	3 ft^3	0.7

6.1.3.4 Glass Former Reagent System Blending Silos

Glass formers are received into one of two blending silos. The HLW and LAW Facilities both have a dedicated blending silo. The blending silos are sized to contain the maximum batch that will be fed plus a 10 % contingency volume. An additional 40 % headspace is required to allow the blending to take place. Air filters are mounted on top of the silo for dust control. Once the glass formers for the batch are received, the load cells in the blender ensure that the correct amount of glass formers have been received. If the overall weight of the batch is not within 2 % of the desired weight, or if the weight of a single component is not within 0.5 %, the batch may be rejected and sent to the reject hopper. Blending is

carried out pneumatically, and after blending, the mixed GFCs are gravity-fed into the blended glass former transporters.

Plant Item Number	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-TK-00019	LAW blending hopper	470 ft^3	252.7
GFR-TK-00021	HLW blending hopper	320 ft^3	205.8

6.1.3.5 Glass Former Reagent System Blender Transporters

Once the mixed GFCs are fed into the blended glass former transporter, the inlet and vent valves are closed. The transporter is compressed with air and the contents are pneumatically transferred to the HLW or LAW glass former mixers. Transporters are sized to optimize compressed air usage, so they will not be able to transfer an entire batch of GFCs at one time. Several transfers from the blender to the transporter, and from the transporter to the mixer, may be required.

Plant Item Number	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-VSL-00007	LAW transporter	80 ft^3	7.8
GFR-VSL-00008	HLW transporter	80 ft^3	5.3

6.1.3.6 Glass Former Reagent System Mixers

There are four glass former mixers, two for each vitrification facility, and they are located in their respective vitrification building. The mixers are sized to accommodate the maximum batch size plus a 10 % contingency volume. Filters are mounted on the mixers for dust mitigation. GFCs are received from the HLW or LAW blending hoppers, and load cells in the mixer ensure that all the batch material has been transferred into the mixer. The mixing process takes 20 min to complete. Four wt % (LAW) or five wt % (HLW) demineralized water is added throughout the mixing process for dust mitigation. Once the batch is homogenized, it is fed to the respective MFPV to be mixed with treated LAW or HLW waste.

Plant Item Number	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-TK-00022	LAW glass former mixer 1	470 ft^3	6.5
GFR-TK-00023	LAW glass former mixer 2	470 ft^3	6.5
GFR-TK-00025	HLW glass former mixer 1	320 ft^3	4.5
GFR-TK-00031	HLW glass former mixer 2	320 ft^3	4.5

6.1.3.7 Glass Former Reagent System Trim Hopper

In the HLW Facility, after a batch of GFCs has been completed and mixed with the HLW, another sample will be taken and analyzed. It may be determined that the GFC batch needs to be altered to optimize the glass output. If this is the case, the trim hopper may be used to add between 100 and 1000 lb of any individual glass former in order to adjust the mixture. System transporters receive the glass formers from

the weigh hoppers and transfer them directly to the trimmer, where they are weighed and transferred to the HLW Facility.

Plant Item Number	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-TK-00029	Trim hopper	10 ft^3	178.8
GFR-VSL-00009	Trim transporter	10 ft^3	1.818

6.1.3.8 Glass Former Reagent System Inert Fill Day Hoppers

Under normal operations, the LAW container will be filled with immobilized low-activity waste (ILAW) glass to at least 90 % of the container volume. Otherwise, silica will be used to fill the free space to less than 10 %. This silica will be supplied by two inert fill day hoppers in the GFR. Each of the inert fill day hoppers is sized to provide inert fill for five ILAW containers per day. This process is only available to the LAW Facility.

Plant Item Number	Alternate Name	Capacity	Outlet Flow Rate (ft^3/min)
GFR-TK-00026	LAW inert fill hopper 1	43 ft^3	0.80
GFR-TK-00027	LAW inert fill hopper 2	43 ft^3	0.80

6.1.4 References

24590-BOF-3PS-G000-T0007, Rev 5, *Engineering Specification for the Glass Former Storage Facility.*

24590-WTP-3YD-GFR-00001, Rev 1, *System Description for the WTP Glass Formers Reagent System (GFR).*

24590-CM-POA-MH00-00001-07-00001, Rev 00D, *List - System Failure Values RAM Data.*

24590-CM-POA-MH00-00001-08-00005, Rev 00C, *Drawing - Process Flow Diagram.*

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6.2 Reagents Received at BOF for Use throughout the WTP (AFR, AMR, NAR, SHR, SPR, and STR)

6.2.1 Function and Requirements

The balance of facilities (BOF) receives, stores, dilutes, and distributes reagents for use within the WTP. The reagents include sodium hydroxide (NaOH, designated as SHR) at several concentrations; nitric acid (HNO_3, designated as NAR) at several concentrations; antifoam (designated as AFR); sodium permanganate ($NaMnO_4$, designated as SPR); and strontium nitrate ($Sr(NO_3)_2$, designated as STR). In addition, anhydrous ammonia (NH3, designated as AMR) is also presented.

The BOF receives sodium hydroxide, nitric acid, sodium permanganate, and strontium nitrate into the Wet Chemical Storage Facility (WCSF) for distribution to the Pretreatment (PT) Facility, High-Level Waste (HLW) Facility, and Low-Activity Waste (LAW) Facility. The BOF also receives diluents from the demineralized water system (DIW). Antifoam is delivered in drums directly to the PT Facility. The anhydrous ammonia reagent system (NH_3, designated as AMR) is another chemical reagent that is processed through WTP for use in both the LAW and HLW offgas systems. A summary of the molar concentrations by chemical reagent and by facility is provided in Table 6.2-1:

- The PT Facility receives: 19 M, 5 M, 2 M, 0.5 M, and 0.1 M sodium hydroxide; 5 M, 2 M, and 0.5 M nitric acid; 1 M sodium permanganate; 1 M strontium nitrate and antifoam.
- The HLW Facility receives: 5 M sodium hydroxide, 2 M nitric acid and anhydrous ammonia.
- The LAW Facility receives: 5 M sodium hydroxide and anhydrous ammonia.

6.2.2 Process Description

The facility users of each of the BOF process reagent systems (hereafter referred to as the System) are listed in Table 6.2-1. A brief description of each of these functional processes are also listed in the following sections. However, a more detailed description of reagents will be found in 24590-WTP-3YD-SHR-00001.

The System receives nitric acid, sodium hydroxide, sodium permanganate, and strontium nitrate bulk chemicals at BOF. The System receives diluents from the DIW system. Antifoam is delivered in drums directly to the PT Facility. Chemicals stored in BOF are new products, not waste.

The System stores both undiluted and diluted reagents. The System mixes reagents and diluents to achieve the desired concentrations. The System also distributes reagents to the PT, HLW, and LAW Facilities. The majority of the consumption is by users located in the PT Facility, with minor consumption by users located within the HLW and LAW Facilities.

The System is designed to contain most filling process accidents. The System also reports on selected system operational conditions for monitoring. Periodically, samples of reagents are taken for analysis to determine their conformance to specifications.

Below is a brief summary for each of the reagents specified in this section. For a more detailed explanation of the role of fresh reagents within the WTP, refer to respective system descriptions, i.e., *System Description for the WTP Reagents (SHR, NAR, AFR, SPR and STR)*, (24590-WTP-3YD-SHR-00001) and *System Description for the Ammonia Reagent System (AMR)*, (24590-WTP-3YD-AMR-00001).

6.2.2.1 Antifoam Reagent (AFR)

Drums of concentrated antifoaming reagent (AFR) are delivered directly to the antifoam reagent vessel (AFR-TK-00001) in the PT Facility. The reagent is diluted with demineralized water to a 3:1 water-to-antifoam ratio, agitated for homogeneity, and then transferred in batches to the specified vessels to reduce foaming caused by sparging. Antifoam is also transferred to the ultrafiltration feed preparation (UFP) vessels as needed to reduce foaming. The target concentration of antifoam in the waste feed evaporation process (FEP) and treated LAW evaporation process is 500 ppm. The target concentration for UFP vessels is 350 ppm (SCT-M0SRLE60-00-99-00009). The antifoam and caustic delivery systems to non-Newtonian vessels provide the means for controlling waste characteristics within the range for acceptable pulse jet mixer (PJM) and sparger performance. In addition, there also exists the ability to add additional AFR capability in HLW should the need arise. AFR delivery systems are to be continually operable in order to provide AFR as needed to the applicable vessels.

6.2.2.2 Ammonia Reagent (AMR)

The purpose of the AMR system is to receive and store liquid anhydrous ammonia, vaporize liquid anhydrous ammonia, and transfer gaseous anhydrous ammonia to the LAW secondary offgas/vessel vent process system (LVP) and the HLW melter offgas treatment process system (HOP) (24590-WTP-3YD-AMR-00001). To perform these functions, the system consists of two ammonia storage vessels (AMR-VSL-00003/4) and two ammonia vaporizers (AMR-VPR-00002/3). The ammonia is vaporized by heaters, which maintains a sufficient amount of ammonia vapor pressure for normal demands on the HOP and LVP systems. The AMR is used by these systems in the selective catalytic reduction units to convert oxides of nitrogen from the melter offgas into nitrogen and water vapor before their release into the environment. The capacity of the two vessels which store the anhydrous ammonia is provided in Appendix B with an estimated use rate of 860 gal/day (24590-WTP-3YD-AMR-00001).

6.2.2.3 Nitric Acid Reagent (NAR)

The BOF receives 12.2 M nitric acid from a delivery truck. The 12.2 M nitric acid is stored in the nitric acid storage vessel (NAR-TK-00004). The 12.2 M nitric acid is diluted to a range of different concentrations ranging from 8 M to 5 M, 2 M, and 0.5 M solutions for distribution to the end users. The vent from the 12.2 M nitric acid tank will pass through a scrubber to reduce NO_X emissions. A 2M nitric acid solution is also stored in the BOF in tank (NAR-TK-00006). A typical volume of the 12.2 M nitric acid solution stored in the WCSF can be found in Appendix B.

6.2.2.4 Sodium Hydroxide Reagent (SHR)

The BOF receives 19 M sodium hydroxide from a delivery truck and stores it in the 19 M sodium hydroxide storage vessel (SHR-TK-00006). The 19 M sodium hydroxide is diluted to 5 M, 2 M, 0.5 M, and 0.1 M solutions for distribution to the end users. The BOF Wet Chemical Storage also includes tanks containing 5 M (SHR-TK-00005), 2 M (SHR-TK-00004), and 0.5 M sodium hydroxide (SHR-TK-00005). The dilution and distribution are controlled by the process control system (PCJ). At 19 M, sodium hydroxide freezes at 54 °F, and is difficult to pump below 85 °F. Therefore, the 19 M sodium hydroxide tank is controlled to a minimum temperature of about 86 °F. Sodium hydroxide is used in the PT, LAW, and HLW Facilities for various functions, but is primarily used for leaching in UFP and regeneration of ion exchange materials, including pH adjustments of solutions and waste streams.

6.2.2.5 Sodium Permanganate Reagent

The BOF (SPR-TK-00001) receives and stores 40 wt% sodium permanganate from a delivery truck and it is diluted to a 1 M concentration by the addition of demineralized water through the 1 M sodium permanganate inline mixer (SPR-MXR-00001). This 1 M solution is added to Envelope C feeds before ultrafiltration to precipitate transuranic elements (TRU) from the solution, and to Envelope D wastes for oxidative leaching of chromium. It is batched by direct distribution to the ultrafiltration feed preparation vessels (UFP-VSL-00001A/B). See Appendix B for vessel volumes for SPR-TK-00001.

6.2.2.6 Strontium Nitrate Reagent

The BOF (STR-TK-00001) receives and stores 40 wt% strontium nitrate from a delivery truck and it is diluted to a 1 M concentration by the addition of demineralized water though the 1 M strontium nitrate inline mixer (STR-MXR-00002). This 1 M solution is added to Envelope C feeds before ultrafiltration to precipitate transuranic elements (TRU) from the solution, and to Envelope D wastes for oxidative leaching of chromium. It is batched by direct distribution to the ultrafiltration feed preparation vessels (UFP-VSL-00001A/B). Again, see Appendix B for vessel volumes for STR-TK-00001.

6.2.3 Sodium Hydroxide Impurities

Sodium hydroxide (NaOH) is used in various places in the process (e.g., pretreatment and the caustic scrubbers). The primary impurity of concern is chloride. The sodium hydroxide grade to be used has not been decided. Standard bulk NaOH contains about 1 to 2 wt % NaCl. However, "Rayon" grade can be <0.01 wt % NaCl.

6.2.4 References

24590-WTP-3YD-AMR-00001, Rev 2, *System Description for the Ammonia Reagent System (AMR).*

24590-WTP-3YD-SHR-00001, Rev 2, *System Description for the WTP Reagents (SHR, NAR, AFR, SPR and STR).*

Occidental Chemical Corp. 2000. *OxyChem Caustic Soda Handbook.*

SCT-M0SRLE60-00-99-00009, Rev 00A, *Ultrafiltration Process (UFP) Caustic Leaching Antifoam Performance.*

Table 6.2-1 Concentrations of WTP Reagents Assigned to Designated User Facilities

Facility/Reagent	WTP[1] Designation	BOF	PTF	HLW	LAW	Process Functions
19M NaOH	SHR	X	X			Receive reagent from tanker Store reagent at BOF Transfer to users (PT)
Contaminated[2] 19M NaOH	SHR		X			Receive reagent from FFTF Store reagent at PT
5M NaOH	SHR	X	X	X	X	Receive demineralized water to dilute to 5 M NaOH (BOF) Mix, store reagent BOF Transfer to users (HLW, LAW and PT)
2M NaOH	SHR	X	X			Receive demineralized water to dilute to 2 M NaOH (BOF) Mix, store reagent BOF Transfer to users (PT)
0.5MNaOH	SHR	X	X			Receive demineralized water to dilute to 0.25 M NaOH (BOF) Mix, store reagent BOF Transfer to users (PT)
0.1M NaOH	SHR	X	X			Receive demineralized water to dilute to 0.1 M NaOH (BOF) Mix, store reagent BOF Transfer to users (PT)
12.2M HNO3	NAR	X				Receive reagent (BOF) Mix, store reagent (BOF) Transfer to users (BOF)
5M to 8M HNO3	NAR	X	X			Receive demineralized water to dilute to 5-8 M (BOF) Mix, store reagent BOF Transfer to users (PT, HLW)

Table 6.2-1 Concentrations of WTP Reagents Assigned to Designated User Facilities

Facility/Reagent	WTP[1] Designation	BOF	PTF	HLW	LAW	Process Functions
2M HNO3	NAR	X	X			Receive demineralized water to dilute to 2 M (BOF) Mix, store reagent BOF Transfer to users (PT, HLW))
0.5M HNO3	NAR	X	X	X		Receive demineralized water to dilute to 0.5 M (BOF) Mix reagent BOF Transfer to users (PT)
Antifoam Reagent	AFR		X			Receive, mix, reagent PT Store reagent in drums and in PT tank
40 wt% NaMnO4	SPR	X				
1M NaMnO4	SPR	X	X			Receive reagent (BOF) Store reagent (BOF) Transfer to users (PT)
40 wt% Sr(NO3)2	STR	X				
1M Sr(NO3)2	STR	X	X			Receive reagent (BOF) Store reagent (BOF) Transfer to users (PT)
NH3 (Anhydrous)[3]	AMR	X		X	X	Receive reagent from tanker Store reagent near BOF Transfer to users (HLW, LAW)

1. 24590-WTP-3YD-SHR-00001
2. FFTF
3. 24590-WTP-3YD-AMR-00001

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6.3 System CHW: Chilled Water

6.3.1 Function and Requirements

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) chilled water system (CHW) provides a continuous supply of primary chilled water at a target temperature of 41 °F with a maximum temperature of 50 °F. The system will provide a nominal pressure of 65 psig at the BOF battery limit. The system will be closed loop direct return and will use a primary and secondary pumping scheme.

6.3.2 Process Description

The CHW process flow is shown in *P&ID, BOF Chilled Water System Yard Distribution Piping* (24590-BOF-M6-CHW-00001001), *P&ID - BOF Chilled Water System CHW-PMP-00008A/B and CHW-PMP-00012A/B* (24590-BOF-M6-CHW-00001002), and *P&ID - BOF Chilled Water System CHW-PMP-00010A/B and CHW-PMP-00011A/B* (24590-BOF-M6-CHW-00001003). The BOF CHW supplies chilled water to the cooling coils of air-handling units throughout the site, including the High-Level Waste (HLW) and Low-Activity Waste (LAW) Facilities, and the Analytical Laboratory (Lab). Chilled water distribution in these facilities is given in their respective P&IDs, such as 24590-HLW-M6-CHW-00001001 for the HLW Facility. The system also supplies chilled water to primary-secondary heat exchangers in both the Pretreatment (PT) and LAW Facilities, and to the air compressors and dryers in the HLW and LAW Facilities. Chilled water for other uses in the PT Facility is supplied by a separate and dedicated PT chiller plant (24590-PTF-3YD-CHW-00001). Additional discussion on the CHW can be found in 24590-WTP-3YD-CHW-00001, *System Description for LAB, BOF, LAW, HLW, and BOF Supplied PTF Chilled Water System (CHW).*

BOF CHW consists of six chillers (two sets of three chillers in parallel), three constant speed pumps (two operating, one spare), expansion vessel, chemical feed vessel, air separator, piping, valves, instruments, and controls. The return loop will be used to meet the cooling requirements for the air compressors. Each chiller consists of an evaporator section, a condenser section, a centrifugal type refrigerant compressor, and controls. The chillers have individual controls, constant speed drives, and modulating inlet vanes for capacity control.

To avoid cross-contamination, the process area CHW users are on a closed secondary loop separated from the BOF primary loop by a plate-and-frame heat exchanger. The primary BOF side pressure will maintain a higher pressure than the process secondary side. The major users of process chilled water in the PT Facility are HLW lag storage and feed blending process system (HLP), ultrafiltration process system (UFP), and cesium nitric acid recovery process system (CNP). In the LAW Facility the major users are LAW primary offgas process system (LOP) and LAW secondary offgas/vessel vent process system (LVP). The closed secondary loop return for PT Facility only will be monitored for detecting any increase in radiation level due to equipment failure. The process service water system (PSW) will be used to charge the primary chilled water system and for make-up. Demineralized water will be used to charge the secondary chilled water system and for make-up.

6.3.3 References

24590-WTP-3YD-CHW-00001, Rev 2, *System Description for LAB, BOF, LAW, HLW, AND BOF Supplied PTF Chilled Water System (CHW).*

24590-BOF-M6-CHW-00001001, Rev 0, *P&ID, BOF Chilled Water System Yard Distribution Piping.*

24590-BOF-M6-CHW-00001002, Rev 0, *P&ID - BOF Chilled Water System CHW-PMP-00008A/B & CHW-PMP-00012A/B.*

24590-BOF-M6-CHW-00001003, Rev 0, *P&ID - BOF Chilled Water System CHW-PMP-00010A/B and CHW-PMP-00011A/B.*

24590-PTF-3YD-CHW-00001, Rev 0, *System Description for Pretreatment Facility Dedicated Chilled Water System (CHW) and Plant Cooling Water System (PCW).*

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6.4 System PCW: Plant Cooling Water

6.4.1 Function and Requirements

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) plant cooling water system (PCW) provides a continuous supply of plant cooling water that will range from a minimum temperature of 57 °F to a maximum of 77 °F. The pressure of the primary system is nominally 65 psig. The system is configured with the primary loop being an open design. Any secondary pressure loop will always operate at a lower pressure to mitigate any suction back into the primary loop system.

6.4.2 Process Description

The PCW supplies cooling water to the air and chiller compressors, steam plant, and process areas. Plant cooling water in the Pretreatment (PT) Facility is used for the following systems: waste feed evaporation process (FEP), treated low-activity waste (LAW) evaporation process (TLP), cesium nitric acid recovery process (CNP), and pretreatment vessel vent process (PVP). Cooling water for the High-Level Waste (HLW) Facility is used for the following systems: HLW canister decontamination handling (HDH) (24590-HLW-M6-HDH-20002), HLW melter feed process (HFP), HLW melter process (HMP), and HLW melter offgas treatment process (HOP). For the LAW Facility the major user is the LAW melter process system (LMP). The BOF plant cooling water process flow is depicted on *P&ID - BOF Plant Cooling Water System Cooling Tower - Distribution Piping* (24590-BOF-M6-PCW-00001001) and *P&ID - BOF Plant Cooling Water System Chiller Compressor Plant Distribution Piping* (24590-BOF-M6-PCW-00002001). Additional discussion on the PCW can be found in system description 24590-WTP-3YD-PCW-00001, *System Description for the WTP Plant Cooling Water Systems (PCW)*.

The multi-cell mechanical draft evaporative cooling tower will be used to exhaust waste heat to the atmosphere. The cooling tower includes a concrete cooling tower basin, a pump pit, and water distribution pumps. The BOF will provide plant cooling water at a temperature between 57 and 77 °F to the distribution system. The cooling tower facility operates continuously, providing plant cooling water during operation and during shutdown. Make-up water delivered to the cooling tower will be domestic water as supplied to the WTP in a single line that feeds into the cooling tower basin. A back-up source of water can be provided from a raw water inlet connection. A biocide (deposit control agent) and pH control agents will be fed to the cooling tower from the water treatment building through separate lines (tubing).

The process area plant cooling water users are on a closed loop from the cooling tower. The major users of process cooling water in the PT Facility are FEP, TLP, CNP, and PVP. For the HLW Facility they are HDH, HFP, HMP, and HOP. For the LAW Facility, the major user is LMP. The design includes plate and frame heat exchangers to separate the process cooling water from the cooling tower water, and supply pumps expansion tanks and air separators. The closed loop supply return will be monitored for indication of high radiation due to equipment failure. Demineralized water will be used to charge the system and for make-up.

6.4.3 References

24590-BOF-M6-PCW-00001001, Rev 0, *P&ID BOF Plant Cooling Water System Cooling Tower - Distribution Piping.*

24590-BOF-M6-PCW-00002001, Rev 0, *P&ID BOF Plant Cooling Water System Chiller Compressor Plant Distribution Piping.*

24590-HLW-M6-HDH-20002, Rev 0, *P&ID - HLW Canister Decontamination Handling System HDH-HX-00002.*

24590-WTP-3YD-PCW-00001, Rev 2, *System Description for the WTP Plant Cooling Water System (PCW).*

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6.5 System LPS, HPS, SCW: Plant Steam

6.5.1 Function and Requirements

The high-pressure steam system (HPS) supplies steam to process equipment, ejectors for transfer of fluid waste. High-pressure steam is pressure-reduced to produce steam for the low-pressure steam system (LPS). The LPS system provides a continuous supply of steam for various users in the Pretreatment (PT) and process facilities. The steam condensate water system (SCW) will collect steam condensate from the steam users, treat the condensate, and feed the steam boilers as required. The Balance of Facilities (BOF) steam plant will supply high pressure steam to the site at a pressure of 135 psig and a temperature of 358 °F, specified in the *Basis of Design* (24590-WTP-DB-ENG-01-001).

6.5.2 Process Description

The origin and distribution of high-pressure steam from the BOF steam plant is depicted on *P&ID - BOF High Pressure Steam System Distribution Header* (24590-BOF-M6-HPS-00001001). The HPS consists of six fire tube boiler packages (five continuously operating at peak conditions and one in standby), blowdown packages, surface and bottom and steam/condensate chemical injection packages. All of these components are in the steam plant facility. An aboveground yard piping distribution network provides HPS to the user facilities. Predominant HPS utilization is by the following systems: waste feed evaporation (FEP), treated LAW evaporation process (TLP), and cesium nitric acid recovery process (CNP), all in the PT Facility. The HPS steam is used in the HLW Facility for process heating and transfer ejectors. The major low-pressure steam (LPS) users are systems FEP, TLP, and cesium nitric acid recovery process (CNP) in the PT Facility. The LPS system provides a continuous supply for users in the PT, LAW, and HLW Facilities and the Analytical Laboratory. Additional descriptions regarding this system and its configurations in other process facilities can be found in 24590-WTP-3YD-HPS-00001.

The steam condensate system collects condensate from the low-pressure users. It consists of collection/flash tanks, pumps, vent coolers, condensate surge tank, de-aerator feed pumps, oxygen scavenger injection package, and de-aerator package. The collected condensate is pumped back to the boilers for reuse. Demineralized water will be used to charge the system and used as a make-up source to the boiler feed water.

The HPS system does not use backup power. An electrical power failure shuts off all fuel, and requires operating personnel attention for a restart.

6.5.3 Ongoing Work and Potential Changes

In the PT Facility, a secondary steam generation and condensate recovery system is to be designed for the FEP, TLP and CNP evaporator system. This system will reduce the potential for contamination of the HPS system.

6.5.4 References

24590-BOF-M6-HPS-00001001, Rev 0, *P&ID - BOF High Pressure Steam System Distribution Header.*

24590-WTP-3YD-HPS-00001, Rev 1, *System Description for the Waste Treatment Plant High Pressure Steam (HPS), Low Pressure Steam (LPS) and Steam Condensate Water (SCW).*

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

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6.6 System PSA, ISA: Plant Air

6.6.1 Function and Requirements

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) Balance of Facilities (BOF) plant service air system (PSA) and the instrument service air system (ISA) are required to provide a continuous supply of clean, dry, and oil free air in the proper quantity and at the desired pressure to the following facilities: Pretreatment (PT) Facility, High-Level Waste (HLW) Facility, Low-Activity Waste (LAW) Facility, the Analytical Laboratory (Lab) buildings, and BOF. However, the BOF PSA system interfaces with but does not cover the safety-class plant service air system (SC PSA). The PSA system, at nominal, delivers 130 psig air at 60 °F at the battery limits of the facilities. When additional process air information is needed regarding specific process building facilities, system descriptions for all WTP facilities, then refer to 24590-WTP-3YD-PSA-00002.

The functions of the PSA system is to: draw air, condition air, separate condensation entrained within the air, store air, filter air, reduce pressure, distribute air, isolate or reduce flow and to report system conditions. Similarly, the functions of the ISA system are to: receive air, store air, reduce pressure, filter air, distribute air, isolate or reduce flow, and to report system conditions. The air from the BOF air system is the source of PSA as well as ISA within each of the process facilities. However, the distribution piping to each process facility does not have two separate pipelines, but one single source pipeline. The split of air distribution into two separate distribution lines, one for PSA and one for ISA, occurs inside the LAW and PT Facilities. HLW has only one distribution network designated ISA. Similarly, Lab has only one distribution network designated PSA.

Compressed air discharge is at a mean temperature of 60 °F, at a minimum dew point of −40 °F (ANSI/ISA-S7.0.01) and at a pressure between 90 and 150 psig (24590-WTP-3PS-JQ07-T00001). The ISA system branches selectively off various portions of the PSA system.

6.6.2 Process Description

The PSA system compressed air production is depicted with the following piping and instrumentation diagrams: 24590-BOF-M6-PSA-00001001, 24590-BOF-M6-PSA-00002001, 24590-BOF-M6-PSA-00003001, 24590-BOF-M6-PSA-00004001, 24590-BOF-M6-PSA-00005001, and 24590-BOF-M6-PSA-00006001.

The compressed air is generated via four 15,000 scfm (24590-CM-POA-MCCA-00001-03-15) centrifugal compressors and three 3350 scfm (24590-CM-POA-MCCA-00001-03-16) rotary screw compressors. Packaged oil-free centrifugal compressors serve as the base load units. Packaged oil-free rotary-screw compressors serve as trim units. All BOF PSA system compressors draw upon atmospheric air and exhaust into a common header (dryer inlet manifold) (24590-CM-POA-MCCA-00001-03-14, Rev 00C).

The PSA system has packaged heat-of-compression dryers. Each of the two dryers is equipped with an inlet manifold, a coalescing separator equipped with a dual drain trap, and twin desiccant towers. Upon exiting the dryer tower the plant air has reached its final dewpoint of −40 °F. Prior to leaving the dryer package, the air passes through an after-filter capable of removing 99.99 % of all particles three micrometers or larger.

The compressed dry air flows through the dryer's outlet manifold header to the receiver inlet piping. The two receivers serve as a reservoir to satisfy sudden or temporary heavy demand upon the PSA system.

The PSA system compressors are designed to operate unattended. Upon loss of power to the air compressors, isolation valves to non-critical PSA users automatically revert to a fail-safe condition.

6.6.3 Safety-Class Plant Service Air (SC PSA)

Hydrogen gas generated in process waste slurries by radiolysis or by thermolysis can rise through the waste and accumulate in the headspace of the process vessels. The PSA system is relied upon to mitigate a buildup of hydrogen gas in these vessels. Specifically, a forced purge supply of PSA is continuously introduced into the vessel headspace to maintain the hydrogen concentration at a level less than 25 % of the LFL (24590-PTF-3YD-PSA-00002).

Should the normal supply of PSA be disrupted for any reason, the SC PSA system will be relied upon to provide a backup supply of compressed air to perform this safety function. The PTF SC PSA provides two air trains (Train 'A' and Train 'B') (24590-PTF-M6-PSA-00045), with each train having sufficient capacity to meet 100 % of compressed air demand from the system. Each train consists of three 1,500 scfm rotary screw, oil-free, air-cooled compressors and a 12,400 gallon (24590-PTF-MVC-PSA-00002) air accumulator (receiver) vessel (PSA-VSL-000137). An emergency diesel generator (EDG) is assigned to each compressor train along with supporting electrical components to operate the sub-station.

6.6.4 References

24590-BOF-M6-PSA-00001001, Rev 0, *P&ID - BOF Plant Service Air System Yard Distribution Piping.*

24590-BOF-M6-PSA-00002001, Rev 0, *P&ID - BOF Plant Service Air System Centrifugal Compressors.*

24590-BOF-M6-PSA-00003001, Rev 0, *P&ID - BOF Plant Service Air System Rotary Screw Compressors.*

24590-BOF-M6-PSA-00004001, Rev 0, *P&ID - BOF Plant Service Air System, Heat-of-Compression Dryers.*

24590-BOF-M6-PSA-00005001, Rev 0, *P&ID - BOF Plant Service Air Receivers PSA-VSL-00004/5.*

24590-BOF-M6-PSA-00006001, Rev 0, *P&ID - BOF Plant Service Air System Yard Distribution Piping to BOF Facilities.*

24590-CM-POA-MCCA-00001-03-14, Rev 00C, *Data Sheet- Regenerative Desiccant Air Dryer Package.*

24590-CM-POA-MCCA-00001-03-15, Rev 00B, *Data Sheet-Centrifugal Air Compressor Package.*

24590-CM-POA-MCCA-00001-03-16, Rev 00C, *Data-Sheet-Rotary-Screw Air Compressor Package.*

24590-PTF-MVC-PSA-00002, Rev 00C, *PTF Sizing of PSA ITS Air Receivers (PSA-VSL-000137 and PSA-VSL-000138)*

24590-PTF-M6-PSA-0045, Rev 2, *P&ID - PTF Plant Service Air System PSA-VSL-00137/138*

24590-PTF-3YD-PSA-00002, Rev 1, *System Description for the Pretreatment Facility Plant Service Air for Important-to-Safety services During off Normal Operations*

24590-WTP-3PS-JQ07-T0001, Rev 3, *Engineering Specification for Instrumentation for Package Systems.*

24590-WTP-3YD-PSA-00002, Rev 0, *System Description for the Waste Treatment Plant Service Air (PSA) System.*

ANSI/ISA-S7.0.01, *Quality Standard for Instrument Air.*

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6.7 System PSW, DIW: Process Service and Demineralized Water

6.7.1 Function and Requirements

There are no primary chemical processes that occur in the Balance of Facilities (BOF) process service water system (PSW) and is viewed as utility. The WTP PSW system is used for operating and maintenance purposes. The BOF PSW system receives water from the Hanford potable water system. The water is stored and then redistributed to the Pretreatment (PT) Facility, Low-Activity Waste (LAW) Facility, High-Level Waste (HLW) Facility, chiller/compressor plant (CCP), and the demineralized water system (DIW) in the water treatment building (WTB). Stub-outs (only) are provided for the wet chemical storage facility (WCSF).

The PSW system performs the following functions: receive water, store PSW, condition water, distribute PSW, and provide information as to the status of PSW system conditions. The system stores PSW in tanks (PSW-TK-00002, PSW-TK-00003). The system filters water before distribution and chlorinates the water downstream of the distribution pumps to retard biological organism growth. Water to the DIW system is not chlorinated. The PSW system distributes water to the DIW system, other support facilities, and users in the process buildings. The PSW system reports data both locally to operators and remotely to the process control system (PCJ) through the Integrated Control Network. A simplified process flow diagram is provided in Figure 6.7-1.

The DIW system performs the following functions: produce ASTM DI 193 Type VI water, store demineralized water, treat DIW for biological growth, distribute demineralized water, and provide information as to the status of the DIW system conditions. The DIW system receives water from the PSW system, filters it down to 1 micron, produces demineralized water, and stores the DIW in tank DIW-TK-00004. The DIW distribution system pumps the water from tank DIW-TK-00004, filters it, treats it with ultraviolet light, and distributes the DIW to support facilities of the plant and other users in the process buildings. A simplified process flow diagram is also provided in Figure 6.7-2.

System requirements are derived from the following top-level Project documents and from calculations. The top-level documents are the *Statement of Work* (DOE 2000); *Operations Requirements Document* (ORD) (24590-WTP-RPT-OP-01-001); *Basis of Design* (24590-WTP-DB-ENG-01-001); *Safety Requirements Document Volume II* (24590-WTP-SRD-ESH-01-001-02); and the *Preliminary Documented Safety Analysis to Support Construction Authorization*; *Balance of Facility Specific Information* (24590-WTP-PSAR-ESH-01-002-05). The information presented in Table 6.7-1, Table 6.7-2, and Table 6.7-3 of this section has been arranged to convey the context of each requirement in terms of services provided, design life, contamination control, and access control. There are no important to safety (ITS) functions identified for the PSW systems.

6.7.2 Process Description

The PSW simplified flow diagram, from 24590-WTP-3YD-PSW-00001, Figure 1, page 2, shown in Figure 6.7-1 provides an overview of the WTP process service water systems. The BOF PSW system includes two storage tanks, pumps, filters, chlorination, and yard distribution piping up to the battery limits of the respective user facilities (PT, LAW, HLW, CCP, WCSF, and WTB). The interface (battery limit) between the BOF PSW system and the LAW and PT Facilities is nominally defined to be 5 ft outside the building. The interface (battery limit) between the BOF PSW system and HLW Facility is defined as 0.5 ft inside the HLW Facility building. Backflow preventers are installed downstream of the process Facility (HLW, LAW, PT) interface to prevent contamination of the originating BOF supply source.

Water to the PSW system is supplied by the DOE potable water system to PSW supply tank PSW-TK-00003. Three pumps, PSW-PMP-00005A/B/C, then transfer the water through filters to remove particles larger than 2 microns. Downstream of the filters, the water is routed to the DIW system and PSW feed tank, PSW-TK-00002. From the feed tank, PSW is pumped by PSW-PMP-00002A/B/C, chlorinated, and distributed to the HLW, LAW, and PT Facilities, the CCP, and the WCSF.

A portion of PSW is routed through the DIW system, which then treats PSW to produce DIW. This DIW is used for specialized WTP processes throughout the plant. The DIW is stored and then distributed to users at the PT Facility, LAW Facility, HLW Facility, the Analytical Laboratory (Lab), and various balance of facility (BOF) users. See Figure 6.7-2 for a simplified view of this DIW system.

The DIW system uses reverse osmosis to generate ASTM D1193, Type IV quality water. The demineralized water is routed through an ultraviolet sterilizer to control biological growth, then through a 1 micron filter prior to distribution to the other facilities. Additional information on the DIW system can be found in 24590-WTP-3YD-DIW-00001, *System Description for the Waste Treatment Plant Demineralized Water System (DIW).*

The piping and instrumentation diagram (P&ID) for the DIW system is given by 24590-BOF-M6-DIW-00001001. The BOF DIW storage tank DIW-TK-00004 has a capacity of 50,000 gal. It is field-fabricated from 304 stainless steel to API-650 and AWWA D100-96 standards with a vent, an overflow, level control instrumentation, and monitoring. Three distribution pumps are provided (DIW-PMP-00003 A/B/C) to pressurize the discharge line and supply DIW to the end users. The pumps are multistage vertical centrifugal type and are designed with one or two operating (depending upon demand) and one on standby. Each pump has a pump rate of 235 gpm.

6.7.3 References

24590-BOF-M6-DIW-00001001, Rev 0, *P&ID-BOF Demineralized Water System Storage and Distribution System.*

24590-BOF-M6C-PSW-00001, Rev 1, *Process Service Water Sizing Calculations.*

24590-WTP-3YD-DIW-00001, Rev 1, *System Description for the Waste Treatment Plant Demineralized Water System (DIW).*

24590-WTP-3YD-PSW-00001, Rev 2, *System Description for the Process Service Water System (PSW).*

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design.*

24590-WTP-PSAR-ESH-01-002-05, Rev 4i, *Preliminary Documented Safety Analysis to Support Construction Authorization; Balance of Facility Specific Information.*

24590-WTP-RPT-OP-01-001, Rev 3, *Operations Requirements Document.*

24590-WTP-SRD-ESH-01-001-02, Rev 5aa, *Safety Requirements Document Volume II.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA.

ASTM D1193, *Standard Specification for Reagent Water.*

API standard 650, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Tenth Edition, February 2002.*

AWWA 100-96, *Sizing of Ground-Supported Standpipes and Reservoirs.*

Figure 6.7-1 PSW Simplified Flow Diagram

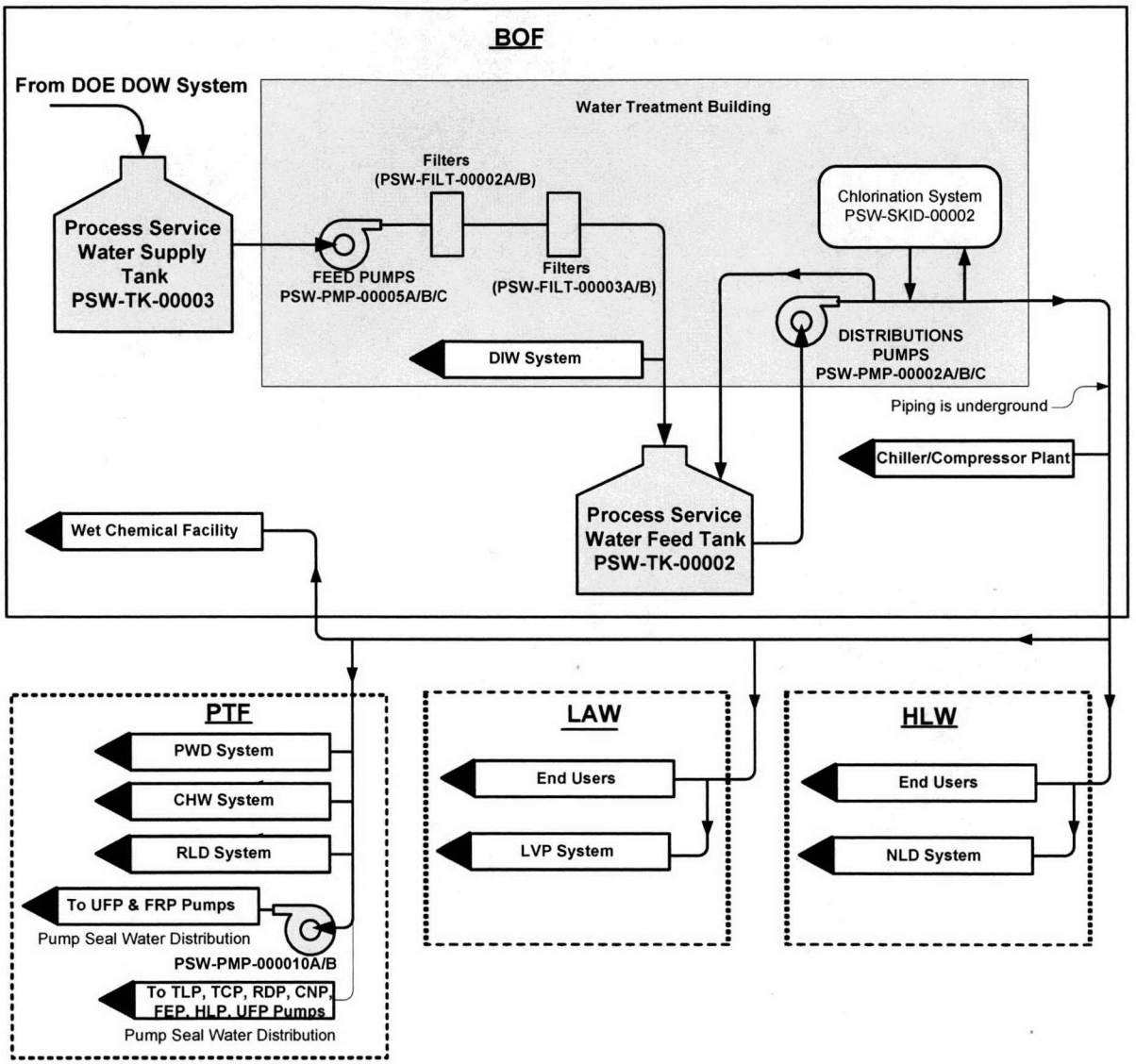

Figure 6.7-2 Demineralized Water (DIW) System - Simplified Diagram

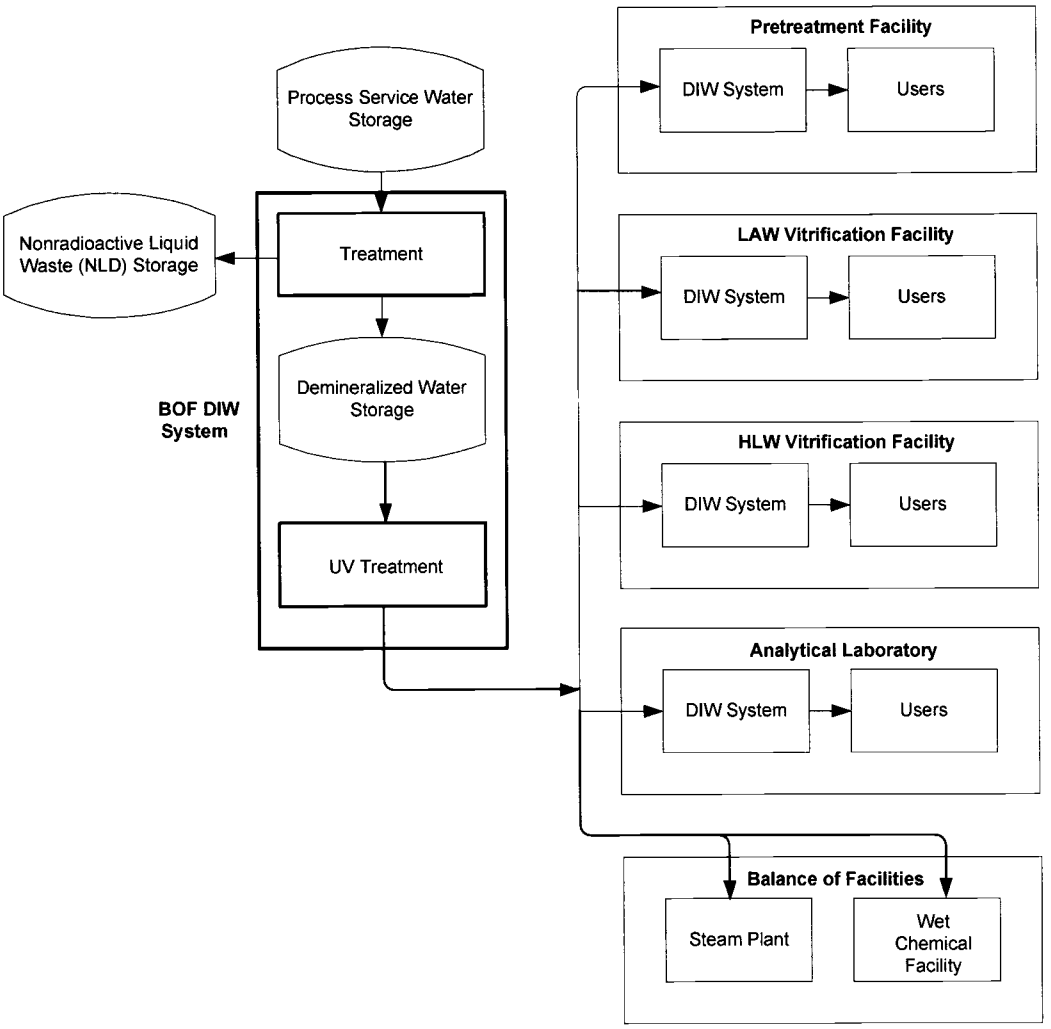

Table 6.7-1 Process Service Water (PSW) - Requirements

Function	Description	Reference
Service	All subsystems and components for the PSW are designated as non-important to safety (non-ITS) except for the controls on all PT actuated (on-off) valves which are designated additional protection class.	
Input (Supply)		
	Potable water provided by DOE shall be used to make process water.	Section 6.4, *Basis of Design* 24590-WTP-DB-ENG-01-001
	To the maximum extent feasible, the WTP facilities shall increase their dependence on water that is collected, used, purified, and reused onsite.	Section 14.14.2, *Basis of Design*
	Water usage shall be reduced by incorporating efficiency and water conservation into process water needs.	Section 14.14.2, *Basis of Design*
Output		
	Chloride free water must be used for flushing and hydrotesting stainless steel piping and equipment to prevent stress corrosion cracking of the stainless steel material. Note that process water and potable water contain chlorides.	Section Appendix H 3.7, *Safety Requirements Document,* 24590-WTP-SRD-ESH-01-001-02
	Process water shall be provided at ambient temperature and a pressure of 87psig at 688 ft elevation.	Section 6.4, *Basis of Design*
	A flow rate of at least 400 US gallons per minute (gpm) shall be provided by the BOF PSW system.	Section 7.1, *Process Service Water Sizing Calculation,* 24590-BOF-M6C-PSW-00001
	A flow rate of at least 100 US gallons per minute (gpm) shall be available to the HLW Facility from the BOF PSW system.	Section 7.1, *Process Service Water Sizing Calculation,* 24590-BOF-M6C-PSW-00001
	A flow rate of at least 8.8 US gallons per minute (gpm) shall be available to the LAW Facility from the BOF PSW system.	Section 7.1, *Process Service Water Sizing Calculation, Rev B,* 24590-BOF-M6C-PSW-00001
	A flow rate of at least 10 US gallons per minute (gpm) shall be available to the PT Facility from the BOF PSW system.	Section 7.1, *Process Service Water Sizing Calculation,* 24590-BOF-M6C-PSW-00001
	Process water shall be free of suspended solids (not untreated river water).	Section 6.4, *Basis of Design*

Table 6.7-2 Process Service Water (PSW) - Requirements

Function	Description	Reference
Reliability, Availability, and Maintainability Factors	The underground portion of the piping shall be below 30 in. (only for potable water) minimum to the top of the pipe.	Section 10.1.5.7, *Basis of Design*
	Electrical heat tracing (freeze protection) shall be provided for liquid filled piping and instrument sensing lines that are subject to freezing.	Section 16.5, *Operations Requirements Document*
	The transfer lines from the facility to the external storage tanks and other onsite facilities may be buried to prevent freezing. Portions of lines exposed to ambient conditions will be freeze protected.	*Balance of Facility Specific Information,* 24590-WTP-PSAR-ESH-01-002-05
	Heat tracing actuation temperature shall be determined based on the fluid properties and the pipe insulation characteristics, but will normally actuate when temperatures reach freezing.	Section 16.5, *Operations Requirements Document*
	The system shall be designed to allow partial outages and preclude total facility outages during maintenance.	Section 14.1, *Operations Requirements Document*
	Modularization of systems and components shall be provided to minimize maintenance time.	Section 7.4, *Operations Requirements Document*
	Where practicable, the design shall include modular equipment to expedite repairs replacement and maintenance activities.	Section 7.4, *Operations Requirements Document*
System Configuration		
	The (PSW) "processes performed at the water treatment building and storage tanks include: Treatment and distribution of process service water."	*Preliminary Documented Safety Analysis to Support Construction Authorization; Balance of Facility Specific Information* (listed in reference section)

Table 6.7-3 Process Service Water (PSW) - Requirements

Function	Description	Reference
Design Life	The system shall have a 40 year operating life.	Section C.7(a)(1), *DOE Statement of Work*, DE-AC27-01RV14136
	A means of breaking a vacuum shall be provided to allow gravity liquid draining.	Section 7.1, *Operations Requirements Document*
	Metallic piping fittings that are within the zone of influence of the cathodic protection system and may be susceptible to stray current corrosion shall be protected by bonding them to the protected pipe.	Section 8.9, *Basis of Design*
Design Standards		
	Water tanks for storage shall be designed in accordance with AWWA-D100, *Welded Steel Tanks for Water Storage*.	Section 11.7.1, *Basis of Design*
Fabrication and Testing		
	Flushing and hydrotest water shall be drained and not be left standing in the pipe after the completion of testing.	Section Appendix H 3.7, *Safety Requirements Document*, Appendix H
Contamination Control		
	PSW system connections to the process shall have properly engineered devices such as air gaps or adequate backflow preventers to prevent or mitigate cross-contamination.	Section 7.1, *Operations Requirements Document*
	Potential for unplanned siphoning or backflow shall be considered in the design.	Section 7.1, *Operations Requirements Document*

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6.8 System MVE and LVE: Medium-Voltage Electrical and Low-Voltage Electrical

6.8.1 Function and Requirements

The Balance of Facilities (BOF) Medium Voltage Electrical (13.8/4.16 Kv) System (MVE) and Low Voltage Electrical (480/208/120 V) System (LVE) use provided electricity and adjust and distribute that electricity as needed. Electricity is supplied by the Office of River Protection (ORP) in accordance with *ICD 11-Interface Control Document for Electricity* (24590-WTP-ICD-MG-01-011). The BOF MVE system provides medium-voltage power to Pretreatment Facility, Low-Activity Waste (LAW) Facility, High-Level Waste (HLW) Facility, the Analytical Laboratory, and a number of BOF systems, including the BOF LVE system. The BOF LVE system provides low-voltage power to BOF load centers, motor control centers, and electrical panels.

The MVE system delivers 13.8 and 4.16-kV electricity, and the LVE system delivers 480-V and 208/120 Vac electricity.

In the event of a loss of offsite power (LOOP), the standby diesel generator (SDG) will initiate and supply electrical power. The main SDG function is to supply ac power to select loads related to LAW and HLW melter plant cooling water system, LAW melter pour cave cooling, LAW C5 exhaust fans, non-safety uninterruptible power supply in HLW and LAW, defined lighting loads in HLW and LAW, and to defined BOF loads in Main Switchgear Building (Bldg 87) and the SDG auxiliary loads in the event of loss of normal offsite power.

On loss of normal offsite power, the SDG automatically starts, accelerates to rated speed, and reaches rated voltage within a short time after receiving a start signal. This short time can be around 60 sec. A loss of normal offsite power will result in a loss of voltage to standby switchgear busses MVE-SWGR-87003A and MVE-SWGR-87003B.

The engine generator, MVE-DG-89014, is diesel engine-driven with 13.8 kV, 3-phase, 60 Hz, 1800 rpm, synchronous generator with brushless exciter, with a nominal continuous duty of 2813 kVA at 0.8 PF (2250 kW), and standby duty of 3375 kVA at 0.8 PF (2700 kW). In standby duty, operation of the generator is limited to 2 hr in a 24-hr period (Section 6.4, 24590-WTP-3YD-MVE-00001). De-rated for the worst site conditions, the genset is limited to 1893 kW of continuous output. Refer to 24590-BOF-E1C-MVE-00004.

Emergency diesel generators that support safety systems are required to run continuously until the loss of offsite power is restored. For a loss of the normal power supply, each EDG will automatically start and, following a pre-designated time interval, and will begin to serve its associated loads automatically (Section 2.8.3.11 of the General Information Volume of the PDSA, 24590-WTP-PSAR-ESH-01-002-01). Additional information can be found in 24590-WTP-3PS-MGEN-T0005, Rev 00D.

6.8.2 Process Description

The BOF, MVE, and LVE systems are depicted on the following single-line diagrams.

- *Switchgear Building 480V Distribution Panel LVE-PNL-87001 and 87001A/B Single Line Diagram* (24590-B87-E1-LVE-00001)
- *Overall Facilities Main Single Line Diagram* (24590-BOF-E1-MVE-00001)

The Hanford Site A-6 substation provides 13.8 kV power to the BOF MVE system at the MVE-SWGR-87001A/B, MVE-SWGR-87002A/B, and MVE-SWGR-87003A/B switchgears in BOF Building 87 for distribution, directly and indirectly, to the WTP facilities, as illustrated in Figure 6.8.1.

6.8.3 References

24590-B87-E1-LVE-00001, Rev 5, *Switchgear Building 480V Distribution Panel LVE-PNL-87001 and 87001A/B Single Line Diagram.*

24590-BOF-E1-MVE-00001, Rev 6, *Overall Facilities Main Single Line Diagram.*

24590-BOF-E1-MVE-00004, Rev 7, *Switchgear Building 13.8 kV Switchgear MVE-SWGR-87003A & 87003B Single Line Diagram.*

24590-BOF-E1-MVE-00007, Rev 10, *BOF Switchgear Building 4.16KV Switchgear MVE-SWGR-91001A Single Line Diagram.*

24590-BOF-E1-MVE-00008, Rev 10, *BOF Switchgear Building 4.16KV Switchgear MVE-SWGR-91001B Single Line Diagram.*

24590-BOF-E1-MVE-00009, Rev 10, *BOF Switchgear Building 4.16KV Switchgear MVE-SWGR-91002A Single Line Diagram.*

24590-BOF-E1-MVE-00010, Rev 10, *BOF Switchgear Building 4.16KV Switchgear MVE-SWGR-91002B Single Line Diagram.*

24590-BOF-E1C-MVE-00004, Rev 00C, *Standby Diesel Generator Sizing.*

24590-WTP-3PS-MGEN-T0005, Rev 00D, *Engineering Specification for ITS Emergency Diesel Generators.*

24590-WTP-3PS-MGEN-T0003, Rev 2, *Engineering Specification for13.8 kV Standby Diesel Generator.*

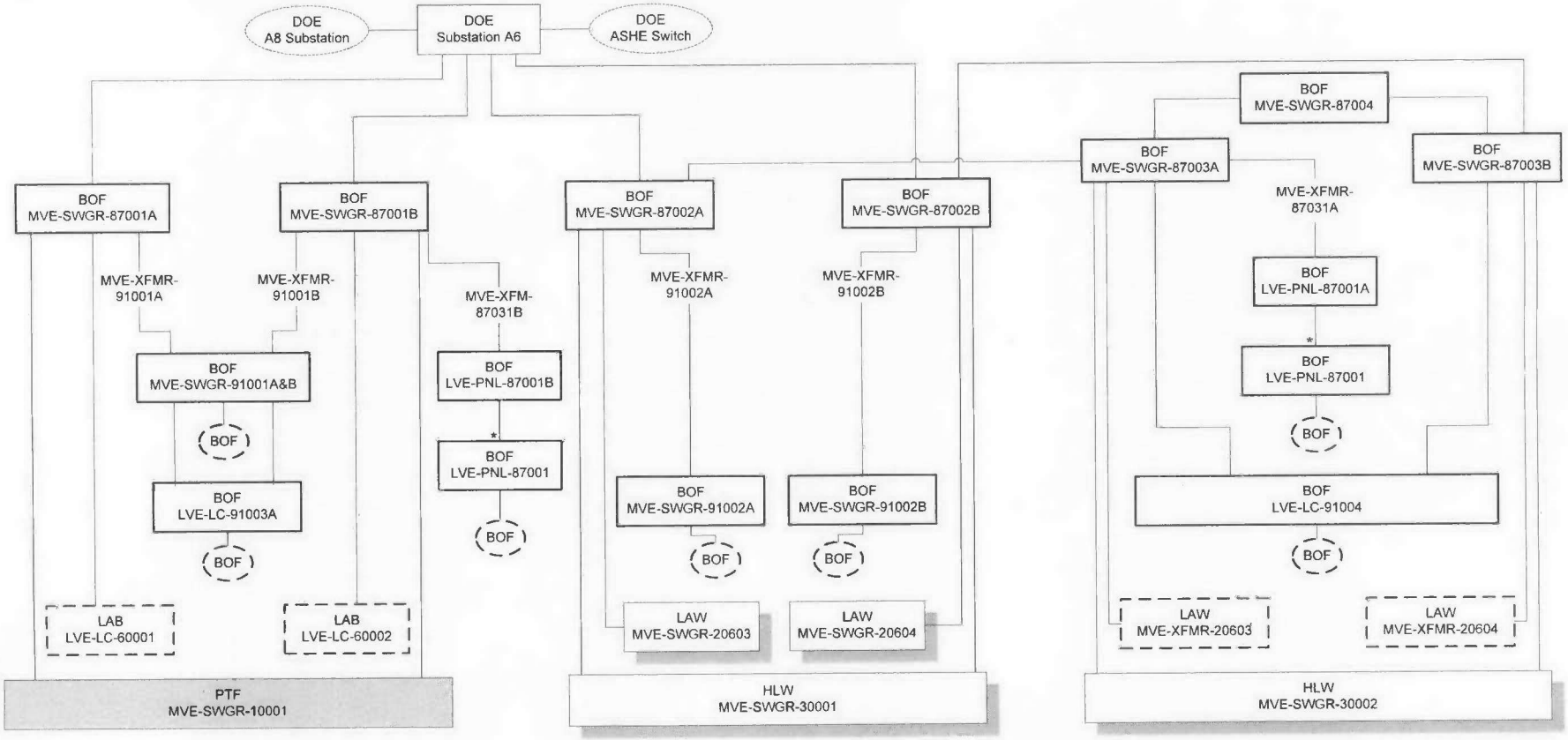
24590-WTP-3YD-MVE-00001, Rev 3, *System Description For The WTP 13.8kV Power Distribution System, MVE.*

24590-WTP-3YD-MVE-00002, Rev 2, *System Description for the Non-ITS 4.16kV Power Distribution System, MVE.*

24590-WTP-ICD-MG-01-011, Rev 4, *ICD-11-Interface Control Document for Electricity.*

24590-WTP-PSAR-ESH-01-002-01, Rev 04o, *Preliminary Documented Safety Analysis to Support Construction Authorization; General Information.*

Figure 6.8.1 Overall Medium Voltage Electrical Distribution System for WTP



*LVE-PNL-87001 supplied by either LVE-PNL-87001A or LVE-PNL-87001B through LVE-ATS-87001

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6.9 System DFO: Diesel Fuel Oil

6.9.1 Function and Requirements

The Balance of Facilities (BOF) diesel fuel oil system (DFO) provides fuel oil to the BOF and the diesel generator facility (EDG and SDG). The diesel fuel is burned as a heat source for steam, fuel source for important to safety (ITS) emergency diesel generators and standby diesel generators. The system description provides an overview and the expanded details as to specific characteristics of the BOF DFO system (24590-BOF-3YD-DFO-00001). Figure 6.9-1 represents a simplified DFO flow diagram of the diesel fueling processes.

6.9.2 Process Description

The origin and distribution of diesel fuel oil within Hanford Tank Waste Treatment and Immobilization Plant is depicted on the piping and instrumentation diagrams 24590-BOF-M6-DFO-00001001, 24590-BOF-M6-DFO-00001002, and 24590-BOF-M6-HPS-00009002, respectively. The DFO system consists of a bulk 275,000 gal storage tank, fuel oil storage tank (DFO-TK-00001), pumps, and piping. The tank serves as the primary containment for the diesel fuel oil. Unloading pumps transfer the contents from the delivery truck into the bulk storage tank. Piping provides containment during transfer. Centrifugal and positive-displacement pumps (24590-BOF-M6-HPS-00009002) transfer the diesel fuel oil to the high pressure steam boilers.

The ITS diesel generators have their own diesel fuel oil supply system, depicted in P&ID drawings 24590-BOF-M6-DFO-00002 and 24590-BOF-M6-DFO-00003. These latter systems distinguish themselves from the steam plant system by using a polishing filter system (DFO-FILT-00001) before being stored in the ITS emergency diesel generator storage vessel (DFO-VSL-00001 A/B) or stored in the standby diesel generator fuel oil day tank (DFO-TK-00004).

6.9.3 References

24590-BOF-3YD-DFO-00001, Rev 1, *System Description for the Diesel Fuel Oil System.*

24590-BOF-M6-DFO-00001001, Rev 0, *P&ID - BOF Diesel Fuel Oil System Unloading and Storage DFO-TK-00001.*

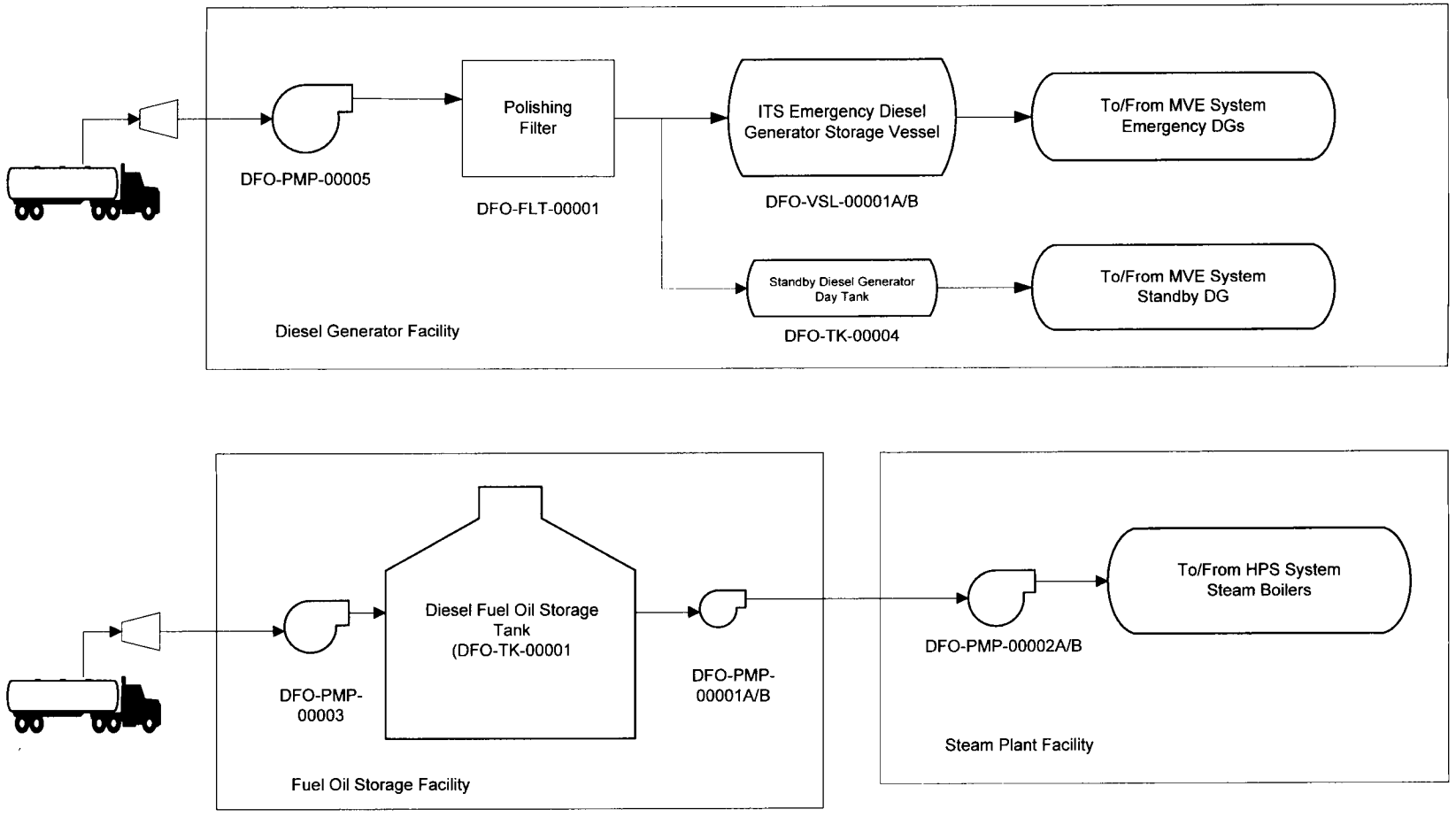
24590-BOF-M6-DFO-00001002, Rev 0, *P&ID - BOF Fuel Oil System Boiler Feed DFO-PMP-00001A/B.*

24590-BOF-M6-DFO-00002, Rev 1, *P&ID - BOF Fuel Oil System ITS Emergency Diesel Gen Fuel Oil Storage Vessels.*

24590-BOF-M6-DFO-00003, Rev 1, *P&ID - BOF Fuel Oil System Standby Diesel Generator Fuel Oil Day Tank.*

24590-BOF-M6-HPS-00009002, Rev 0, *P&ID - BOF Steam Plant Facility SCW-TK-00014 and DFO-TK-00002A/B.*

Figure 6.9-1 Simplified DFO Flow Diagram



7 Emissions

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7.1 Air Emissions

7.1.1 Introduction

The steady-state flowsheet model (SSFM) provides material and energy balance information for the Hanford Tank Waste Treatment and Immobilization Plant (WTP). It also provides air emissions release estimates from all the WTP process flues for the Pretreatment (PT) Facility, Low-Activity Waste (LAW) Facility, and the High-Level Waste (HLW) Facility. The SSFM provides material and energy balance information and air emission release estimates specifically for the systems related to the following process flues: PT process vessel vent exhaust (PVV), PT pulse jet mixer/reverse flow diverter (PJM/RFD), LAW secondary offgas process system (LVP), HLW melter 1 offgas treatment process system (HOP), HLW melter 2 offgas treatment process system (HOP), and HLW pulse jet ventilation system (PJV). Information from the SSFM supports environmental air permit applications and risk assessment analysis. Even though the same flowsheet is used, parameters and operational logic used for air emissions estimates differ from the ones used for design verification. This ensures that the air emissions estimates bound the actual emissions from the WTP. The major differences between the parameters are found in the feed vector and equipment performance, plant throughput, and operating assumptions.

7.1.2 Purpose

The purpose of this section is to present the bases to be used for the WTP emissions estimates performed in the SSFM.

7.1.3 Bases for Emissions Runs

This section presents the bases to be used for all the emissions runs performed in the SSFM. This section will be periodically updated to reflect the latest plant design or outcomes from negotiations with federal and state regulators.

7.1.3.1 Feed Vector

The feed vector used for the latest emissions run is presented in 24590-WTP-M4C-FRP-00001, *WTP Air Emissions Inorganic and Radionuclide Constituents Feed Vector*. Table 7.1-1 through Table 7.1-4 show the LAW and HLW feed concentrations for the radionuclide and inorganic constituents, respectively. The emissions feed vector is subject to periodic revision.

The methodology for determining the feed composition of 219 organic species is based on the following key assumptions:

- Total organic carbon (TOC) in the waste feed is 4 wt %
- 90 % of the TOC is not significantly regulated (complexants and low molecular weight acids)
- Non-analyzed and non-detected species are present in the waste
- Result values and analytical detection limits (analyzed or not) are scaled (multiplier = 189) to describe the TOC balance (10 %) as constituents of concern

Refer to CCN 097844 and Section 4 of RPT-24590-EN00003, *RPP-WTP Waste Feed Assessment*, for a more detailed description of the bases of organic constituents selected for air emissions analysis.

Table 7.1-5 presents the organic feed vector used for emissions estimates. The basis for the feed concentration for the 14 co-planar polychlorinated biphenyls (PCB) congeners analyzed is that all 14 constituents make up 1 % of the total PCB air emissions concentrations. The PCB feed concentration has been specified as follows per 24590-WTP-RPT-PO-03-008, Section 8.2.1:

- HLW feed: 50 mg/kg
- LAW feed: 0.4 mg/L

Not all the constituents in Table 7.1-1 through Table 7.1-5 will be modeled in the SSFM. A subset of organic, inorganic, and radionuclide constituents of potential concern (COPC) shall be selected to represent the entire group. These subsets should be identified based on the physical and chemical properties of the compounds.

7.1.3.2 Operating Assumptions

There are some specific operating assumptions for the air emissions estimations which allow the estimate to be bounding. These assumptions are outlined in the list below. The list includes throughput and feed specifications used for the emissions runs. All contents of the list are described in 24590-WTP-RPT-PO-03-008:

- LAW glass production: 50 metric tons per day
- HLW glass production: 7.5 metric tons per day
- Sodium molarity for both HLW and LAW feed: 4 M (thereby allowing the feed to be treated through the feed evaporator)
- Treated LAW Evaporation Process System (TLP) evaporator sodium molarity: 8 M
- LAW waste oxide loading: 20 %
- HLW waste loading: 40 %
- All PT vessels operate at the same time thus maximizing air emissions from PVV system
- All PT PJM/RFDs operate at the same time
- All HLW PJM/RFDs operate at the same time

7.1.3.3 Equipment Decontamination Factors

Equipment decontamination factors (DF) used in the air emissions estimates are more conservative than those used for design. This ensures the emissions estimates obtained are bounding. The inorganic and radionuclide constituent DFs used for emissions purposes are shown in Table 7.1-6 and Table 7.1-7. Table 7.1-6 shows the DFs in the PT Facility and Table 7.1-7 shows the DFs in the LAW and HLW Facilities.

Similarly, conservative DFs used for emissions purposes of organic constituents are shown in Table 7.1-8 for the PT Facility, and Table 7.1-9 for the LAW and HLW Facilities.

7.1.3.4 Organics Calculations

Henry's law is applied to estimate vessel vent releases for all modeled organic constituents in the PT, HLW, and LAW Facilities. The PT evaporators also use Henry's law to estimate organics overhead releases. This method is not applied in the RFDs or PJMs. The regular specified release fraction used for inorganics and radionuclides is also used for organic constituents in this equipment.

Where Henry's law is used, a Henry's law constant is applied per constituent to estimate releases. These constants were obtained from two sources: the *Interactive PhysProp Database Demo* (Syracuse 2007) and the *Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry* (Sander 1999). The latter source has presented an equation for Henry's law as a function of temperature.

A Henry's law constant may also be provided in WTP documents issued by Environmental & Nuclear Safety to support risk assessment and permitting.

A simple way to calculate Henry's law constant, k_H, as a function of temperature is:

$$k_H = k_H^{\theta} \times \exp\left[\left(-\Delta_{soln}H/R\right) \times \left(1/T - 1/T^{\theta}\right)\right] \qquad \text{(Sander 1999, p 3)}$$

where:

k_H^{θ} = Henry's law constant at standard conditions,
$\Delta_{soln}H/R$ = enthalpy of solution
T^{θ} = 298.15 Kelvin.

Here, the temperature dependence is:

$$\left[-d\ln k_H / d(1/T)\right] = \left(\Delta_{soln}H/R\right) \qquad \text{(Sander 1999, p 3)}$$

Table 7.1-10 lists the Henry's law constants for organic constituents. Some of the constants in the table do not show temperature dependence values. Constants obtained from the *Interactive PhysProp Database Demo* do not have documented temperature dependence values, and are shown as k_H values. Constants obtained from the *Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry*, k_H^{θ} values, have an accompanying temperature dependence which are applied in the equations above.

7.1.4 Ongoing Work and Potential Changes

As future emission reports are issued, the tables concluding this section will be updated to reflect the new values.

7.1.5 References

24590-WTP-M4C-FRP-00001, Rev 00D, *WTP Air Emissions Inorganic Radionuclide Constituents Feed Vector.*

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Table 7.1-1 LAW Chemical Analytes Emissions Feed Vector

Analyte	kg	Analyte	kg
Ag	2.32E+01	NO2	2.60E+05
Al	7.02E+04	NO3	4.74E+05
As	7.09E+01	OH	2.92E+05
B	1.70E+02	Oxalate	9.43E+03
Ba	2.71E+01	Pb	2.76E+02
Be	3.81E+00	Pd	1.09E+01
Bi	4.86E+01	PO4	1.01E+04
Ca	5.38E+02	Pr	6.98E-02
Cd	4.12E+01	Rb	4.16E+00
Ce	6.36E+01	Rh	1.02E+01
Cl	1.48E+04	Ru	1.50E+01
CN	1.17E+01	Sb	4.20E+01
Co	2.04E+01	Se	7.19E+01
Cr	3.24E+03	Si	5.64E+02
Cu	2.30E+01	SO4	2.44E+04
F	3.18E+03	Sr	4.13E+00
Fe	5.27E+02	Ta	5.53E+00
Hg	7.62E+01	Te	1.14E-01
K	3.48E+04	Th	6.59E+01
La	1.40E+01	Ti	7.93E+00
Li	1.96E+01	TIC as CO3	1.25E+05
Mg	7.27E+01	Tl	5.06E+01
Mn	1.78E+02	U(total)	3.37E+02
Mo	1.68E+02	V	2.78E+01
Na	6.21E+05	W	4.89E+01
Nd	8.32E+01	Y	5.29E+00
NH3	3.25E+02	Zn	4.05E+01
Ni	2.91E+02	Zr	4.17E+01

Table 7.1-2 LAW Radionuclide Emissions Feed Vector

Analyte	Ci	Analyte	Ci
106Ru	8.60E+01	236U	7.76E-02
113mCd	1.33E+02	237Np	1.60E+00
125Sb	1.88E+03	238Pu	9.04E+00
126Sn	2.99E+01	238U	8.98E-01
129I	1.26E+00	239Pu	1.25E+02
134Cs	1.44E+03	240Pu	3.24E+01
137Cs	1.47E+07	241Am	2.02E+03
137mBa	4.78E+06	241Pu	6.80E+02
14C	4.13E+01	242Cm	7.69E+00
151Sm	2.64E+04	242Pu	3.43E-03
152Eu	1.52E+01	243Am	1.32E+00
154Eu	3.15E+03	243Cm	2.18E-01
155Eu	9.11E+02	244Cm	5.16E+00
226Ra	2.55E-04	3H	3.52E+02
227Ac	1.99E-02	59Ni	7.00E+01
228Ra	3.03E-01	60Co	2.71E+02
229Th	9.96E-03	63Ni	4.88E+03
231Pa	2.09E-01	79Se	3.37E+00
232Th	4.86E-02	90Sr	5.86E+05
232U	2.64E-02	90Y	2.74E+05
233U	1.62E+00	93mNb	1.20E+02
234U	1.15E+00	93Zr	1.95E+02
235U	4.53E-02	99Tc	5.20E+03

Table 7.1-3 HLW Chemical Analytes Emissions Feed Vector

Analyte	kg	Analyte	kg
Ag	2.74E+02	NO2	1.56E+04
Al	3.85E+04	NO3	1.20E+04
As	1.72E+01	OH	1.42E+05
B	2.35E+02	Oxalate	4.66E+03
Ba	2.51E+02	Pb	2.14E+03
Be	6.31E+00	Pd	8.77E+01
Bi	1.30E+03	PO4	9.49E+03
Ca	1.50E+03	Pr	8.65E+01
Cd	9.19E+02	Rb	3.72E+01
Ce	3.14E+02	Rh	2.80E+01
Cl	3.07E+02	Ru	1.96E+02
CN	4.98E+00	Sb	6.75E+00
Co	1.30E+01	Se	1.17E+01
Cr	7.78E+02	Si	3.00E+03
Cu	1.07E+02	SO4	3.53E+03
F	5.55E+03	Sr	1.41E+02
Fe	3.98E+04	Ta	4.35E+02
Hg	1.56E+02	Te	4.92E+01
K	7.88E+02	Th	4.77E+03
La	4.65E+02	Ti	5.66E+01
Li	3.26E+01	TIC as CO3	3.45E+04
Mg	3.08E+02	Tl	1.33E+03
Mn	3.65E+03	U(total)	6.99E+03
Mo	1.78E+01	V	1.12E+01
Na	6.18E+04	W	8.52E+01
Nd	5.04E+02	Y	4.74E+01
NH3	1.14E-01	Zn	1.42E+02
Ni	1.63E+03	Zr	9.71E+03

Table 7.1-4 HLW Radionuclide Emissions Feed Vector

Analyte	Ci	Analyte	Ci
106Ru	5.12E+01	236U	5.58E-01
113mCd	3.88E+02	237Np	1.20E+02
125Sb	5.19E+04	238Pu	5.68E+02
126Sn	2.43E+02	238U	9.56E+00
129I	4.71E-01	239Pu	5.03E+03
134Cs	1.23E+02	240Pu	1.33E+03
137Cs	2.43E+06	241Am	1.46E+05
137mBa	3.50E+05	241Pu	3.57E+04
14C	1.05E+01	242Cm	2.48E+01
151Sm	6.31E+05	242Pu	2.48E+01
152Eu	7.79E+02	243Am	1.18E+01
154Eu	8.44E+04	243Cm	2.05E+02
155Eu	1.25E+04	244Cm	4.66E+03
226Ra	5.16E-04	3H	1.05E+02
227Ac	2.02E+00	59Ni	3.01E+01
228Ra	1.48E+00	60Co	1.62E+04
229Th	5.53E-01	63Ni	2.81E+03
231Pa	1.70E-01	79Se	5.24E+00
232Th	3.97E+00	90Sr	1.62E+07
232U	2.26E+00	90Y	5.52E+06
233U	3.25E+02	93mNb	1.13E+02
234U	1.69E+01	93Zr	2.09E+02
235U	4.06E-01	99Tc	2.43E+04

Table 7.1-5 Organics Feed Concentration for LAW and HLW

CAS #	COPC	Concentration (mg/L)
100-00-5	p-Nitrochlorobenzene	40
100-21-0	p-Phthalic acid	60
100-41-4	Ethyl benzene	4
100-42-5	Styrene	4
10061-01-5	cis-1,3-Dichloropropene	4
10061-02-6	trans-1,3-Dichloropropene	4
101-55-3	4-Bromophenylphenyl ether	60
101-84-8	Diphenyl ether	10
106-35-4	3-Heptanone	4
106-42-3	p-Xylene (Dimethyl benzene)	10
106-46-7	1,4-Dichlorobenzene	4
106-88-7	1,2-Epoxybutane	10
106-93-4	Ethylene dibromide (Dibromethane)	4
106-97-8	Butane	10
106-99-0	1,3-Butadiene	4
107-02-8	Acrolein	10
107-05-1	3-Chloropropene (Allyl chloride)	4
107-06-2	1,2-Dichloroethane (Ethylene chloride)	4
107-12-0	Propionitrile	10
107-13-1	Acrylonitrile	20
107-18-6	2-Propene-1-ol	60
107-31-3	Formic acid, methyl ester	60
107-66-4	Dibutylphosphate	60
107-87-9	2-Pentanone	20
108-03-2	1-Nitropropane	60
108-05-4	Vinyl acetate	60
108-10-1	Hexone (4-Methyl-2-pentanone or MIBK)	10
108-20-3	Bis(isopropyl)ether	10
108-38-3	m-Xylene (Dimethyl benzene)	10
108-39-4	m-Cresol	10
108-87-2	Methylcyclohexane	10
108-88-3	Toluene	4

Table 7.1-5 Organics Feed Concentration for LAW and HLW

CAS #	COPC	Concentration (mg/L)
108-90-7	Chlorobenzene	4
108-93-0	Cyclohexanol	10
108-94-1	Cyclohexanone	10
108-95-2	Phenol	60
109-66-0	n-Pentane	10
109-99-9	Tetrahydrofuran	4
110-12-3	5-Methyl-2-hexanone	4
110-43-0	2-Heptanone	4
110-54-3	n-Hexane	10
110-62-3	n-Valeraldehyde	60
110-82-7	Cyclohexane	10
110-83-8	Cyclohexene	4
110-86-1	Pyridine	20
111-65-9	n-Octane	10
111-76-2	Ethylene glycol monobutyl ether	60
111-84-2	n-Nonane	10
117-81-7	Bis(2-ethylhexyl)phthalate (DEHP)	60
117-84-0	n-Dioctyl phthalate	60
120-12-7	Anthracene	60
120-82-1	1,2,4-Trichlorobenzene	10
120-83-2	2,4-Dichlorophenol	60
121-44-8	Triethylamine	10
121-69-7	Dimethylaniline	10
122-39-4	N,N-Diphenylamine	20
123-19-3	4-Heptanone	4
123-38-6	n-Propionaldehyde	20
123-51-3	3-Methyl-1-butanol	10
123-86-4	Acetic acid n-butyl ester	0.2
123-91-1	1,4-Dioxane	2
126-73-8	Tributyl phosphate	40
126-98-7	2-Methyl-2-propenenitrile (Methacrylonitrile)	10
127-18-4	Perchloroethylene (tetrachloroethylene)	4

Table 7.1-5 Organics Feed Concentration for LAW and HLW

CAS #	COPC	Concentration (mg/L)
127-19-5	N,N-Dimethylacetamide	10
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	20
129-00-0	Pyrene	60
1321-64-8	Pentachloronaphthalene	60
1321-65-9	Trichloronaphthalene	60
132-64-9	Dibenzofuran	60
1335-87-1	Hexachloronaphthalene	60
1335-88-2	Tetrachloronaphthalene	60
1336-36-3	Polychlorinated biphenyls (PCBs)	0.4
141-78-6	Acetic acid ethyl ester (Ethyl acetate)	0.2
141-79-7	4-Methyl-3-penten-2-one	60
142-82-5	n-Heptane	10
156-60-5	trans-1,2-Dichloroethylene	10
1634-04-4	Methyl tert-butyl ether	10
189-55-9	Dibenzo[a,i]pyrene	60
189-64-0	Dibenzo[a,h]pyrene	60
191-24-2	Benzo(g,h,i)perylene	60
191-30-0	Benzo[a,i]pyrene	60
192-65-4	Dibenzo[a,e]pyrene	60
193-39-5	Indeno(1,2,3-cd)pyrene	60
206-44-0	Fluoranthene	60
208-96-8	Acenaphthylene	60
2234-13-1	Octachloronaphthalene	0.2
224-42-0	Dibenz[a,j]acridine	60
226-36-8	Dibenz[a,h]acridine	60
25551-13-7	Trimethyl benzene	10
26140-60-3	Terphenyls	60
27154-33-2	Trichlorofluoroethane	10
287-92-3	Cyclopentane	10
3697-24-3	5-Methylchrysene	60
3825-26-1	Ammonium perfluorooctanoate	60
4170-30-3	2-Butenaldehyde (2-Butenal or Crotonaldehyde)	10

Table 7.1-5 Organics Feed Concentration for LAW and HLW

CAS #	COPC	Concentration (mg/L)
50-00-0	Formaldehyde	10
50-32-8	Benzo(a)pyrene	38
53-70-3	Dibenzo(a,h)anthracene	38
540-59-0	1,2-Dichloroethylene	10
540-84-1	2,2,4-Trimethylpentane	10
541-73-1	1,3-Dichlorobenzene	4
56-23-5	Carbon tetrachloride	4
563-80-4	3-Methyl-2-butanone	10
56-49-5	3-Methylcholanthrene	60
57-14-7	1,1-Dimethylhydrazine	60
58-90-2	2,3,4,6-Tetrachlorophenol	60
591-78-6	2-Hexanone	10
59-50-7	4-Chloro-3-methylphenol	60
59-89-2	N-Nitrosomorpholine	60
602-87-9	5-Nitroacenaphthene	60
60-29-7	Ethyl ether	60
603-34-9	Triphenylamine	60
60-34-4	Methylhydrazine	10
60-35-5	Acetamide	10
621-64-7	Di-n-Propylnitrosamine (N-Nitroso-di-n-propylamine)	60
624-83-9	Methyl isocyanate	10
627-13-4	Nitric acid, propyl ester	5
62-75-9	N-Nitroso-N,N-dimethylamine (Dimethylnitrosamine)	60
630-20-6	1,1,1,2-Tetrachloroethane	10
64-17-5	Ethyl alcohol	10
64-19-7	Acetic acid	10
67-56-1	Methyl alcohol (Methanol)	2
67-63-0	2-Propyl alcohol (Isopropanol; Propan-2-01)	20
67-64-1	2-Propanone (Acetone)	4
67-66-3	Chloroform	60
67-72-1	Hexachloroethane	10
684-16-2	Hexafluoroacetone	4

Table 7.1-5 Organics Feed Concentration for LAW and HLW

CAS #	COPC	Concentration (mg/L)
71-23-8	n-Propyl alcohol	10
71-36-3	n-Butyl alcohol	4
71-43-2	Benzene	4
71-55-6	Methyl chloroform (1,1,1-Trichloroethane)	4
74-83-9	Bromomethane (Methyl bromide)	4
74-87-3	Chloromethane (Methyl chloride)	10
74-97-5	Bromochloromethane	60
74-99-7	Methylacetylene	4
75-00-3	Chloroethane	4
75-01-4	Vinyl chloride (1-Chloroethene)	10
75-05-8	Acetonitrile	60
75-07-0	Acetaldehyde	4
75-09-2	Dichloromethane (Methylene chloride)	60
75-12-7	Formamide	10
75-15-0	Carbon disulfide	2
75-21-8	Ethylene oxide (Oxirane)	10
75-27-4	Bromodichloromethane	4
75-34-3	1,1-Dichloroethane	10
75-35-4	1,1-Dichloroethene (Vinylidene chloride)	4
75-43-4	Dichlorofluoromethane	4
75-45-6	Chlorodifluoromethane	10
75-50-3	Trimethylamine	60
75-52-5	Nitromethane	60
75-55-8	2-Methylaziridine	10
75-61-6	Difluorodibromomethane	10
75-63-8	Trifluorobromomethane	10
75-65-0	2-Methyl-2-propanol	10
75-69-4	Trichlorofluoromethane	10
75-71-8	Dichlorodifluoromethane	10
76-03-9	Trichloroacetic acid	60
76-11-9	1,1,1,2-Tetrachloro-2,2-difluoroethane	60
76-12-0	1,1,2,2-Tetrachloro-1,2-difluoroethane	10

Table 7.1-5 Organics Feed Concentration for LAW and HLW

CAS #	COPC	Concentration (mg/L)
76-13-1	1,2,2-Trichloro-1,1,2-trifluoroethane (Freon 113)	10
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane	10
76-15-3	Chloropentafluoroethane	60
78-83-1	2-Methylpropyl alcohol (Isobutyl alcohol)	4
78-87-5	1,2-Dichloropropane	4
78-92-2	1-Methylpropyl alcohol (2-Butanol)	10
78-93-3	Methyl ethyl ketone (MEK, 2-Butanone)	10
79-00-5	1,1,2-Trichloroethane	10
79-01-6	Trichloroethylene	60
79-09-4	Propionic acid	60
79-20-9	Methyl acetate	0.02
79-34-5	1,1,2,2-Tetrachloroethane	60
83-32-9	Acenaphthene	60
84-66-2	Diethyl phthalate	60
84-74-2	Dibutyl phthalate	60
85-01-8	Phenanthrene	60
85-68-7	Butylbenzyl phthalate	60
86-73-7	Fluorene	10
87-68-3	Hexachlorobutadiene	60
88-06-2	2,4,6-Trichlorophenol	10
88-72-2	2-Nitrotoluene	60
88-75-5	2-Nitrophenol	60
88-89-1	Picric acid	2
91-20-3	Naphthalene	60
91-22-5	Quinoline	60
91-58-7	2-Chloronapthalene	40
92-52-4	1,1`-Biphenyl	60
92-93-3	4-Nitrobiphenyl	60
95-13-6	Indene	4
95-47-6	o-Xylene	10
95-48-7	o-Cresol (2-Methylphenol)	60
95-49-8	2-Chlorotoluene	4

Table 7.1-5 Organics Feed Concentration for LAW and HLW

CAS #	COPC	Concentration (mg/L)
95-50-1	o-Dichlorobenzene (1,2-Dichlorobenzene)	60
95-57-8	2-Chlorophenol	60
95-95-4	2,4,5-Trichlorophenol	1
96-18-4	1,2,3-Trichloropropane	20
96-22-0	3-Pentanone	60
96-69-5	Bis (3-tert-butyl-4-hydroxy-6-methyl-phenyl) sulfide	60
98-51-1	p-tert-Butyltoluene	60
98-82-8	Cumene	10
98-83-9	alpha-Methylstyrene	40
98-86-2	Acetophenone	40
98-95-3	Nitrobenzene	40

Table 7.1-6 Pretreatment Inorganics and Radionuclides Decontamination Factors

Analytes	HEME	Thermal Oxidizer	NaOH Scrubber	Carbon Beds	HEPA 1	HEPA 2	PJV Demister
Inorganic							
Ag	200	1	3.5	1	2000	100	5
Al	200	1	3.5	1	2000	100	5
As	200	1	3.5	1	2000	100	5
B	200	1	3.5	1	2000	100	5
Ba	200	1	3.5	1	2000	100	5
Bi	200	1	3.5	1	2000	100	5
Ca	200	1	3.5	1	2000	100	5
Cd	200	1	3.5	1	2000	100	5
Cl	200	1	3.5	1	2000	100	5
Cr	200	1	3.5	1	2000	100	5
Cu	200	1	3.5	1	2000	100	5
F	200	1	3.5	1	2000	100	5
Fe	200	1	3.5	1	2000	100	5
Hg	1	1	1	1	1	1	1
K	200	1	3.5	1	2000	100	5
Li	200	1	3.5	1	2000	100	5
Mg	200	1	3.5	1	2000	100	5
Mn	200	1	3.5	1	2000	100	5
Na	200	1	3.5	1	2000	100	5
Ni	200	1	3.5	1	2000	100	5
NO_2 (s)	200	1	3.5	1	2000	100	5
NO_3 (s)	200	1	3.5	1	2000	100	5
OH	200	1	3.5	1	2000	100	5
P	200	1	3.5	1	2000	100	5
Pb	200	1	3.5	1	2000	100	5
PO_4	200	1	3.5	1	2000	100	5
S	200	1	3.5	1	2000	100	5
Si	200	1	3.5	1	2000	100	5
SO_4	200	1	3.5	1	2000	100	5
Sr	200	1	3.5	1	2000	100	5
Zn	200	1	3.5	1	2000	100	5

Table 7.1-6 Pretreatment Inorganics and Radionuclides Decontamination Factors

Analytes	HEME	Thermal Oxidizer	NaOH Scrubber	Carbon Beds	HEPA 1	HEPA 2	PJV Demister
Zr	200	1	3.5	1	2000	100	5
Be	200	1	3.5	1	2000	100	5
CN	200	1	3.5	1	2000	100	5
Co	200	1	3.5	1	2000	100	5
Mo	200	1	3.5	1	2000	100	5
Rh	200	1	3.5	1	2000	100	5
Sb	200	1	3.5	1	2000	100	5
Se	200	1	3.5	1	2000	100	5
Sn	200	1	3.5	1	2000	100	5
Ta	200	1	3.5	1	2000	100	5
Tl	200	1	3.5	1	2000	100	5
U	200	1	3.5	1	2000	100	5
V	200	1	3.5	1	2000	100	5
W	200	1	3.5	1	2000	100	5
Y	200	1	3.5	1	2000	100	5
CO	1	1	1	1	1	1	1
NO	1	1	1.8	1	1	1	1
NO_2	1	1	1.8	1	1	1	1
SO_2	1	1	3	1	1	1	1
NH_3	1	1	3	1	1	1	1
Radionuclide							
^{241}Am	200	1	3.5	1	2000	100	5
^{14}C	1	1	1	1	1	1	1
^{60}Co	200	1	3.5	1	2000	100	5
^{243}Cm	200	1	3.5	1	2000	100	5
^{244}Cm	200	1	3.5	1	2000	100	5
^{137}Cs	200	1	3.5	1	2000	100	5
^{152}Eu	200	1	3.5	1	2000	100	5
^{154}Eu	200	1	3.5	1	2000	100	5
^{155}Eu	200	1	3.5	1	2000	100	5
^{3}H	Follows water	1	Follows water	1	1	1	1
^{129}I	1	1	3.5	1	1	1	1

Table 7.1-6 Pretreatment Inorganics and Radionuclides Decontamination Factors

Analytes	HEME	Thermal Oxidizer	NaOH Scrubber	Carbon Beds	HEPA 1	HEPA 2	PJV Demister
^{63}Ni	200	1	3.5	1	2000	100	5
^{237}Np	200	1	3.5	1	2000	100	5
^{238}Pu	200	1	3.5	1	2000	100	5
^{239}Pu	200	1	3.5	1	2000	100	5
^{240}Pu	200	1	3.5	1	2000	100	5
^{241}Pu	200	1	3.5	1	2000	100	5
^{125}Sb	200	1	3.5	1	2000	100	5
^{151}Sm	200	1	3.5	1	2000	100	5
^{126}Sn	200	1	3.5	1	2000	100	5
^{90}Sr	200	1	3.5	1	2000	100	5
^{99}Tc	200	1	3.5	1	2000	100	5
^{232}Th	200	1	3.5	1	2000	100	5
^{233}U	200	1	3.5	1	2000	100	5
^{234}U	200	1	3.5	1	2000	100	5
^{235}U	200	1	3.5	1	2000	100	5
^{236}U	200	1	3.5	1	2000	100	5
^{238}U	200	1	3.5	1	2000	100	5
^{90}Y	200	1	3.5	1	2000	100	5
^{106}Ru	200	1	3.5	1	2000	100	5
^{134}Cs	200	1	3.5	1	2000	100	5
^{137}mBa	200	1	3.5	1	2000	100	5
^{242}Pu	200	1	3.5	1	2000	100	5
^{226}Rd	200	1	3.5	1	2000	100	5
^{232}U	200	1	3.5	1	2000	100	5
^{231}Pa	200	1	3.5	1	2000	100	5
^{59}Ni	200	1	3.5	1	2000	100	5
^{227}Ac	200	1	3.5	1	2000	100	5
^{243}Am	200	1	3.5	1	2000	100	5
^{228}Ra	200	1	3.5	1	2000	100	5
^{242}Cm	200	1	3.5	1	2000	100	5
^{229}Th	200	1	3.5	1	2000	100	5
^{93}Zr	200	1	3.5	1	2000	100	5

Table 7.1-6 Pretreatment Inorganics and Radionuclides Decontamination Factors

Analytes	HEME	Thermal Oxidizer	NaOH Scrubber	Carbon Beds	HEPA 1	HEPA 2	PJV Demister
^{93}mNb	200	1	3.5	1	2000	100	5
^{113}mCd	200	1	3.5	1	2000	100	5
^{79}Se	200	1	3.5	1	2000	100	5

Table 7.1-7 LAW and HLW Inorganic and Radionuclide Constituents Decontamination Factors

Analytes	LAW Melter	HLW Melter	LAW SBS	HLW SBS	LAW and HLW WESP	HLW HEME	LAW Caustic Scrubber	HEPA 1	HEPA 2	LAW and HLW Thermal Oxidizer	LAW and HLW SCR	LAW Treated Activated Carbon Beds	HLW Treated Activated Carbon Beds	HLW Silver Mordenite Column
Inorganic Constituents														
Ag	30	30	1.8	1.8	50	100	1	2000	100	1	1	1	1	1
Al	100	100	40	40	11	90	1	2000	100	1	1	1	1	1
As	6	56	4.8	4.8	20	90	1	2000	100	1	1	1	1	1
B	30	30	16.1	30	11	90	1	2000	100	1	1	1	1	1
Ba	100	100	90	90	12	90	1	2000	100	1	1	1	1	1
Bi	80	100	2.6	2.6	30	100	1	2000	100	1	1	1	1	1
Ca	75	75	20	20	11	90	1	2000	100	1	1	1	1	1
Cd	10	10	1.6	1.6	80	110	1	2000	100	1	1	1	1	1
Cl	1.9	1.3	3.4	3.4	20	100	1	2000	100	1	1	1	1	1
Cr	41	64	3.4	3.4	13	90	1	2000	100	1	1	1	1	1
Cu	200	192	2.9	2.9	30	100	1	2000	100	1	1	1	1	1
F	4	1.7	4.8	4.8	20	90	1	2000	100	1	1	1	1	1
Fe	200	109	40	40	11	90	1	2000	100	1	1	1	1	1
Hg	1	1	3.7	3.7	1	1	1	1	1	1	1	100	1000	1
K	20	20	1.7	1.7	60	110	1	2000	100	1	1	1	1	1
Li	100	100	2.1	2.1	40	100	1	2000	100	1	1	1	1	1
Mg	200	55	3.6	20	11	90	1	2000	100	1	1	1	1	1
Mn	75	75	30	30	10	90	1	2000	100	1	1	1	1	1
Na	100	100	2.6	2.6	30	100	1	2000	100	1	1	1	1	1
Ni	89	89	4	5.9	20	90	1	2000	100	1	1	1	1	1
NO_2 (s)	Destroyed	Destroyed	6.5	18	18	90	1	2000	100	1	1	1	1	1
NO_3 (s)	Destroyed	Destroyed	6.5	18	18	90	1	2000	100	1	1	1	1	1

Table 7.1-7 LAW and HLW Inorganic and Radionuclide Constituents Decontamination Factors

Analytes	LAW Melter	HLW Melter	LAW SBS	HLW SBS	LAW and HLW WESP	HLW HEME	LAW Caustic Scrubber	HEPA 1	HEPA 2	LAW and HLW Thermal Oxidizer	LAW and HLW SCR	LAW Treated Activated Carbon Beds	HLW Treated Activated Carbon Beds	HLW Silver Mordenite Column
OH	1	1	6.5	18	18	90	1	2000	100	1	1	1	1	1
P	40	40	1.7	18	18	90	1	2000	100	1	1	1	1	1
Pb	82	98	2.3	2.3	36	100	1	2000	100	1	1	1	1	1
PO_4	40	40	1.7	18	18	90	1	2000	100	1	1	1	1	1
S	Calculated	1.9	20	3.2	18	90	1	2000	100	1	1	1	1	1
Si	300	203	30	30	11	90	1	2000	100	1	1	1	1	1
SO_4	Calculated	1.9	5.6	5	18	90	1	2000	100	1	1	1	1	1
Sr	100	100	40	40	11	90	1	2000	100	1	1	1	1	1
Zn	100	100	17.7	20	11	90	1	2000	100	1	1	1	1	1
Zr	300	180	16.7	30	10	90	1	2000	100	1	1	1	1	1
Be	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
CN	40	40	1	18	18	90	1	2000	100	1	1	1	1	1
Co	200	130	3.2	3.2	20	100	1	2000	100	1	1	1	1	1
Mo	50	64	1	2.8	30	100	1	2000	100	1	1	1	1	1
Rh	53	50	3.3	30	11	90	1	2000	100	1	1	1	1	1
Sb	100	100	3.7	3.7	12	90	1	2000	100	1	1	1	1	1
Se	2	2	1	1.9	50	100	1	2000	100	1	1	1	1	1
Sn	200	130	40	40	12	90	1	2000	100	1	1	1	1	1
Ta	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
Tl	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
U	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
V	200	130	1	2.5	30	100	1	2000	100	1	1	1	1	1
W	200	130	1	40	10	90	1	2000	100	1	1	1	1	1
Y	300	130	1	50	11	90	1	2000	100	1	1	1	1	1

Table 7.1-7 LAW and HLW Inorganic and Radionuclide Constituents Decontamination Factors

Analytes	LAW Melter	HLW Melter	LAW SBS	HLW SBS	LAW and HLW WESP	HLW HEME	LAW Caustic Scrubber	HEPA 1	HEPA 2	LAW and HLW Thermal Oxidizer	LAW and HLW SCR	LAW Treated Activated Carbon Beds	HLW Treated Activated Carbon Beds	HLW Silver Mordenite Column
CO	Processed	Processed	1	1	1	1	1	1	1	20	1	1	1	1
NO	Processed	Processed	1	1	1	1	1	1	1	1	20	1	1	1
NO_2	Processed	Processed	1	1	1	1	1	1	1	1	20	1	1	1
SO_2	Processed	Processed	1	1	1	1	30	1	1	1.2	1	1	1	1
NH_3	Processed	Processed	4	4	1	1	1	1	1	1	1	1	1	1
Radionuclide Constituents														
^{241}Am	80	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{14}C	1	1	1	1	1	1	1	1	1	1	1	1	1	1
^{60}Co	200	130	3.2	3.2	20	100	1	2000	100	1	1	1	1	1
^{243}Cm	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{244}Cm	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{137}Cs	2	30	2.4	2.4	30	100	1	2000	100	1	1	1	1	1
^{152}Eu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{154}Eu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{155}Eu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{3}H	Follows Water	Follows Water	Follows Water	Follows Water	Follows Water	Follows Water	1	1	1	1	1	1	1	1
^{129}I	1.1	1.1	1.2	1.2	1	1	1	1	1	1	1	100	1	1000
^{63}Ni	89	89	4	5.9	20	90	1	2000	100	1	1	1	1	1
^{237}Np	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{238}Pu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{239}Pu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{240}Pu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{241}Pu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{125}Sb	80	100	3.7	3.7	12	90	1	2000	100	1	1	1	1	1
^{151}Sm	1370	130	73	40	11	90	1	2000	100	1	1	1	1	1
^{126}Sn	200	130	40	40	12	90	1	2000	100	1	1	1	1	1
^{90}Sr	100	100	40	40	11	90	1	2000	100	1	1	1	1	1

Table 7.1-7 LAW and HLW Inorganic and Radionuclide Constituents Decontamination Factors

Analytes	LAW Melter	HLW Melter	LAW SBS	HLW SBS	LAW and HLW WESP	HLW HEME	LAW Caustic Scrubber	HEPA 1	HEPA 2	LAW and HLW Thermal Oxidizer	LAW and HLW SCR	LAW Treated Activated Carbon Beds	HLW Treated Activated Carbon Beds	HLW Silver Mordenite Column
^{99}Tc	3	1.6	3.3	3.9	20	90	1	2000	100	1	1	1	1	1
^{232}Th	250	130	73	40	11	90	1	2000	100	1	1	1	1	1
^{233}U	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{234}U	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{235}U	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{236}U	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{238}U	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{90}Y	300	130	1	50	11	90	1	2000	100	1	1	1	1	1
^{106}Ru	3.9	4	3.6	3.6	20	90	1	2000	100	1	1	1	1	1
^{134}Cs	8.4	30	1	2.4	30	100	1	2000	100	1	1	1	1	1
^{137}mBa	8.4	30	1	2.4	30	100	1	2000	100	1	1	1	1	1
^{242}Pu	200	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{226}Rd	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{232}U	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{231}Pa	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{59}Ni	89	89	4	5.9	20	90	1	2000	100	1	1	1	1	1
^{227}Ac	300	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{243}Am	80	130	40	40	11	90	1	2000	100	1	1	1	1	1
^{228}Ra	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{242}Cm	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{229}Th	200	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{93}Zr	300	180	1	30	10	90	1	2000	100	1	1	1	1	1
^{93}mNb	300	130	1	40	11	90	1	2000	100	1	1	1	1	1
^{113}mCd	10	10	1	1.6	80	110	1	2000	100	1	1	1	1	1
^{79}Se	3.4	2.1	1	1.9	50	100	1	2000	100	1	1	1	1	1

Table 7.1-8 Pretreatment Facility Organics Decontamination Factors

CAS#	Compound	Phase Type	PT Caustic Scrubber	PT HEME	PT/PJV HEPA (First)	PT/PJV HEPA (Second)	PJV Demister	PT Thermal Oxidizer	PT Carbon Bed Adsorber
100-21-0	p-Phthalic acid	Particle	3.3	200	2000	100	5	20	50
88-89-1	Picric acid	Particle	3.3	200	2000	100	5	10,000	5
144-62-7	Oxalic acid	Vapor	1	1	1	1	1	10	20
75-12-7	Formamide	Vapor	1	1	1	1	1	10,000	1
60-35-5	Acetamide	Vapor	1	1	1	1	1	10,000	2
87-68-3	Hexachlorobutadiene	Particle	3.3	200	2000	100	5	50	5
126-73-8	Tributyl phosphate	Vapor	1	1	1	1	1	10,000	5
108-95-2	Phenol	Particle	3.3	200	2000	100	5	10	20
84-66-2	Diethyl phthalate	Particle	3.3	200	2000	100	5	10,000	5
62-75-9	N-Nitroso-N, N-dimethylamine	Vapor	1	1	1	1	1	10,000	2
122-39-4	N, N-Diphenylamine	Vapor	1	1	1	1	1	50	5
4170-30-3	2-Butenaldehyde (2-Butenal or Crotonaldehyde)	Vapor	1	1	1	1	1	10,000	1
58-90-2	2, 3, 4, 6-Tetrachlorophenol	Particle	3.3	200	2000	100	5	3.33	10
98-86-2	Acetophenone	Particle	3.3	200	2000	100	5	100	2
57-14-7	1, 1-Dimethylhydrazine	Vapor	1	1	1	1	1	10,000	1
120-12-7	Anthracene	Particle	3.3	200	2000	100	5	1000	5
75-05-8	Acetonitrile	Vapor	1	1	1	1	1	1000	1
208-96-8	Acenaphthylene	Vapor	1	1	1	1	1	3.33	50
132-64-9	Dibenzofuran	Vapor	1	1	1	1	1	3.33	50
106-93-4	Ethylene dibromide	Vapor	1	1	1	1	1	1	10
91-20-3	Naphthalene	Particle	3.3	200	2000	100	5	100	2

Table 7.1-8 Pretreatment Facility Organics Decontamination Factors

CAS#	Compound	Phase Type	PT Caustic Scrubber	PT HEME	PT/PJV HEPA (First)	PT/PJV HEPA (Second)	PJV Demister	PT Thermal Oxidizer	PT Carbon Bed Adsorber
120-82-1	1, 2, 4-Trichlorobenzene	Particle	3.3	200	2000	100	5	100	5
10061-01-5	cis-1, 3-Dichloropropene	Vapor	1	1	1	1	1	100	1
108-88-3	Toluene	Vapor	1	1	1	1	1	10,000	1
71-43-2	Benzene	Vapor	1	1	1	1	1	100	1
79-01-6	Trichloroethylene	Vapor	1	1	1	1	1	10,000	1
127-18-4	Perchloroethylene (tetrachloroethylene)	Vapor	1	1	1	1	1	1	10
56-23-5	Carbon tetrachloride	Vapor	1	1	1	1	1	1	5
106-99-0	1, 3-Butadiene	Vapor	1	1	1	1	1	10,000	1
110-82-7	Cyclohexane	Vapor	1	1	1	1	1	10,000	1
108-87-2	Methylcyclohexane	Vapor	1	1	1	1	1	10,000	1
106-97-8	Butane	Vapor	1	1	1	1	1	10,000	1
110-54-3	n-Hexane	Vapor	1	1	1	1	1	10,000	1
111-84-2	n-Nonane	Vapor	1	1	1	1	1	10,000	2
76-15-3	Chloropentafluoroethane	Vapor	1	1	1	1	1	1	1
50-32-8	Benzo(a)Pyrene	Particle	3.3	200	2000	100	5	3.33	50
84-74-2	Dibutyl phthalate	Particle	3.3	200	2000	100	5	10,000	5
603-34-9	Triphenylamine	Vapor	1	1	1	1	1	3.33	50
129-00-0	Pyrene	Particle	3.3	200	2000	100	5	3.33	50
1336-36-3	Polychlorinated biphenyls (PCB)	Particle	3.3	200	2000	100	5	3.33	50

Table 7.1-9 LAW and HLW Facility Organics Decontamination Factors

CAS#	Compound	Phase Type	LAW and HLW Melters	LAW and HLW Submerged Bed Scrubber	LAW and HLW WESP	HLW HEME	LAW Caustic Scrubber	LAW and HLW HEPA (First)	LAW and HLW HEPA (Second)	LAW and HLW Thermal Catalytic Oxidizer
100-21-0	p-Phthalic acid	Particle	1.1	40	11	90	1	2000	100	20
88-89-1	Picric acid	Particle	1.1	40	11	90	1	2000	100	20
144-62-7	Oxalic acid	Vapor	1.1	1	1	1	1	1	1	20
75-12-7	Formamide	Vapor	1.1	1	1	1	1	1	1	20
60-35-5	Acetamide	Vapor	1.1	1	1	1	1	1	1	20
87-68-3	Hexachlorobutadiene	Particle	1.1	40	11	90	1	2000	100	20
126-73-8	Tributyl phosphate	Vapor	1.1	1	1	1	1	1	1	20
108-95-2	Phenol	Particle	1.1	40	11	90	1	2000	100	20
84-66-2	Diethyl phthalate	Particle	1.1	40	11	90	1	2000	100	20
62-75-9	N-Nitroso-N, N-dimethylamine	Vapor	1.1	1	1	1	1	1	1	20
122-39-4	N, N-Diphenylamine	Vapor	1.1	1	1	1	1	1	1	20
4170-30-3	2-Butenaldehyde (2-Butenal or Crotonaldehyde)	Vapor	1.1	1	1	1	1	1	1	20
58-90-2	2, 3, 4, 6-Tetrachlorophenol	Particle	1.1	40	11	90	1	2000	100	20
98-86-2	Acetophenone	Particle	1.1	40	11	90	1	2000	100	20
57-14-7	1, 1-Dimethylhydrazine	Vapor	1.1	1	1	1	1	1	1	20
120-12-7	Anthracene	Particle	1.1	40	11	90	1	2000	100	20
75-05-8	Acetonitrile	Vapor	1.1	1	1	1	1	1	1	20
208-96-8	Acenaphthylene	Vapor	1.1	1	1	1	1	1	1	20

Table 7.1-9 LAW and HLW Facility Organics Decontamination Factors

CAS#	Compound	Phase Type	LAW and HLW Melters	LAW and HLW Submerged Bed Scrubber	LAW and HLW WESP	HLW HEME	LAW Caustic Scrubber	LAW and HLW HEPA (First)	LAW and HLW HEPA (Second)	LAW and HLW Thermal Catalytic Oxidizer
132-64-9	Dibenzofuran	Vapor	1.1	1	1	1	1	1	1	20
106-93-4	Ethylene dibromide	Vapor	1.1	1	1	1	1	1	1	20
91-20-3	Naphthalene	Particle	1.1	40	11	90	1	2000	100	20
120-82-1	1, 2, 4-Trichlorobenzene	Particle	1.1	40	11	90	1	2000	100	20
10061-01-5	cis-1, 3-Dichloropropene	Vapor	1.1	1	1	1	1	1	1	20
108-88-3	Toluene	Vapor	1.1	1	1	1	1	1	1	20
71-43-2	Benzene	Vapor	1.1	1	1	1	1	1	1	20
79-01-6	Trichloroethylene	Vapor	1.1	1	1	1	1	1	1	20
127-18-4	Perchloroethylene (tetrachloroethylene)	Vapor	1.1	1	1	1	1	1	1	20
56-23-5	Carbon tetrachloride	Vapor	1.1	1	1	1	1	1	1	20
106-99-0	1, 3-Butadiene	Vapor	1.1	1	1	1	1	1	1	20
110-82-7	Cyclohexane	Vapor	1.1	1	1	1	1	1	1	20
108-87-2	Methylcyclohexane	Vapor	1.1	1	1	1	1	1	1	20
106-97-8	Butane	Vapor	1.1	1	1	1	1	1	1	20
110-54-3	n-Hexane	Vapor	1.1	1	1	1	1	1	1	20
111-84-2	n-Nonane	Vapor	1.1	1	1	1	1	1	1	20
76-15-3	Chloropentafluoroethane	Vapor	1.1	1	1	1	1	1	1	20
50-32-8	Benzo(a)Pyrene	Particle	1.1	40	11	90	1	2000	100	20
84-74-2	Dibutyl phthalate	Particle	1.1	40	11	90	1	2000	100	20
603-34-9	Triphenylamine	Vapor	1.1	1	1	1	1	1	1	20

Table 7.1-9 LAW and HLW Facility Organics Decontamination Factors

CAS#	Compound	Phase Type	LAW and HLW Melters	LAW and HLW Submerged Bed Scrubber	LAW and HLW WESP	HLW HEME	LAW Caustic Scrubber	LAW and HLW HEPA (First)	LAW and HLW HEPA (Second)	LAW and HLW Thermal Catalytic Oxidizer
129-00-0	Pyrene	Particle	1.1	40	11	90	1	2000	100	20
1336-36-3	Polychlorinated biphenyls (PCB)	Particle	1.1	40	11	90	1	2000	100	20

Table 7.1-10 Henry's Law Constants for Organics

CAS Registry Number	Compound	H Constant ($atm*m^3/mol$)	H Constant ($bar*m^3/kgmol$)	Temperature Dependence Value (K)
100-21-0	p-Phthalic acid	3.88E-13	3.93E-10	n/a
10061-01-5	cis-1, 3-Dichloropropene	2.71E-03	2.75E+00	n/a
106-93-4	Ethylene dibromide (Dibromoethane)	6.67E-04	6.76E-01	3900
106-97-8	Butane	8.33E-01	8.44E+02	3100
106-99-0	1, 3-Butadiene	7.14E-02	7.24E+01	4500
108-87-2	Methylcyclohexane	1.03E-01	1.04E+02	9400
108-88-3	Toluene	5.56E-03	5.63E+00	4100
108-95-2	Phenol	3.45E-07	3.49E-04	6800
110-54-3	n-Hexane	1.00E+00	1.01E+03	7500
110-82-7	Cyclohexane	1.79E-01	1.81E+02	3200
111-84-2	n-Nonane	4.17E-01	4.22E+02	210
120-12-7	Anthracene	2.86E-05	2.90E-02	4000
120-82-1	1, 2, 4-Trichlorobenzene	2.17E-03	2.20E+00	4000
122-39-4	N, N-Diphenylamine	2.69E-06	2.73E-03	n/a
126-73-8	Tributyl phosphate	1.41E-06	1.43E-03	n/a
127-18-4	Perchloroethylene (tetrachloroethylene)	1.69E-02	1.72E+01	4800
129-00-0	Pyrene	1.19E-05	1.21E-02	n/a
132-64-9	Dibenzofuran	2.13E-04	2.16E-01	n/a
1336-36-3	Polychlorinated biphenyls (PCBs)	4.15E-04	4.20E-01	n/a
144-62-7	Oxalic acid	1.43E-10	1.45E-07	n/a
208-96-8	Acenaphthylene	1.14E-04	1.16E-01	n/a
4170-30-3	2-Butenaldehyde (2-Butenal or Crotonaldehyde)	1.67E-05	1.69E-02	3600

Table 7.1-10 Henry's Law Constants for Organics

CAS Registry Number	Compound	H Constant ($atm*m^3/mol$)	H Constant ($bar*m^3/kgmol$)	Temperature Dependence Value (K)
50-32-8	Benzo(a)pyrene	4.55E-07	4.61E-04	4700
56-23-5	Carbon tetrachloride	2.94E-02	2.98E+01	4200
57-14-7	1, 1-Dimethylhydrazine	1.29E-05	1.31E-02	n/a
58-90-2	2, 3, 4, 6-Tetrachlorophenol	8.84E-06	8.96E-03	n/a
603-34-9	Triphenylamine	5.41E-06	5.48E-03	n/a
60-35-5	Acetamide	1.12E-08	1.13E-05	n/a
62-75-9	N-Nitroso-N, N-dimethylamine (Dimethylnitrosamine)	1.82E-06	1.84E-03	n/a
71-43-2	Benzene	5.26E-03	5.33E+00	3800
75-05-8	Acetonitrile	2.08E-05	2.11E-02	4000
75-12-7	Formamide	1.39E-09	1.41E-06	n/a
76-15-3	Chloropentafluoroethane	2.94E+00	2.98E+03	2800
79-01-6	Trichloroethylene	1.00E-02	1.01E+01	4600
84-66-2	Diethyl phthalate	8.33E-07	8.44E-04	5600
84-74-2	Dibutyl phthalate	1.81E-06	1.83E-03	n/a
87-68-3	Hexachlorobutadiene	1.01E-02	1.02E+01	4700
88-89-1	Picric acid	1.70E-11	1.72E-08	n/a
91-20-3	Naphthalene	4.76E-04	4.83E-01	3600
98-86-2	Acetophenone	9.09E-06	9.21E-03	6000
193-39-5	Indeno(1,2,3-cd)pyrene	3.45E-07	3.49E-04	3600
319-85-7	beta-BHC (Benzene-cis-hexachloride)	4.40E-07	4.46E-04	n/a
59-89-2	N-Nitrosomorpholine	2.45E-08	2.48E-05	n/a
64-18-6	Formic Acid	1.12E-07	1.14E-04	6100

Table 7.1-10 Henry's Law Constants for Organics

CAS Registry Number	Compound	H Constant ($atm*m^3/mol$)	H Constant ($bar*m^3/kgmol$)	Temperature Dependence Value (K)
64-19-7	Acetic Acid	2.44E-07	2.47E-04	6300
87-86-5	2,3,4,5,6-Pentachlorophenol	9.09E-05	9.21E-02	1300
101-84-8	Diphenyl ether	2.79E-04	2.83E-01	n/a
1321-64-8	Pentachloronaphthalene	1.18E-04	1.20E-01	n/a
206-44-0	Fluoranthene	9.09E-06	9.21E-03	6900
218-01-9	Chrysene (1,2,5,6-Dibenzonaphthalene)	5.23E-06	5.30E-03	n/a
26140-60-3	Terphenyls (m-Terphenyl)	3.18E-05	3.22E-02	n/a
309-00-2	Aldrin	4.45E-05	4.51E-02	n/a
3697-24-3	5-Methylchrysene	5.53E-06	5.60E-03	n/a
58-89-9	Lindane (Hexachlorane)	3.57E-06	3.62E-03	5500
60-57-1	Dieldrin	1.00E-05	1.01E-02	n/a
621-64-7	Di-n-Propylnitrosamine (N-Nitroso-di-n-propylamine)	5.38E-06	5.45E-03	n/a
76-44-8	Heptachlor	2.94E-04	2.98E-01	n/a
8001-35-2	Campheclor (Chlorinated Camphene)	6.00E-06	6.08E-03	n/a
83-32-9	Acenaphthene	2.44E-04	2.47E-01	2800
118-74-1	Hexachlorobenzene	4.76E-04	4.83E-01	5800
95-50-1	o-Dichlorobenzene (1,2-Dichlorobenzene)	1.82E-03	1.84E+00	5900
88-85-7	4,6-Dinitro-2-sec-butylphenol	4.56E-07	4.62E-04	n/a

8 Energy Balance (Deleted)

8.1 Energy Balance (Deleted)

9 Radioactive Solid Waste Management

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9.1 System RSW: Radioactive Solid Waste Management

9.1.1 Function and Requirements

The current baseline Radioactive Solid Waste System (RSW) per the WTP Contract (DE-AC27-01RV14136 [DOE 2000]), consists of a group of localized facilities known as the WTP where secondary solid waste is routinely generated. These sites include the Pretreatment (PT) Facility, the High-Level Waste (HLW) Facility, the Low-Activity Waste (LAW) Facility, and the Analytical Laboratory. In addition, the RSW system consists of a transfer pad for preparation of spent melters for shipment to disposal, and retention of the original baseline failed melter storage facility.

Definition

In this document, secondary solid waste is defined as any non-product, non-immobilized LAW or non-immobilized HLW radioactive solid waste stream that is not recycled back into the process. Spent high-efficiency particulate air (HEPA) filters, melter bubblers, or ion exchange resins are typical examples of secondary solid waste streams. Also included in this definition are spent HLW and LAW melters that have been packaged for transportation and/or disposal per the requirements of *ICD-03-Interface Control Document for Radioactive Solid Waste* (ICD 03) (24590-WTP-ICD-MG-01-003).

The WTP *Statement of Work* (SOW) (DE-AC27-01RV14136), Facility Specification, Section C.7(a)(5) states the following:

> *Disposition all secondary wastes in accordance with ICD requirements; secondary wastes are identified in Section C.9, Interface Control Documents and Standard 6, Product Qualification, Characterization and Certification.*

ICD-03 has been developed to govern the packaging and transfer of radioactive solid wastes.

WTP SOW Facility Specification, Section C.7 (a)(15) states:

> *[Minimize:]*
> *(ii) Generation of secondary wastes, including: Radioactive Solid Wastes, Dangerous Wastes, Non-Radioactive, Non-Dangerous Liquid Effluents; Radioactive, Dangerous Liquid Effluents....*

The purpose of the RSW system is to package the facility's generated wastes locally for transportation to a processor away from the WTP site.

9.1.2 Process Description

Secondary solid wastes are generated throughout the WTP site in every area where waste processing takes place.

Tank Farm waste is pumped to the PT Facility, where it is subjected to a number of processing steps including ultrafiltration, ion exchange, and mixing. As a result of these waste processing activities, fouled or worn ultrafilter membranes (UFP-FILT-00001A/B, 00002A/B, 00003A/B) and spent ion exchange resins (CXP-IXC-00001, 00002, 00003, 00004) are produced as process expendables. Additionally, spent HEPA cartridges are produced by the process vessel vent systems (10-PVV-HEPA-

00001A/B/C, 00002A/B/C) and pulse jet vessel mixers (10-PJV-HEPA-00001A/B/C/D/E/F/G, 00002A/B/C/D/E/F, 00003A/B). There are also a number of waste streams produced during PT maintenance. These include worn pipe jumpers, failed mechanical or instrumentation equipment, and degreasing or decontamination materials. The resultant solid wastes are contact or remotely handled, as applicable, and placed into drums (HEPA cartridges, failed equipment, decontamination materials), boxes (ultrafilter modules, pipe jumpers), or are sluiced into high-integrity containers and dewatered (ion exchange resins). After the filtration and maintenance wastes have been securely packaged, they are transferred by the Tank Farm Contractor (TFC) across the interface point (ICD-03) to the Hanford central remote processing site for stabilization and, if necessary, repackaged for disposal. The stabilized wastes are then transported to the Hanford burial ground. After dewatering the resins, they are transferred to the TFC across the interface point for further treatment, if needed, before disposal. For more detailed information, see Figure 9.1-1 and Section 9.1.3.2.1.

LAW melter feed streams are sent to the LAW Facility for processing in the melters. As a result of processing waste through the LAW melter system, solid and liquid secondary wastes are produced. Melter operation directly produces a number of waste products. Offgas from operation of the melters passes through a number of components of the offgas treatment system which result in the production of contaminated solid and liquid waste byproducts. Maintenance of the LAW Facility results in additional contaminated solid wastes. The LAW vitrification process (LMP-MLTR-00001, 00002) produces expended melter bubbler/thermowell wastes and periodically, spent melters. Operation of the melter offgas and vent system produces loaded, or occasionally failed, HEPA filters (LVP-HEPA-00001A/B/C/D/E/F, 00002A/B/C/D/E/F, 00003A/B/C/D/E/F, 00004A/B/C/D/E/F), expended sulfur-carbon adsorbent modules (LVP-ADBR-00001), fouled or damaged scrubber packing (LVP-SCB-00001), fouled thermal catalytic modules (LVP-SCO-00001), and fouled selective catalytic reduction modules (LVP-SCR-00001, 00002). LAW Facility maintenance operations produce spent grit blasting material and other decontamination materials, worn or fouled pipe jumpers, and failed process equipment. There are also spent HEPA filters produced from the operation of the LAW Secondary Offgas/Vessel Vent Process System (LVP). The solid wastes (e.g., HEPA cartridges, failed equipment, decontamination materials) are remotely handled and placed into drums, while other solid wastes (bubblers/thermowells, catalyst modules, pipe jumpers) are remotely handled and placed into boxes. After the filtration, sorption, or maintenance wastes have been securely packaged in accordance with the current version of the *Hanford Site Solid Waste Acceptance Criteria* (HSSWAC [CHPRC 2010]), they are transferred by the TFC across the interface point (ICD-03) to the Hanford central remote processing site for stabilization and, if necessary, repackaging for disposal. The stabilized wastes are then transported to the Hanford burial ground. The LAW Facility is projected to produce about nine spent melters over the course of the 20-year life cycle. This consists of two spent melters every 5 years plus one additional melter as a contingency. The spent LAW melters are packaged for transportation, moved to the transfer pad, and then transferred to the TFC across the interface point and are delivered directly to the burial ground. For more detailed information, see Figure 9.1-1 and Section 9.1.3.2.2.

HLW melter feed streams are sent to the HLW Facility for processing in the HLW melters. As a result of vitrifying the HLW streams, contaminated secondary wastes are produced. Solid secondary wastes produced by the melters (HMP-MLTR-00001/00002) include failed or expended melter bubblers and thermowells. In addition, each melter line is expected to produce one spent melter every 5 years. The operation of the melters produces offgas which passes through a number of components of the HLW Melter Offgas Treatment System (HOP) and results in the production of contaminated waste byproducts. The HOP offgas system produces solid wastes such as spent HEPA filters (HOP-HEPA-00001A/B and HOP-HEPA-00002A/B), spent sulfur-carbon adsorbent (HOP-ADBR-00001), spent silver mordenite adsorbent (HOP-ABS-00002), and fouled thermal catalyst (HOP-SCO-00001) and selective reduction catalyst (HOP-SCR-00001) modules. HLW Facility maintenance operations produces worn or fouled

pipe jumpers, and failed equipment. Additionally, spent HEPA filters (PJV-HEPA-00004A/B and PJV-HEPA-00005A/B) are discharged from the vessel pulse jet vent system. The solid wastes (e.g., HEPA cartridges, failed equipment, decontamination materials) are remotely handled and placed into drums, while other solid wastes (e.g., bubblers, thermowells, catalyst modules, pipe jumpers) are remotely handled and placed into boxes. After the filtration, sorption, and maintenance wastes have been securely packaged in accordance with the current version of the HSSWAC, they are transferred to the TFC across the interface point (ICD-03) to the Hanford central remote processing site for stabilization and, if necessary, repackaging for disposal. The stabilized wastes are then transported to the Hanford burial ground. The HLW Facility is projected to produce about nine spent melters over the course of the 20-year life cycle. This consists of two spent melters every 5 years plus one additional melter as a contingency. The spent HLW melters are shielded and encapsulated, and then moved to the transfer pad where they are transferred by the TFC across the interface point and are delivered directly to the burial ground for disposal. For more detailed information, see Figure 9.1-1 and Section 9.1.3.2.3.

9.1.3 Basis

The basis for operation of the radioactive solid waste system is to ensure that contaminated secondary solid wastes are disposed in accordance with the intent of the WTP SOW (DE-AC27-01RV14136), Facility Specifications C.7(a)(5) and C.7(a)(15) with regard to waste disposition and minimization, see Section 9.1.1. In general, the requirements are to have a clear path to disposal for all non-recycled secondary wastes and to minimize, to the greatest extent practicable, the volume of wastes sent for disposal.

The design basis for the Radioactive Solid Waste System (RSW) system is as follows: two LAW melters, each capable of producing 15 metric tons of glass (MTG) per day and two HLW melters each producing up to 3.75 MTG/day.

9.1.3.1 General

The RSW system is designed to remove the wastes from the point of generation and collect the wastes at the respective facility export area. At the facility export area the wastes will be packaged for transfer to the Hanford remote waste processing facility, or in select cases, to the Hanford disposal site. Waste is designated as contact handled (CH) if the dose rate on the container surface is less than 200 mrem/h; otherwise, the waste is designated as remote handled (RH). The dominant waste streams by volume in RH category are Cs ion exchange resins generated at the PT Facility, offgas and hot cell HEPAs, high-efficiency mist eliminator filters, and melter expendables. All solid secondary radioactive waste streams generated in the PT, LAW, and HLW facilities will be handled in this manner.

9.1.3.2 System RSW

9.1.3.2.1 Pretreatment RSW

The PT Facility generates solid secondary waste streams during the separation and conditioning of the Tank Farm wastes. Processed LAW waste product is sent to LAW melter feed. Processed HLW waste product is sent to HLW melter feed. The resultant PT secondary solid waste streams, such as filters, resins, or failed equipment, are not recycled into the treatment process, but are instead packaged for transfer to remote treatment and/or disposal. The secondary waste streams of concern are radioactively contaminated, some of which may also meet the State of Washington standards for dangerous wastes. Nonradioactive wastes will be handled by offsite contractors.

Figure 9.1-1 tracks the disposition of PT secondary solid waste streams. Typical secondary waste streams come from the following PT sources: spent HEPA filters that are used to remove particulate contamination from the PT vessel vent and extraction system (Process Vessel Vent Exhaust System [PVV]/Pretreatment Vessel Vent Process System [PVP]); spent ion exchange resin discharged from the Cesium Ion Exchange Process System (CXP); fouled or damaged membrane modules from the Ultrafiltration Process System (UFP); and miscellaneous parts, decontamination materials, and debris from PT maintenance operations throughout the facility. The solid wastes are collected in the maintenance cave, spent resin dewatering area (see Section 2.1.1, System RDP: Spent Resin Collection and Dewatering Process, for more detail), and the filter cave. All secondary waste streams are sent to the PT waste export area for packaging. HEPA filters are placed in enclosed metal filter baskets when first removed and then transported to the export area, where they are placed into 55-gal drums and lidded. Spent ion exchange resins are eluted to the lowest radionuclide concentration reasonably achievable, in the ion exchange vessel, then are sluiced into high-integrity container, located in the resin dewatering area, and are dewatered to meet site standards for free water content. Fouled ultrafilter modules are sheared and put into standard waste disposal boxes and transferred to the export area. Worn parts and failed equipment are put into metal waste baskets and transferred to the export area where the baskets are put into drums.

Any wastes not meeting the land disposal restrictions (LDR) requirements will be transferred, after packaging, across an interface point (as defined in ICD-03) by the TFC to the Hanford central remote facility for processing. There the wastes will be processed, usually by encapsulation, to an acceptable waste form to meet LDR requirements. Upon completion of stabilization, the waste is, if necessary, repackaged, excluding resins, and transported by the TFC to the Hanford disposal site. Spent ion exchange resin will be placed into high-integrity containers, dewatered, and transported by the TFC across the interface point. Dewatered resins in high-integrity containers currently meet LDR requirements, per the baseline.

See Table 9.1-1, which shows the facility generating the expected RSW streams, waste stream description, mixed waste, debris waste, number of drums or containers, waste volume, and potential treatment for the waste.

9.1.3.2.2 LAW RSW

The LAW Facility generates secondary solid waste streams during the preparation and treatment of the Tank Farm wastes. Secondary solid waste streams are not recycled into the vitrification process, but are packaged for transfer to treatment and/or disposal. The secondary waste streams of concern are those that are contaminated with radionuclides. Some of these waste streams may also meet the State of Washington standards for dangerous wastes.

Figure 9.1-1 tracks the disposition of secondary solid waste. Typical waste streams come from various locations in the LAW Facility. The LAW LVP system produces spent HEPA filter cartridges, carbon absorbent, caustic scrubber packing, and catalyst modules. The LAW Melter Process System (LMP) produces failed bubblers/thermowells and spent melters. Maintenance operations will produce the balance of the waste streams. The waste streams are all sent to the LAW container export area for packaging. HEPA filters are placed in enclosed metal filter baskets when removed and transported to the export area, where they are placed into drums and lidded. Sorbent and catalyst modules are placed into boxes and transferred to the export area. Worn parts and failed equipment are put into waste baskets and transferred to the export area, where they are put in drums. Spent LAW melters are packaged to meet transportation, HSSWAC, and LDR requirements. Spent melters are moved to the transfer pad and transferred across the interface to the TFC for disposal in the Hanford low level waste trench.

After packaging, wastes not meeting the LDR requirements, except for LAW spent melters, are transferred across an interface point (as defined in ICD-03) to the Hanford central remote facility for processing to an acceptable waste form to meet LDR requirements. Upon completion of stabilization, the waste is repackaged if necessary, and transported by the TFC to the Hanford disposal site.

See Table 9.1-1, which shows the facility generating the expected RSW streams, waste stream description, mixed waste, debris waste, number of drums or containers, waste volume, and potential treatment for the waste.

9.1.3.2.3 HLW RSW

The HLW Facility generates secondary solid waste streams during the preparation and vitrification of the Tank Farm wastes. HLW secondary solid waste streams are not recycled into the vitrification process, but are instead packaged for transfer to remote treatment and/or disposal. The secondary waste streams of concern are those that are contaminated with radionuclides. Some of these waste streams may also meet the State of Washington standards for dangerous wastes.

Figure 9.1-1 tracks the disposition of HLW secondary solid waste streams. Typical waste streams come from the following HLW sources: spent HEPA filters, silver mordenite, carbon absorbent, and catalyst from the HLW HOP system; HEPA filters from the Pulse Jet Ventilation System (PJV); failed bubblers and thermowells from the HLW Melter Process System (HMP); spent melters from the HMP system; and miscellaneous parts and debris from maintenance operations. The waste streams are all sent to the HLW waste transfer area for packaging. HEPA filters are placed in enclosed metal filter baskets when removed and transported to the export area where they are placed into drums and lidded. Sorbent and catalyst modules are placed into boxes and transferred to the export area. Worn parts and failed equipment are put into waste baskets and transferred to the export area, where they are put in drums. Spent HLW melters are encapsulated and packaged to meet LDR requirements prior to transfer to the melter transfer pad. At the pad, the melters are transferred to the TFC and transported to the Hanford trench for disposal.

After packaging, waste not meeting the LDR requirements, with the exception of HLW spent melters, will be transferred across an interface point (as defined in ICD-03) to the Hanford central remote facility for processing to an acceptable waste form. Upon completion of stabilization the waste is repackaged, if necessary, and transported by the TFC to the disposal site.

See Table 9.1-1, which shows the facility generating the expected RSW streams, waste stream description, mixed waste, debris waste, number of drums or containers, waste volume, and potential treatment for the waste.

9.1.4 Ongoing Work and Potential Changes

None identified.

9.1.5 References

40 CFR 268, Title 40. *Land Disposal Restrictions*, Code of Federal Regulations.

24590-BOF-RPT-G-03-001, Rev 0, *Radioactive Solid Waste Disposition Study.*

24590-HLW-3YD-HOP-00001, Rev 2, *System Description for the HLW Melter Offgas Treatment Process and Process Vessel Vent Exhaust (HOP and PVV Systems).*

24590-HLW-3YD-PJV-00001, Rev 3, *System Description for the HLW Pulse Ventilation System (System PJV).*

24590-LAW-3YD-LOP-00001, Rev 3, *System Description for the LAW Primary Offgas (LOP) and Secondary Offgas/Vessel Vent (LVP) Systems.*

24590-PTF-3YD-PFH-00001, Rev 1, *System Description for the Pretreatment Filter Cave Handling System (PFH).*

24590-PTF-3YD-PJV-00001, Rev 0, *System Description for the PTF Pulse Jet Ventilation System (PJV).*

24590-PTF-3YD-PVP-00001, Rev 1, *System Description for Pretreatment Vessel Vent Process System, PVP.*

24590-PTF-3YD-PVV-00001, Rev 0, *System Description for the Pretreatment Vessel Vent Exhaust System (PVV).*

24590-PTF-3YD-RDP-00001, Rev 1, *System Description for the Spent Resin Collection and Dewatering Process System (RDP).*

24590-WTP-3YD-RWH-00001, Rev 3, *System Description for the WTP System RWH Radioactive Solid Waste Handling.*

24590-WTP-ICD-MG-01-003, Rev 3, *ICD-03-Interface Control Document for Radioactive Solid Waste.*

24590-WTP-ICF-M-03-001, *ICD-3: Updated Projection of WTP Melters Requiring Disposal.*

24590-WTP-RPT-ENS-10-010, Rev 0, *WTP Estimate of Secondary Radioactive Solid Waste Generation.*

24590-WTP-RPT-PET-07-003, Rev 0, *Waste Treatment Plant Reliability Availability Maintainability (RAM) Basis Report.*

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DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

CHPRC. 2010. CH2M Hill, *Hanford Site Solid Waste Acceptance Criteria*, HNF-EP-0063, Rev 15, Richland, WA, February 2010.

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
REMOTE HANDLED TRU MIXED WASTE (RH-TRUM)							
55 - GALLON DRUMS							
2 YEAR + GENERATION FREQUENCY							**RH-TRUM**
HLW	HMP Melter Discharge Chamber Thermowells	X	X	4	1.0	Volume reduction and Category 3 radioactive waste stabilization	Actual generation frequency is predicted to be every 2.5 years.
Waste Totals: 4 drums (1 m^3) every 2.5 years							
CONTACT HANDLED TRU MIXED WASTE (CH-TRUM)							
MELTER OVERPACK							
5 YEAR GENERATION FREQUENCY							**CH-TRUM**
HLW	Spent High-Level Melter	X	X	2	245.1	Transfer to CWC for storage for WIPP certification and disposal	External dose rate on the melter overpack allows the package contact handled.
Waste Totals: 2 melter overpacks (245.1 m^3) every 5 years							
REMOTE HANDLED CATEGORY 3 MIXED WASTE (RH-MLLW-3)							
55 - GALLON DRUMS							
1 YEAR GENERATION FREQUENCY							**RH-MLLW-3**
HLW	HMP Glass Bubblers	X	X	84	21.6	Volume reduction and Category 3 radioactive waste stabilization	Includes IHLW glass shards from the canister fill HEPA vacuum

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
HLW	HMP Pool Thermowells	X	X	3	0.8	Volume reduction and Category 3 radioactive waste stabilization	Includes IHLW glass shards from the canister fill HEPA vacuum
HLW	HMP Glass Pool Level Detectors	X	X	3	0.8	Volume reduction and Category 3 radioactive waste stabilization	Includes IHLW glass shards from the canister fill HEPA vacuum
HLW	Miscellaneous metal parts - HLW hotcell jumpers, pumps, valves, canister weld heads, in-cave tools (nutrunners), tubing, cables, Isolok needles and parts, and other metal debris	X	X	22	5.7	Volume reduction and Category 3 radioactive waste stabilization	Determination that these wastes are RH is based on limited decontamination capabilities and throughput.
HLW	Miscellaneous metal debris wastes including MSM hands, in-cave tools, decontamination pumps	X	X	4	1.0	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction may be need to package miscellaneous HSH compactable debris in a 55 gallon drum.
HLW	Miscellaneous HSH compactable debris wastes including HSH MSM boots, central vacuum filters, vacuum gaskets, vacuum hoses, hydraulic hose reel	X	X	2	0.5	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction may be needed to package miscellaneous HSH compactable debris.
Waste Totals: 118 drums (30.4 m^3) every year							
5 YEAR GENERATION FREQUENCY							**RH-MLLW-3**
PTF	PVP HEPA filters	X	X	9	2.3	Volume reduction and Category 3 radioactive waste stabilization	

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
HLW	HOP HEPA Filters	X	X	16	4.1	Volume reduction and Category 3 radioactive waste stabilization	
HLW	PJV HEPA Filters	X	X	40	10.3	Volume reduction and Category 3 radioactive waste stabilization	
HLW	HFP Melter Feed ADS pumps (total of 4 ADS pumps)	X	X	10	2.6	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction required. ADS pumps will be packaged in 55 gallon drums and assumes 2.5 drum for each ADS pump.
HLW	HOP HEME Cartridges	X	X	100	25.7	Volume reduction and Category 3 radioactive waste stabilization	
HLW	Miscellaneous HSH metal debris wastes including jumpers, HSH MSM hands, in-cave tools, decontamination pumps	X	X	1	0.3	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction may be need to package miscellaneous HSH compactable debris in a 55 gallon drum.
HLW	Miscellaneous HSH compactable debris wastes including HSH manipulator boots, central vacuum filters, vacuum gaskets, vacuum hoses, hydraulic hose reel, etc.	X	X	25	6.4	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction may be needed to package miscellaneous HSH compactable debris.
Waste Totals: 205 drums (52.7 m^3) every 5 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
10 YEAR GENERATION FREQUENCY							**RH-MLLW-3**
HLW	Miscellaneous HSH metal debris wastes including jumpers, HSH MSM hands, in-cave tools, decontamination pumps	X	X	4	1.0	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction may be needed to package miscellaneous HSH compactable debris in a 55 gallon drum.
HLW	Miscellaneous HSH compactable debris wastes including HSH MSM boots, central vacuum filters, vacuum gaskets, vacuum hoses, hydraulic hose reel	X	X	9	2.3	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction may be needed to package miscellaneous HSH compactable debris.
Waste Totals: 13 drums (3.3 m^3) every 10 years							
CS IX HIGH INTEGRITY CONTAINER - HIC (6' × 6' × 6')							
1 YEAR GENERATION FREQUENCY							**RH-MLLW-3**
PTF	CXP IX Resin	X		4	24.5	Stabilization (STABL[5]) for RCRA metals and Category 3 radioactive waste stabilization	Possible WA only toxic waste
Waste Totals: 4 HICs (24.5 m3) every year							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
CONTACT HANDLED CATEGORY 3 MIXED WASTE (CH-MLLW-3)							
MELTER OVERPACK							
5 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
LAW	Spent Low-Activity Melter	X	X	2	619.1	Transfer to IDF for treatment (if required, e.g. macroencapsulation) and disposal	
Waste Totals: 2 melter overpacks (619.1 m^3) every 5 years							
55 - GALLON DRUM							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
LAB	Hotcell prefilters	X		46	11.8	Volume reduction and Category 3 radioactive waste stabilization	If designates as characteristic mixed waste, otherwise classified as CH-LLW-3.
LAB	Radiological lab miscellaneous compactable debris	X	X	298	76.6	Volume reduction	Estimate based on lab glassware and other lab consumables, PPE, rags, and other compactable debris.
LAB	Miscellaneous hotcell compactable debris including sample bottles, ASX carriers, Isolok needles and parts, etc.	X	X	201	51.7	Volume reduction and macroencapsulation	Estimate based on hotcell lab glassware and other compactable lab consumables.

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
LAB	Eichrom resin columns (hotcell resins)	X		6	1.5	Thermal treatment at a commercial TSD	Assumed to be mixed non-debris waste (organic waste stream that will require organic stabilization or thermal treatment).
Waste Totals: 551 drums (141.6 m^3) every year							
2 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Large hotcell instrument jumpers	X	X	4	1.0	Volume reduction and Category 3 radioactive waste stabilization	
PTF	Small hotcell instrument jumpers	X	X	5	1.3	Volume reduction and Category 3 radioactive waste stabilization	
PTF	Hotcell electrical flex jumpers	X	X	200	51.4	Volume reduction and Category 3 radioactive waste stabilization	
LAW	LMP - Glass Debris from the Bagging Station	X	X	1	0.3	Stabilization (STABL[5]) for RCRA metals and Category 3 radioactive waste stabilization	Actual generation frequency is predicted to be every 3 years.
Waste Totals: 210 drums (54 m^3) every 2 years							
5 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Miscellaneous hotcell wastes, metal debris, IX feed coolers, UFP Skid frames, misc. hotcell valve internals, size reduction equipment, in-cell tools, etc.	X	X	5	1.3	Volume reduction and Category 3 radioactive waste stabilization	

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
PTF	Ultrafiltration Feed Pumps	X	X	2	14.4	Volume reduction and Category 3 radioactive waste stabilization	Assumes rinsing and decontamination to achieve CH mixed waste classification.
PTF	PJV HEPA filters	X	X	81	20.8	Volume reduction and Category 3 radioactive waste stabilization	
PTF	PVV HEPA filters	X	X	18	4.6	Volume reduction and Category 3 radioactive waste stabilization	
Waste Totals: 106 drums (41.1 m^3) every 5 years							
MB-VI Boxes (5' × 5' × 9')							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Waste feed transfer pump (FRP-PMP-00002A)	X	X	1	7.2	Volume reduction and macroencapsulation	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
HLW	HSH miscellaneous metal debris including main crane cables, crane wire ropes, manipulator belts, MSM arms, decon lances and hoses, hydraulic hose reels, HOP carbon absorber & silver mordenite absorber discharge filters	X	X	11	79.2	Volume reduction and macroencapsulation	Decontamination and size reduction will be needed to package miscellaneous debris.
Waste Totals: 12 MB-VI boxes (86.4 m^3) every year							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
2 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Waste feed evaporator concentration pump (FEP-PMP-00008A/B)	X	X	4	28.8	Volume reduction and macroencapsulation	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
PTF	PTF- HLP Solids Transfer Pumps (HLP-PMP-00017A/B)	X	X	2	14.4	Volume reduction and macroencapsulation	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
PTF	PTF- HLP Melter Feed Pumps (HLP-PMP-00019A/B)	X	X	2	14.4	Volume reduction and macroencapsulation	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
PTF	PTF Hotcell 12" ultrafilter valve jumpers	X	X	4	28.8	Volume reduction and macroencapsulation	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
PTF	PTF- HLP Melter Feed Receipt Transfer Pump (HLP-PMP-00021)	X	X	1	7.2	Volume reduction and macroencapsulation	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 13 MB-VI boxes (93.6 m^3) every 2 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
10 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	UFP Ultrafilter Modules	X	X	5	36.0	Volume reduction and Category 3 radioactive waste stabilization	If dose rate info will support further loading then 2 tubes cut in half (four 6.75 ft pieces could be loaded in each box)
Waste Totals: 5 MB-VI boxes (36.0 m^3) every 10 years							
20 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Large Hotcell Valves and Valve Jumpers	X	X	2	14.4	Volume reduction and Category 3 radioactive waste stabilization	Assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 2 MB-VI boxes (14.4 m^3) every 20 years							
B-25 BOX (4'× 4'× 6')							
4 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Cs IX Feed Pumps	X	X	2	5.8	Volume reduction and macroencapsulation	Actual generation frequency is predicted to be every 4 years.
Waste Totals: 2 B-25 boxes (5.8 m3) every 4 years							
5 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
HLW	HFP - Vessel Feed Pumps	X	X	6	17.4	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction needed. Assumes 1 pump per B-25 box.

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
HLW	HFP Agitator Shafts and Blades (total of 4 agitator shaft assemblies)	X	X	4	11.6	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction needed. Assumes 1 agitator shaft and blade assembly per box.
Waste Totals: 10 B-25 boxes (29.1 m^3) every 5 years							
10 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Small Hotcell Valves and Valve Jumpers	X	X	3	8.7	Volume reduction and Category 3 radioactive waste stabilization	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 3 B-25 boxes (8.7 m^3) every 10 years							
20 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
HLW	HFP - Vessel Feed Pump Drives (total of 6 pump drives)	X	X	6	17.4	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction needed. Assumes 1 pump drive per B-25 box.
HLW	HFP Agitators Drives (total of 4 agitator drives)	X	X	4	11.6	Volume reduction and Category 3 radioactive waste stabilization	Decontamination and size reduction needed. Assumes 1 agitator shaft and blade assembly per box.
Waste Totals: 10 B-25 boxes (29.1 m^3) every 20 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
SEALAND BOX (8' × 8' × 20')							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-3**
PTF	Miscellaneous hotcell wastes, metal debris, IX feed coolers, UFP Skid frames, misc. hotcell valve internals, size reduction equipment, in-cell tools, etc.	X	X	2	64.0	Volume reduction and Category 3 radioactive waste stabilization	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 2 SeaLand boxes (64.0 m^3) per year							
10 YEAR GENERATION FREQUENCY							
PTF	CXP IX Columns	X	X	4	128.1	Volume reduction and macroencapsulation	Assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 4 SeaLand boxes (128.1 m^3) every 10 years							
CONTACT HANDLED CATEGORY 1 MIXED WASTE (CH-MLLW-1)							
LIQUID EFFLUENT							
PTF	RLD Effluent to LERF/ETF	X		NA	~ 500/day (5220 gph)	LERF/ETF treatment (UV Oxidation [CHOXD[5]] and stabilization)	Discharge from PTF RLD-VSL-00006A/B in accordance with the LERF/ETF treatability envelope
Waste Totals: 5220 gallons per hour (500 m^3/day)							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
16 - GALLON DRUM							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
HLW	HSH grease gun cartridges (packed in 16 gallon drums)	X		2	0.2	Volume reduction and macroencapsulation	Organic waste stream that will require organic waste stabilization or thermal treatment
Waste Totals: 2 drums (0.2 m^3) per year							
5 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
HLW/LAW	HFP agitator gearbox oil and HSH organic wastes (gearbox oil, glycol/ hydraulic fluids and cable greases, packed in 16 gallon drums)	X		15	1.1	Thermal treatment at a commercial TSD	Organic waste stream that will require organic waste stabilization or thermal treatment
Waste Totals: 15 drums (1.1 m^3) every 5 years							
55 - GALLON DRUM							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	Miscellaneous metal parts - including jumpers, pumps, valves, and other metal debris, Isolok needles and parts	X		27	6.9	Stabilization (STABL[5]) for RCRA metals, volume reduction and macroencapsulation for radionuclides	Assumes 50 % of wastes packaged in 55 gallon drums and 50 % packaged in B-25 boxes.

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
LAW	LVP HEPA Filters		X	27	6.9	Volume reduction and macroencapsulation	
HLW	HOP Activated (Sulfur) Carbon Bed media	X		90	25.7	Thermal treatment at a commercial TSD (Retorting [RMERC] and Amalgamation [AMLGM][5])	
HLW	HSH miscellaneous metal debris including main crane cables, crane wire ropes, manipulator belts, MSM arms, decon lances and hoses, and hydraulic hose reels	X	X	2	0.5	Volume reduction and macroencapsulation	Decontamination and size reduction may be needed to package miscellaneous HSH compactable debris.
Waste Totals: 146 drums (37.4 m^3) per year							
2 YEAR + GENERATION FREQUENCY							**CH-MLLW-1**
LAW	LVP Sulfur Impregnated Carbon Absorbent Media	X		136	16.7	Thermal treatment at a commercial TSD (Retorting [RMERC] and Amalgamation [AMLGM][5])	
LAB	Miscellaneous non-compactable hotcell debris	X	X	12	3.1	Volume reduction and macroencapsulation	Estimate based on non-compactable debris such as lab microwaves, furnaces, pumps, irreparable manipulators.
Waste Totals: 208 drums (53.6 m^3) every 2 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
5 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
PTF	PVP HEME filter cartridges	X	X	60	15.4	Volume reduction and Category 3 radioactive waste stabilization	
LAW	LVP Caustic Scrubber Mist Eliminator Modules (internal to scrubber)	X	X	20	5.1	Volume reduction and macroencapsulation	
HLW	HOP Silver Mordenite Absorbent media	X		72	18.5	Stabilization (STABL[5]) for RCRA metals and volume reduction and macroencapsulation for radionuclides	
Waste Totals: 152 drums (39 m^3) every 5 years							
10 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
HLW	HSH miscellaneous metal debris including main crane cables, crane wire ropes, manipulator belts, MSM arms, decon lances and hoses, and hydraulic hose reels	X	X	4	1.0	Volume reduction and macroencapsulation	Decontamination and size reduction may be needed to package miscellaneous HSH compactable debris.
Waste Totals: 4 drums (1 m^3) every 10 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
20 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
HLW	HSH miscellaneous metal debris including main crane cables, crane wire ropes, manipulator belts, MSM arms, decon lances and hoses, and hydraulic hose reels	X	X	12	3.1	Volume reduction and macroencapsulation	Decontamination and size reduction may be needed to package miscellaneous HSH compactable debris.
Waste Totals: 12 drums (3.1 m^3) every 20 years							
30 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	LVP Caustic Scrubber Packing	X	X	15	3.9	Volume reduction and macroencapsulation	
Waste Totals: 15 drums (3.9 m^3) every 30 years							
B-25 BOX (4' × 4' × 6')							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	Miscellaneous metal parts - including jumpers, pumps, valves, and other metal debris, Isolok needles and parts	X		3	8.7	Volume reduction and macroencapsulation	Assumes 50 % of wastes packaged in 55 gallon drums and 50 % packaged in B-25 boxes.
Waste Totals: 3 B-25 boxes (8.7 m^3) per year							
2 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	LVP Thermal Catalytic Oxidizer media	X	X	1	2.9	Volume reduction and macroencapsulation	
LAW	LVP Selective Catalytic Reduction media	X	X	1	2.9	Volume reduction and macroencapsulation	
Waste Totals: 2 B-25 boxes (5.8 m^3) every 2 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
3 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
HLW	HOP Selective Catalytic Oxidizer media	X	X	0.5	1.5	Volume reduction and macroencapsulation	Package with HOP Selective Catalytic Reducer in a single B-25 box.
HLW	HOP Selective Catalytic Reducer media	X	X	0.5	1.5	Volume reduction and macroencapsulation	Package with HOP Selective Catalytic Oxidizer in a single B-25 box.
Waste Totals: 1 B-25 box (2.9 m^3) every 3 years							
5 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	LMP Melter Discharge Chamber Thermowells	X	X	1	2.9	Volume reduction and Category 3 radioactive waste stabilization	
Waste Totals: 1 B-25 box (2.9 m^3) every 5 years							
20 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	LAW-Vessel Mounted Pump Drives (LCP, LFP, LOP, RLD) (total of 16 pump drives)	X	X	8	23.2	Volume reduction and macroencapsulation	Assumes 2 pump drives per box. Assumes that some size reduction or disassembly will be required to fit pump assemblies in B-25 box
Waste Totals: 8 B-25 boxes (23.2 m^3) every 30 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
MB-VI BOX (5' × 5' × 9')							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
PTF	Waste Feed Evaporator Feed Pumps (FEP-PMP-00007A/B)	X	X	2	14.4	Volume reduction and macroencapsulation	Waste packaging assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 2 MB-VI boxes (14.4 m^3) per year							
3 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
PTF	PVP Thermal Oxidizer Bed	X	X	1	7.2	Volume reduction and macroencapsulation	
Waste Totals: 1 MB-VI box (7.2 m^3) every 3 years							
5 YEAR GENERATION FREQUENCY							
PTF	Spent Resin Slurry Pumps	X	X	2	14.4	Volume reduction and macroencapsulation	Assumes rinsing and decontamination to achieve CH mixed waste classification.
PTF	Cs IX Feed Coolers	X	X	2	14.4	Volume reduction and macroencapsulation	Assumes rinsing and decontamination to achieve CH mixed waste classification.
PTF	Ultrafiltration Recirculation Pumps	X	X	2	14.4	Volume reduction and macroencapsulation	Assumes rinsing and decontamination to achieve CH mixed waste classification.

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
PTF	PTF - Treated LAW Evaporation Recirculation Pump (TLP-PMP-00001)	X	X	1	7.2	Volume reduction and macroencapsulation	Assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 7 MB-VI boxes (50.4 m^3) every 5 years							
10 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
PTF	UFP Heat Exchangers	X	X	2	14.4	Volume reduction and macroencapsulation	Assumes rinsing and decontamination to achieve CH mixed waste classification.
Waste Totals: 2 MB-VI boxes (14.4 m^3) every 5 years							
S-0480-1376 BOX (4.25' × 4.5' × 12')							
1 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	LMP Melter Pool Bubblers/Thermowells	X	X	18	116.1	Volume reduction and Category 3 radioactive waste stabilization	
LAW	LMP melter consumables - melter glass, pool level detectors, film cooler spray nozzles, differential pressure indicator probe, thermocouple melter refractory (packaged together)	X	X	1	6.5	Volume reduction and Category 3 radioactive waste stabilization	
Waste Totals: 13 S-0480-1376 boxes (122.6 m^3) per year							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
5 YEAR GENERATION FREQUENCY							**CH-MLLW-1**
LAW	Vessel Agitators Shafts and Blade Assemblies (LCP, LFP, LOP, RLD) (Total of 8 agitators)	X	X	4	25.8	Volume reduction and macroencapsulation	Assumes 2 vessel agitator assemblies per box and that some size reduction or disassembly will be required to fit agitators in each S-0480-1376 box.
LAW	LFP Melter Feed ADS (total of 12 ADS pumps)	X	X	2	12.9	Volume reduction and macroencapsulation	Assumes 6 ADS pumps per box and that some size reduction or disassembly will be required to fit ADS pump assemblies in each S-0480-1376 box.
LAW	LAW-Vessel Mounted Pumps (LCP, LFP, LOP, RLD - total of 16 vessel mount pumps)	X	X	8	51.6	Volume reduction and macroencapsulation	Assumes 2 vessel mounted pump per box and that some size reduction or disassembly will be required to fit pump assemblies in each S-0480-1376 box.
Waste Totals: 14 S-0480-1376 boxes (90.3 m^3) every 5 years							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
20 YEAR GENERATION FREQUENCY							
LAW	Vessel Agitator Drives (LCP, LFP, LOP, RLD - total of 8 agitators)	X	X	4	25.8	Volume reduction and macroencapsulation	Assumes 2 vessel agitator drive assemblies per box and that some size reduction or disassembly will be required to fit agitator drives in each S-0480-1376 box.
Waste Totals: 4 S-0480-1376 boxes (25.8 m^3) every 20 years							
CONTACT HANDLED CATEGORY 3 LOW LEVEL WASTE							
16 - GALLON DRUM							
1 YEAR GENERATION FREQUENCY							**CH-LLW-3**
HLW/LAW	HFP agitator gearbox oil and HSH organic wastes (gearbox oil, glycol/ hydraulic fluids and cable greases, packed in 16 gallon drums)	X		44	3.3	Thermal treatment at a commercial TSD	Organic waste stream that will require organic waste stabilization or thermal treatment
HLW	HSH grease gun cartridges (packed in 16 gallon drums)	X		2	0.2	Volume reduction and macroencapsulation	Organic waste stream that will require organic waste stabilization or thermal treatment
Waste Totals: 46 drums (3.5 m^3) per year							

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
55 - GALLON DRUM							
1 YEAR GENERATION FREQUENCY							**CH-LLW-3**
PTF	Miscellaneous compactable debris		X	430	110.5	Volume reduction	Assumed to be CH-LLW only. Approx. 3 drums/day for all facilities (PTF/LAW/HLW/LAB).
LAB	Eichrom resin columns (radiological lab resins)		X	3	0.8	Thermal treatment at a commercial TSD	Assumed to be mixed non-debris waste.
LAB	Spent chemical /reagents (liquid lab pack)	X		4	1.0	Thermal treatment at a commercial TSD	Estimate based on lab packs limited to 15 gallons of liquid per 55 gallon drum.
Waste Totals: 437 drums (112.3 m^3) every year							
5 YEAR GENERATION FREQUENCY							**CH-LLW-3**
PTF	PVV In-bleed HEPA filters		X	8	2.1	Volume reduction and macroencapsulation	CH-LLW-1
PTF	C3 HVAC HEPA filters		X	48	12.3	Volume reduction	CH-LLW-1
PTF	C5 HVAC HEPA prefilters		X	48	12.3	Volume reduction	CH-LLW-3
PTF	C5 HVAC HEPA filters		X	50	12.9	Volume reduction and macroencapsulation	CH-LLW-3
HLW	C5 HVAC HEPA filters		X	82	21.1	Volume reduction and macroencapsulation	RH-LLW-3
LAB	C5 HVAC HEPA filters		X	82	21.1	Volume reduction and macroencapsulation	CH-LLW-3

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
WTP	ASX, glovebox, and HVAC system prefilters		X	12	3.1	Volume reduction and macroencapsulation	CH-LLW-1
Waste Totals: 330 drums (84.9 m^3) every 5 years							
CONTACT HANDLED CATEGORY 1 LOW LEVEL WASTE							
55 - GALLON DRUM							
1 YEAR GENERATION FREQUENCY							**CH-LLW-1**
LAW/HLW/LAB	Miscellaneous compactable debris		X	870	223.6	Volume reduction	Assumed to be CH-LLW only. Approx. 3 drums/day for all facilities (LAW/HLW/LAB).
Waste Totals: 870 drums (223.6 m^3) every year							
5 YEAR GENERATION FREQUENCY							**CH-LLW-1**
PTF	C2 HVAC HEPA filters		X	60	15.4	Volume reduction	Assumed to be CH-LLW only.
LAW	C2 HVAC HEPA filters		X	40	10.3	Volume reduction	CH-LLW-1
LAW	C3 HVAC HEPA filters		X	24	6.2	Volume reduction and macroencapsulation	CH-LLW-1
LAW	C5 HVAC HEPA filters		X	80	20.6	Volume reduction and macroencapsulation	CH-LLW-1
HLW	C2 HVAC HEPA filters		X	84	21.6	Volume reduction	CH-LLW-1
HLW	C3 HVAC HEPA filters		X	42	10.8	Volume reduction	CH-LLW-1
LAB	C2V HEPA filters		X	40	10.3	Volume reduction	CH-LLW-1

Table 9.1-1 WTP Secondary Waste Stream Summary

Generating Facility	Waste Stream Description	Mixed Waste[1]	Debris Waste[2]	Number of Drums or Containers	Waste Volume[3] (m^3)	Potential Treatment[4]	Notes
LAB	C3V HEPA filters		X	56	14.4	Volume reduction and macroencapsulation	CH-LLW-1
Waste Totals: 426 drums (109.6 m^3) every 5 years							

Source: 24590-WTP-RPT-ENS-10-010, *WTP Estimate of Secondary Radioactive Solid Waste Generation.*

1 The terms mixed waste, TRU, CH, RH are provided in the definitions section of the *Hanford Site Solid Waste Acceptance Criteria,* (HSSWAC) HNF-EP-0063. The term Category 3 is provided in the Appendix A 1.4 of the *Hanford Site Solid Waste Acceptance Criteria.*

2 The term debris is provided in the definition section of the Washington Administrative Code Dangerous Waste Regulations, WAC -173-303-040.

3 Waste volume estimates are based on the exterior area of a waste container using container sizes provided in the annual SWIFT database. For example, the volume of a 55 gallon drum is based on an exterior volume of a 55 gallon drum of 0.257 m3 multiplied times the number of containers generated in a given period and rounded to the nearest 0.1 m3.

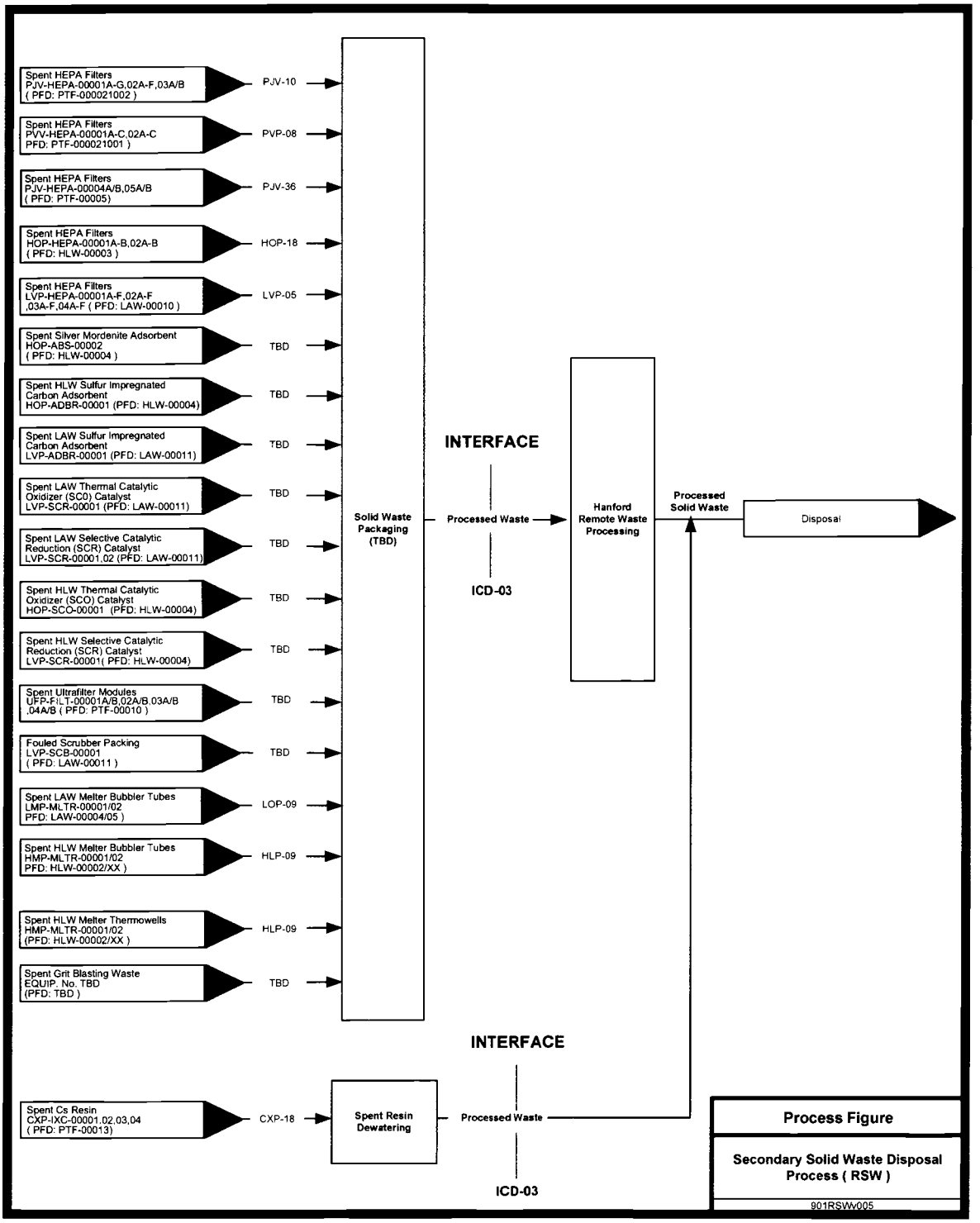
4 Treatment for Category 3 radionuclide and/or mobile radionuclides includes stabilization in concrete or other stabilization agents as defined by U.S. Nuclear Regulatory Commission (NRC) Technical Position Paper on Waste Form, Section C.2 and Appendix A (NRC, 1991). Several Hanford-approved concrete mix formulas have been developed that can be used to meet the stabilization criteria.

5 LDR Treatment Standards are defined in 40 CFR 268.40 (consult table 1, "Technology Codes and Description of Technology-Based Standards" of 40 CFR 268.42 for specifics).

NOTES:

'X' = applicable to this category

Figure 9.1-1 Secondary Solid Waste Disposal Process



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9.2 Systems RLD and NLD: Liquid Effluents

9.2.1 Function and Requirements

The liquid effluent collection and disposal system consists of two subsystems: the radioactive liquid waste disposal system (RLD) and the non-radioactive liquid waste disposal system (NLD).

System RLD receives effluent wastes from; a) Low-Activity Waste (LAW) Facility functional areas: melter primary offgas treatment system (LOP); LAW secondary offgas/vessel vent treatment system (LVP); process wastes, vessel washes, C3/C5 floor drain and sump wastes, and vessel vent header drainage, all of which are expected to have low levels of radioactive contamination; b) High-Level Waste (HLW) Facility functional areas: primary and secondary offgas treatment (HOP) and HLW canister decontamination handling system (HDH), vessel washes, offgas drains, laboratory effluents, and C3/C5 floor drains and sumps system; and c) Pretreatment (PT) sources: RLD system vessels and tanks, which are primarily concerned with the collection of solutions that may be discharged to Liquid Effluent Retention Facility/Effluent Treatment Facility (LERF/ETF), such as process condensates from evaporators, caustic waste from the LAW caustic scrubber, and spent reagents from the resin addition process.

The NLD system for LAW and HLW facilities receives effluent from the C1/C2 floor drains and sump systems; the effluent from these systems is expected to have no radioactive contamination. The purpose of the system is to receive routine process effluents for interim storage and sample for measuring radioactive contamination. After the contents have been determined to be free of radiological contamination, the effluents are transferred to the Balance of Facilities (BOF) for ultimate disposal at Treated Effluent Disposal Facility (TEDF). If radioactive contamination is detected, the contents are transferred to the PT Facility (treated LAW evaporator) for processing.

The following is stated in the WTP *Statement of Work* (SOW) (DE-AC27-01RV14136) Facility Specification, Section C.7(a)(5) on Liquid Effluent Treatment:

> *Disposition all secondary wastes in accordance with ICD requirements; secondary wastes are identified in Section C.9, Interface Control Documents and Standard 6, Product Qualification, Characterization Certification.*

Interface Control Document (ICD)-05 (2490-WTP-ICD-MG-01-005, Rev 4) and ICD-06 (24590-WTP-ICD-MG-01-006, Rev 4) have been developed to govern various liquid effluent systems and operations, including transfer to the Tank Farm Contractor.

The WTP SOW Facility Specification, Section C.7(d)(1)(vi) states:

> *Liquid Effluent Treatment: This operation collects the WTP effluent and provides for the discharge to the Hanford Site 200 East Area Effluent Treatment Facility (ETF) or allows for the re-use of liquid effluent as process water with the WTP. Treated effluent will be transferred to the Hanford Site ETF as required.*

9.2.2 Process Description

9.2.2.1 PT Liquid Effluents

The PT RLD system is composed of four vessels (RLD-VSL-00017A/B and RLD-TK-00006A/B) with dedicated influent lines (24590-PTF-M5-V17T-00022003, Rev 2). The RLD system vessels/tanks are primarily concerned with the collection of solutions that may be discharged to LERF/ETF. Most of the wastes received into system RLD are process condensates from evaporators, caustic waste from the LAW caustic scrubber, and spent reagents from the resin addition process. A brief description of each vessel/tank in the system along with its normal mode of operation follows.

The main influents to the alkaline effluent vessels (RLD-VSL-00017A/B) are LAW caustic scrubber waste and spent reagents from the ion exchange resin addition process. The vessel discharge pumps are centrifugal. The wastewater influent is expected to have low levels of contamination. The tanks can be operated in such a way that one tank can be online receiving waste while the other is isolated for 50 hr waiting for sample results. Based on sampling results, the wastewater is transferred to the process condensate tank (RLD-TK-00006B) with the other process condensate tank (RLD-TK-00006A) as a backup (24590-PTF-M5-V17T-00022004, Rev 2), or transferred to TLP-VSL-00009A/B. The alkaline effluent vessels also receive effluent from the process reagent sumps and C3 drains. These are off-normal flows and not included in the flowsheet. The alkaline effluent vessels are described in detail in Section 2.17.3.1.

Although the process condensate tanks (RLD-TK-00006A/B) are functionally identical, they operate differently. RLD-TK-00006A receives wastes that have been monitored online. These wastes include process condensate from FEP-VSL-00005 and TLP-VSL-00002 (the feed and LAW evaporators). After the wastes have been sampled, the low-activity effluent waste is discharged as process condensate for recycle, with the excess sent to RLD-TK-00006B. RLD-TK-00006B also receives batches of discharge from RLD-VSL-00017A/B. The waste accumulated in RLD-TK-00006B is transferred to LERF/ETF if it meets the LERF/ETF treatability envelope. The LERF/ETF radiological acceptance criteria HNF-3172, Rev 3, Table D-1, *Liquid Waste Processing Facilities Waste Acceptance Criteria*, is included in Table 9.2-1.

The tanks may also receive process water. This water is used to fill the tank to a level so that there is sufficient fluid to provide recycle effluents when needed. This is used during startup and off-normal conditions. The process condensate tanks are described in detail in Section 2.17.3.2.

9.2.2.2 LAW Liquid Effluents

The LAW liquid effluents collection system (24590-WTP-3YD-NLD-00001, Rev 1) consists of four vessels that collect, detain, mix, sample, and discharge radioactive and nonradioactive secondary effluents from the LAW Facility. The process stream numbers (24590-WTP-RPT-PR-01-008) referred to in the following pages are used in process flow diagrams and in process models.

System NLD receives fire water and nonradioactive effluents from the C1/C2 floor drains and sumps (stream RLD26). These wastes are collected by the C1/C2 drains and sump collection tank (NLD-VSL-00005), stored, sampled, and, depending on sample results, discharged to either the BOF nonradioactive effluent tank (NLD-TK-00001) as stream NLD01 or to the PT Facility via the plant wash vessel (RLD-VSL-00003). In the event of a fire, floor drains in the C1/C2 areas are directed to the C1/C2 vessel. If the vessel volume is exceeded, the fire water overflows to a berm surrounding the C1/C2 vessel. A sump pump in the berm can direct the berm contents back to the C1/C2 vessel for

transfer to PT or BOF. Only effluents meeting TEDF discharge limits (Table 9.2-1) are sent to the BOF non-radioactive effluent tank. From the BOF, the nonradioactive effluents pass through an interface point (ICD-05), and are disposed at the TEDF. Contaminated effluents are directed to the LAW plant wash vessel (RLD-VSL-00003) and then to the PT Process Plant Wash and Disposal System (PWD) (24590-PTF-M5-V17T-00022002, Rev 2) and Waste Feed Evaporation Process System (FEP) for further processing. Ultimately, the treated effluents (stream RLD01) are sent through an interface point (ICD-06) and to the LERF/ETF. The C1/C2 drain/sump collection tank is described in Section 3.4.3.2.1.

Radioactive effluents received from C3/C5 sumps and vessel washes (stream RLD25) are collected by the plant wash vessel (RLD-VSL-00003), stored until the level setpoint is reached, mixed, sampled as needed (24590-LAW-M5-V17T-00014, Rev 5), and discharged (stream RLD27) to PWD. After processing in the FEP, the remaining effluents (stream RLD01) meeting LERF/ETF radiological acceptance criteria (Table 9.2-1) are sent through an interface point (ICD-06) and disposed by the LERF/ETF operator. The plant wash vessel is described in Section 3.4.3.1.1.

The C3/C5 drain/sump collection vessel (RLD-VSL-00004) collects fire water and radioactive effluent from the wet electrostatic precipitator (WESP) drains (stream LOP10), overflows from LAW concentrate receipt vessels (LCP-VSL-00001, LCP-VSL-00002), overflows from the LAW melter feed preparation vessels (LFP-VSL-00001, LFP-VSL-00003), vessel vent headers drainage, and C3/C5 area floor drain and sump effluents (stream RLD28). These effluents are held, mixed, sampled as needed, and discharged to either the submerged bed scrubber (SBS), condensate collection vessel (RLD-VSL-00005), or LAW plant wash vessel (RLD-VSL-00003), depending on their source. The C3/C5 drain/sump collection vessel transfers WESP drainage to the SBS condensate collection vessel, where it is mixed with SBS condensate before discharge (stream RLD21) to Treated LAW Evaporation System (TLP). There the SBS effluents are processed by the evaporators. The resultant excess LAW condensate (stream RLD01) meeting LERF/ETF acceptance criteria is sent through an interface point (ICD-06) to LERF/ETF, and the evaporator bottoms are sent to LAW vitrification feed. The C3/C5 drain/sump collection vessel transfers concentrate receipt vessel overflows, vent drainage, and floor drain/sump drainage to the plant wash vessel (RLD-VSL-00003), where it is mixed with other LAW vessel washes before discharge (stream RLD27) to PWD. From there it is processed in FEP and recycled. Any excess meeting the LERF/ETF acceptance criteria is sent as LAW condensate (stream RLD01) through the interface point (ICD-06) to LERF/ETF for disposal. The evaporator bottoms are sent to waste feed. The C3/C5 drain/sump collection vessel is detailed in Section 3.4.3.1.2.

SBS condensate purges (stream LOP05) from the SBS vessels (LOP-SCB-00001, LOP-SCB-00002) and SBS condensate vessels (LOP-VSL-00001, LOP-VSL-00002) are collected by the SBS condensate collection vessel (RLD-VSL-00005). The SBS effluents are held for up to 2 days, mixed, sampled as needed, and discharged (stream RLD21) to pretreatment process. There the effluents are pH adjusted and sent through the evaporator. The resultant excess LAW condensate (stream RLD01), meeting LERF/ETF acceptance criteria, is ultimately discharged through an interface point (ICD-06) to the LERF/ETF operator and the evaporator bottoms are sent to the LAW Facility. The SBS condensate collection vessel is described in Section 3.4.3.1.3.

9.2.2.3 HLW Liquid Effluents

The HLW liquid effluents disposal process system (24590-HLW-3YD-RLD-00001, Rev 3) consists of four vessels that will receive, store, mix, sample, and transfer radioactive and nonradioactive secondary effluents from the HLW Facility (24590-HLW-M5-V17T-0000701, Rev 5, 24590-HLW-M5-V17T-0000702, Rev 5).

Radioactive, low pH condensate purge (stream HOP03) from the SBS condensate receiver vessels (HOP-VSL-00903, HOP-VSL-00904), SBS purge (stream HOP05) from the submerged bed scrubbers (HOP-SCB-00001, HOP-SCB-00002), and discharge from the waste neutralization vessel (stream HDH06) are sent to the HLW acid waste storage vessel (RLD-VSL-00007) for mixing, sampling, and 1-day storage. Sodium hydroxide addition (stream RLD68), if neutralization is required for pretreatment, is also sent to the HLW acid waste storage vessel (RLD-VSL-00007) for mixing, sampling, and 1-day storage. Normally, the HLW acid waste storage vessel (stream RLD62) discharges to the HLW effluent transfer vessel (PWD-VSL-00043) in the PWD. In the unlikely event that the HLW effluent transfer vessel (PWD-VSL-00043) is unavailable to receive the discharge, and the HLW acid waste storage vessel has insufficient remaining capacity, the vessel can be manually directed to discharge the contents to the plant wash and drains vessel (RLD-VSL-00008) for additional storage capacity. The contents of the plant wash and drains vessel are then discharged (stream RLD63) to the HLW effluent transfer vessel (PWD-VSL-00043) in pretreatment. In either case, the vessel contents would be mixed and neutralized in the PT process and then sent to FEP. The evaporator concentrate is sent to waste feed. The condensate is discharged (stream RLD01) from PT, if it meets acceptance criteria for the LERF/ETF (Table 9.2-1), through an interface point (ICD-06), where it leaves WTP control and is handed over for disposal through LERF/ETF. The HLW acid waste storage vessel is described in Section 4.5.3.1.1.

Offgas drainage (stream HOP16) from the ductwork located between the high-efficiency mist eliminator and the high-efficiency particulate air filters (24590-HLW-M5-V17T-00003, Rev 5) is directed to the offgas drains collection vessel (RLD-VSL-00002). The offgas drains collection vessel provides a seal for 100 in. WG negative pressure in the ductwork and collects condensation that forms during system startup and shutdown. The vessel operating level is controlled by level detectors to maintain an adequate depth for the seal. Whenever there is condensation drainage from the primary offgas system, the design liquid level in the vessel is maintained by discharging the excess to the plant wash and drains vessel (RLD-VSL-00008). The offgas drainage is added to the contents of the plant wash and drains vessel and mixed. The plant wash and drains vessel discharges (stream RLD63) the effluent to the HLW effluent transfer vessel (PWD-VSL-00043) in the PT Facility. The effluent is processed by PT evaporators in (FEP), which will separate any solids. The remaining condensate, meeting LERF/ETF acceptance criteria, will be discharged (stream RLD01) through the interface point (ICD-06) to the LERF/ETF. The offgas drains collection vessel is described in Section 4.5.3.1.3.

Neutral pH waste drainage from vessel and sump washings, acidic waste transferred (nonroutinely) from vessel RLD-VSL-00007, and offgas system drainage transferred from vessel RLD-VSL-00002 are directed to the plant wash and drains vessel (RLD-VSL-00008). The plant wash and drains vessel receives, mixes, samples, and stores for up to 2 days the effluent before it discharges to the HLW effluent transfer vessel (PWD-VSL-00043), as stream RLD63. In the unlikely event that the HLW effluent transfer vessel is unavailable to accept the transfer, the discharged effluent (stream RLD64) can be directed to the PT Facility vessel (PWD-VSL-00033). In either case, these effluents are processed by PT evaporators in (FEP) and the remaining condensate, meeting LERF/ETF acceptance criteria, will be discharged (stream RLD01) through the interface point (ICD-06) to LERF/ETF. The plant wash and drains vessel is described in Section 4.5.3.1.2.

The C1/C2 drains collection tank (NLD-TK-00006) receives C1/C2 area drains, sumps, and washes effluent (RLD-67). The effluent is mixed, stored for up to 30 days, and sampled. If the effluent meets TEDF discharge limits, the waste (stream NLD12) (24590-HLW-M5-V17T-00009, Rev 5) is transferred by a centrifugal discharge pump (NLD-PMP-00001) to the BOF nonradioactive effluent tank (NLD-TK-00001). The nonradioactive effluent tank discharges the effluents through an interface point (ICD-05) as they are transferred to TEDF. If the effluents are radioactive, and do not comply with TEDF limits, they will not be discharged to the nonradioactive effluent tank. Instead they will be returned to the

plant wash and drains vessel (RLD-VSL-00008). From there the active effluents will be transferred (stream RLD64) to pretreatment where they will be processed in the waste feed evaporator (FEP). After evaporation, the condensate, meeting LERF/ETF acceptance criteria (stream RLD01), will be transferred through the interface point (ICD-06) to LERF/ETF. The C1/C2 drains collection tank is described in Section 4.5.3.2.1.

LERF/ETF radiological acceptance criteria are listed in Table 9.2-1. The TEDF discharge limits are listed in Table 9.2-2.

9.2.2.4 Lab Liquid Effluents

The Analytical Laboratory (Lab) RLD and NLD systems collect liquid effluents from throughout the Lab and provide interim storage before transfer. The RLD is the last collection point in the Lab for liquid effluent before it is transferred to the PT Facility, BOF NLD tank (C2 vessel only), or a tanker truck (optionally, prior to hot commissioning). Some of the effluent is returned to PT via PWD vessel (PWD-VSL-00044). A simplified flow diagram of liquid effluent in the RLD is provided in Figure 9.2-2. This figure and most of the following discussion is derived from reference 24590-LAB-3YD-RLD-00001.

9.2.2.4.1 Floor Drain Collection Vessel (RLD-VSL-00163)

The floor drain collection vessel (RLD-VSL-00163) functions include collection, containment, sampling, staging, and transfer of typically non-contaminated liquid effluent. The floor drain collection vessel is located in a cell underneath the C2/C3 filter/fan room (room A-0160) in the Lab. The vessel and cell are large enough to handle anticipated upset events. In the event of a fire, the contents of the vessel may overflow into the vessel cell.

Sampling capability for RLD-VSL-00163 is provided by a grab sample from a tap off the discharge of the floor drain collection vessel pumps (RLD-PMP-00190A/B). After development of an initial waste profile, the contents of RLD-VSL-00163 will be allowed to transfer to the NLD storage tank (NLD-TK-00001), if radioactive screening analysis shows that the contents of the C2 vessel are not contaminated. Periodic samples receive full analysis to ensure TEDF criteria are met.

During routine operations, the C2 liquid effluent is transferred to the laboratory area sink drain collection vessel (RLD-VSL-00164), the hot cell drain collection vessel (RLD-VSL-00165), or the NLD storage tank in BOF (NLD-TK-00001). Prior to hot commissioning, it may be transferred to a tanker truck. There is an air gap or backflow preventer at the tanker truck. The cell area provides buffer volume and the associated sump is equipped with leak detection.

The cell area is used to collect any vessel overflow or leakage from the RLD. Vessel RLD-VSL-00163 is vented to the C2 ventilation system. An airflow velocity is maintained through the C2 drain collection network, RLD-VSL-00163, and into the HVAC C2 exhaust system to minimize potential cross-contamination between C2 areas without the use of loopseals.

A floor drain collection vessel pump (RLD-PMP-00190A) is installed for discharging vessel and sump contents, and sampling vessel contents. An additional floor drain collection vessel pump (RLD-PMP-00190B) is installed for redundancy.

When required, vessel washings are transferred to the hot cell drain collection vessel (RLD-VSL-00165) during normal operations. A manual hose station is located near the C2 vessel for vessel washing.

9.2.2.4.2 Laboratory Area Sink Drain Collection Vessel (RLD-VSL-00164)

The laboratory area sink drain collection vessel (RLD-VSL-00164) functions include collection, containment, staging, and transfer of radioactive liquid streams. The laboratory area sink drain collection vessel (RLD-VSL-00164) is designed in accordance with applicable sections of ASME VIII, Div. 1. Similarly, the RLD-VSL-00164 vessel system is designed to meet applicable secondary containment, leak detection, integrity, and other criteria defined in WAC 173-303-640. The laboratory area sink drain collection vessel is located in a stainless steel lined cell underneath the C2/C3 filter/fan room (Room A-0160) in the Lab. The cell is designed as a C3 area. There is no cell access during normal operations. The vessel is large enough to handle anticipated upset events. In the event of a fire, the contents of the vessel may overflow into the vessel cell.

During routine operations, vessel RLD-VSL-00164 discharges to the hot cell drain collection vessel (RLD-VSL-00165). The space to accommodate an alternate destination of the C3 effluent is available. This possible future connection would require the installation of a new spool piece to allow the transfer to the PT Facility plant wash vessel (PWD-VSL-00044). Prior to hot commissioning, it may be transferred to a tanker truck. There is an air gap or backflow preventer at the tanker truck.

The partially stainless steel lined cell area provides secondary containment and the associated sump is equipped with leak detection. The cell area is used to collect any vessel overflow or leakage from the RLD. Areas above the liner are bare concrete and exposed steel that are not designed to support decontamination or allow manned entry.

The laboratory area sink drain collection vessel (RLD-VSL-00164) and drain traps are vented to the C3 ventilation system.

A laboratory area sink drain collection vessel pump (RLD-PMP-00182A) recirculates vessel contents through eductors for mixing. An additional laboratory area sink drain collection vessel pump (RLD-PMP-00182B) is installed for redundancy. Secondary containment with leak detection is provided for the pumps and valves by the pump pit and the pump pit sump.

Washrings are provided for both vessel and vessel cell rinsing to support maintenance activities or decontamination in the event of a spill. When required, vessel washings are discharged to the hot cell drain collection vessel (RLD-VSL-00165) during normal operations

9.2.2.4.3 Hot Cell Drain Collection Vessel (RLD-VSL-00165)

The hot cell drain collection vessel (RLD-VSL-00165) functions include collection, containment, staging, and transfer of radioactive liquid streams. The hot cell drain collection vessel (RLD-VSL-00165) is designed in accordance with applicable sections of ASME VIII, Div. 1. Similarly, the RLD-VSL-00165 vessel system is designed to meet applicable secondary containment, leak detection, integrity, and other criteria defined in WAC 173-303-640. The hot cell drain collection vessel is located in a partially stainless steel lined cell under the C5 pump maintenance room (Room A-0167) in the Lab. The cell is designated as a C5 area. There is no cell access during normal operations. The vessel is large enough to handle anticipated upset events. In the event of a fire, the contents of the vessel may overflow into the vessel cell.

During routine operations, the hot cell drain collection vessel discharges to the PT Facility plant wash vessel (PWD-VSL-00044). Prior to hot commissioning, the contents of the vessel may be transferred to a tanker truck. There is an airgap or backflow preventer at the tanker truck.

The partially stainless steel lined cell area provides secondary containment and the associated sump is equipped with leak detection. The cell area is used to collect any vessel overflow or leakage from the RLD. Areas above the liner are bare concrete and exposed steel that are not designed to support decontamination or allow manned entry.

Vessel RLD-VSL-00165 is vented to the C5 ventilation system. An airflow velocity is maintained through the C5 drain collection network, RLD-VSL-00165, and into the HVAC C5 exhaust system to minimize cross-contamination between the hot cells without the need for loopseals.

A hot cell drain collection vessel pump (RLD-PMP-00183A) recirculates vessel contents through eductors for mixing. An additional hot cell drain collection vessel pump (RLD-PMP-00183B) is installed for redundancy. Secondary containment with leak detection is provided for the pumps and valves by the pump and piping pits and the respective sumps.

9.2.3 Basis

The two subsystems are designed to stage, transfer, sample, and mix incidental effluents collected during the operation of the LAW Facility. Holdup is required to allow time for analysis to determine whether the waste meets pretreatment process or BOF acceptance criteria.

The two systems provide staging/transfer vessels for incidental wastes collected during operation of the HLW Facility.

9.2.4 Ongoing Work and Potential Changes

No additional work on or potential changes to the liquid effluent systems are currently underway.

9.2.5 References

24590-HLW-3YD-RLD-00001, Rev 3, *System Description for the HLW Radioactive Liquid Waste Disposal System RLD.*

24590-HLW-M5-V17T-00003, Rev 5, *Process Flow Diagram HLW Vit Melter 1 Primary Offgas Treatment (System HOP).*

24590-HLW-M5-V17T-00004, Rev 5, *Process Flow Diagram HLW Vitrification Melter 1 Secondary Offgas Treatment (System HOP).*

24590-HLW-M5-V17T-00006, Rev 6, *Process Flow Diagram HLW Vitrification HLW Canister Decon (System HDH).*

24590-HLW-M5-V17T-00007001, Rev 5, *Process Flow Diagram HLW Vitrification Liquid Waste Effluent (System RLD) (Sheet 1).*

24590-HLW-M5-V17T-00007002, Rev 5, *Process Flow DiagramHLW Vitrification Liquid Waste Effluent (System RLD) (Sheet 2).*

24590-HLW-M5-V17T-00009, Rev 5, *Process Flow Diagram HLW C2 Drains Collection (System NLD).*

24590-HLW-M6-NLD-00002, Rev 3, *P&ID - HLW Non-radioactive Liquid Waste Disposal System Non-active Effluent Collection.*

24590-HLW-M6C-RLD-00004, Rev 00C, *HLW Offgas Drains Collection Vessel RLD-VSL-00002 Sizing Calculation.*

24590-HLW-M6C-RLD-00005, Rev 00C, *HLW Plant Wash and Drain Vessel RLD-VSL-00008 Sizing Calculation.*

24590-LAB-3YD-RLD-00001, Rev 4, *System Description for the Analytical Laboratory radioactive Liquid Waste Disposal System.*

24590-LAB-M4C-RLD-00003, Rev 0, *Bounding Sample Inventory in the WTP Analytical Laboratory.*

24590-LAW-3YD-LOP-00001, Rev 3, *System Description for the LAW Primary Offgas (LOP) and Secondary Offgas/Vessel Vent (LVP) System.*

24590-LAW-M5-V17T-00001, Rev 5, *Process Flow Diagram LAW Concentrate Receipt and Melter 1 Feed (System LCP, GFR, and LFP).*

24590-LAW-M5-V17T-00002, Rev 5, *Process Flow Diagram LAW Concentrate Receipt and Melter 2 Feed (System LCP, GFR, and LFP).*

24590-LAW-M5-V17T-00007, Rev 4, *Process Flow Diagram Melter 1 Primary Offgas Treatment System (System LOP).*

24590-LAW-M5-V17T-00008, Rev 4, *Process Flow Diagram Melter 2 Primary Offgas Treatment System (System LOP).*

24590-LAW-M5-V17T-00010, Rev 4, *Process Flow Diagram LAW Vitrification Ammonia & Secondary Offgas (System AMR & LVP).*

24590-LAW-M5-V17T-00011, Rev 5, *Process Flow Diagram LAW Vit Secondary Offgas Treatment (System LVP).*

24590-LAW-M5-V17T-00014, Rev 5, *Process Flow Diagram LAW Liquid Effluent (System RLD).*

24590-LAW-M6C-NLD-00001, Rev 1, *C1/C2 Drains Sump Collection Vessel NLD-VSL-00005.*

24590-LAW-M6C-RLD-00001, Rev 2, *LAW C3/C5 Drains/Sump Collection Vessel RLD-VSL-00004 Sizing.*

24590-LAW-M6C-RLD-00005, Rev 2, *Vessel Sizing Calculation for Plant Wash Vessel RLD-VSL-00003.*

24590-LAW-M6C-RLD-00006, Rev 2, *SBS Condensate Collection Vessel Sizing (RLD-VSL-00005).*

24590-PTF-M5-V17T-00022002, Rev 2, *Process Flow Diagram Pretreatment Plant Wash and Disposal System PWD.*

24590-PTF-M5-V17T-00022003, Rev 2, *Process Flow Diagram-Pretreatment Radioactive Liquid Disposal System RLD Sheet 3 of 4.*

24590-PTF-M5-V17T-00022004, Rev 2, *Process Flow Diagram Pretreatment Radioactive Liquid Disposal/Recycle System RLD Sheet 4 of 4.*

24590-PTF-M6-PWD-00040, Rev 3, *P&ID - PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-PTF-M6-PWD-00041, Rev 3, *P&ID - PTF Plant Wash & Disposal System C2 Area Floor Drains Collection Vessel.*

24590-PTF-M6-PWD-00042, Rev 3, *P&ID - PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-PTF-M6-PWD-00043, Rev 3, *P&ID - PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-PTF-M6-PWD-00044, Rev 3, *P&ID - PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 0-0 Thru 56-0).*

24590-WTP-3YD-NLD-00001, Rev 1, *System Description for the Waste Treatment Plant Non-radioactive Liquid Waste Disposal (NLD) System.*

24590-WTP-ICD-MG-01-005, Rev 4, *ICD-05 - Interface Control Document for Non-radioactive, Nondangerous Liquid Effluents.*

24590-WTP-ICD-MG-01-006, Rev 4, *ICD-06 - Interface Control Document for Radioactive, Dangerous Liquid Effluents.*

24590-WTP-PL-RT-03-003, Rev 3, *Secondary Wastes Compliance Plan.*

24590-WTP-RPT-PR-01-008, Rev 6, *Process Stream Numbers.*

24590-WTP-RPT-PR-02-001, Rev 0, *Plant Wash Philosophy.*

DOE. 2000. *DOE Statement of Work*, DE-AC27-01RV14136, US Department of Energy, Office of River Protection, Richland, WA, as amended.

Ecology. 2000a. *State Waste Discharge Permit Number ST 4502*, issued April 18, 2000. State of Washington, Department of Ecology, Kennewick, WA.

Ecology. 2000b. *Fact Sheet for State Waste Discharge Permit Number ST 4502*, issued April 18, 2000. State of Washington, Department of Ecology, Kennewick, WA.

FH. 2005. Fluor Hanford, *Liquid Waste Processing Facilities Waste Acceptance Criteria*, HNF-3172, Rev 4, Richland, WA.

Table 9.2-1 LERF/ETF Radiological Acceptance Criteria

Radionuclide	LERF/ETF Acceptance Criteria (Curies/liter)
Tritium	2.4 E-04
Carbon-14	1.6 E-06
Cobalt-60	2.4 E-06
Selenium-79	1.5 E-07
Strontium-90	4.2 E-05
Niobium-94	2.6 E-07
Technetium-99	1.8 E-05
Ruthenium-106	6.5 E-07
Iodine-129	1.8 E-06
Cesium-134	4.1 E-07
Cesium-137	1.0 E-05
Cerium-144	2.0 E-05
Europium-154	9.8 E-06
Europium-155	6.3 E-05
Radium-226	6.4 E-08
Uranium (gross as Uranium-234)	2.1 E-10
Neptunium-237	2.1 E-09
Plutonium-238	2.8 E-09
Plutonium-239/240	1.8 E-08
Plutonium-241	2.6 E-08
Americium-241	1.4 E-09
Curium-244	2.5 E-08

Source: HNF-3172, *Liquid Waste Processing Facilities Waste Acceptance Criteria*, Table D-1.

Table 9.2-2 TEDF Discharge Limits

Constituent	TEDF Limit
Average flow rate	Not specified
Chloride	58,000 µg/L
Cyanide	50 µg/L
Nitrate	620 µg/L
Sulfate	No target limits
Ammonia	No target limits
Arsenic	15 µg/L
Cadmium	5 µg/L
Chromium	20 µg/L
Iron	300 µg/L
Lead	10 µg/L
Manganese	50 µg/L
Mercury	2 µg/L
Total dissolved solids	250,000 µg/L
Conductivity	No target limits
pH	6.5 to 8.5
Gross alpha	15 pCi/L
Gross beta	50 pCi/L
Radium total	5 pCi/L
Radium-226	No target limits
Bis (2-ethylhexyl phthalate)	10 µg/L
Oil and grease	No target limits
Phenol	10 µg/L
Carbon tetrachloride	5 µg/L
Methyl chloride	5 µg/L
1,1,1-Trichloroethane	5 µg/L
Trihalomethanes (total)	20 µg/L
Chloroform	7 µg/L

Sources:

Ecology. 2000a. *State Waste Discharge Permit Number ST 4502*, issued April 18, 2000, State of Washington, Department of Ecology, Kennewick, WA.

Ecology. 2000b. *Fact Sheet for State Waste Discharge Permit Number ST 4502*, issued April 18, 2000, State of Washington, Department of Ecology, Kennewick, WA.

Figure 9.2-1 WTP Liquid Effluent Systems

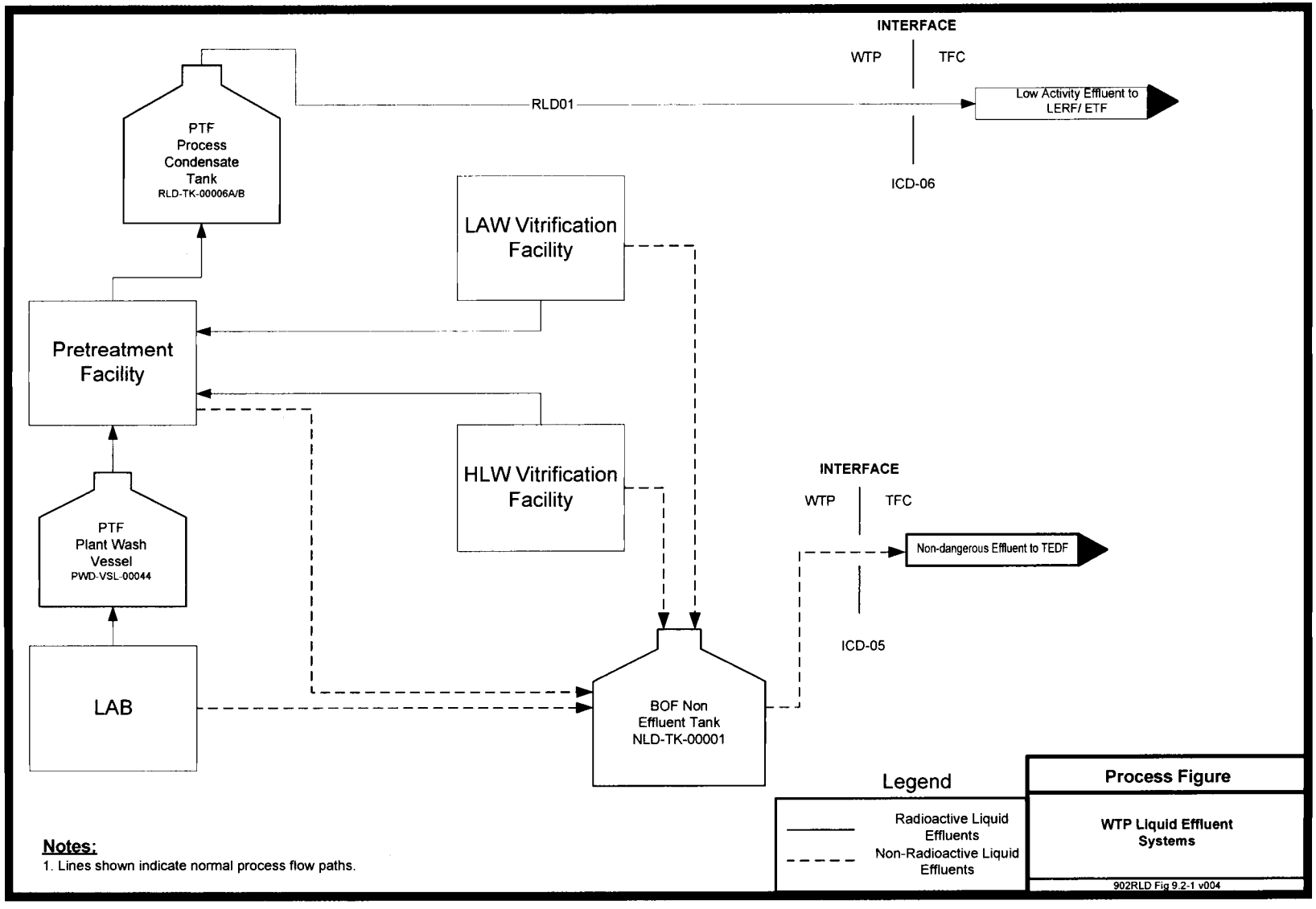
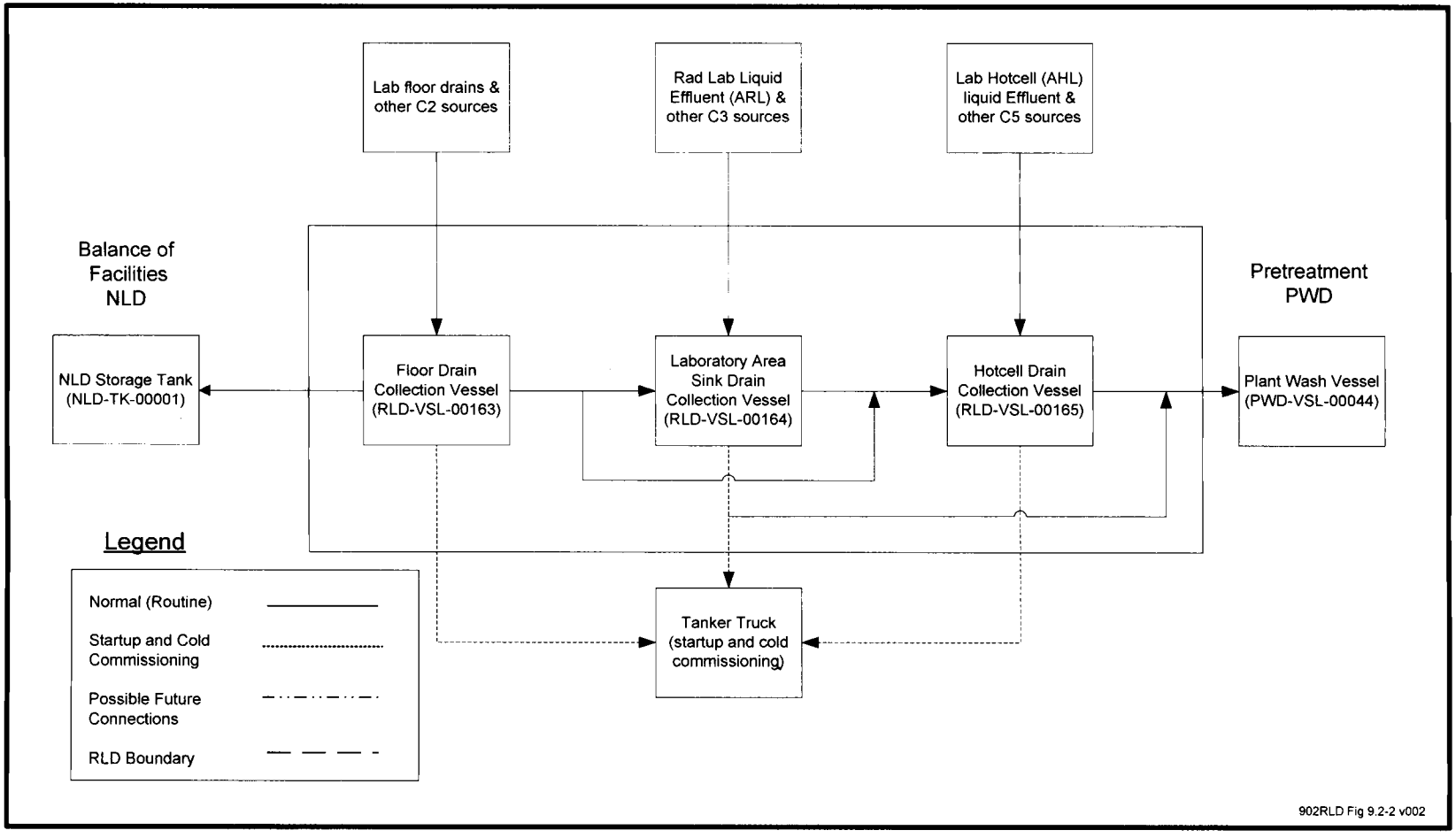


Figure 9.2-2 Simplified Process Flow of Effluent Streams for the Analytical Laboratory



10 Reliability, Availability, and Maintainability Data

Contents

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10.1 Reliability, Availability, and Maintainability Data

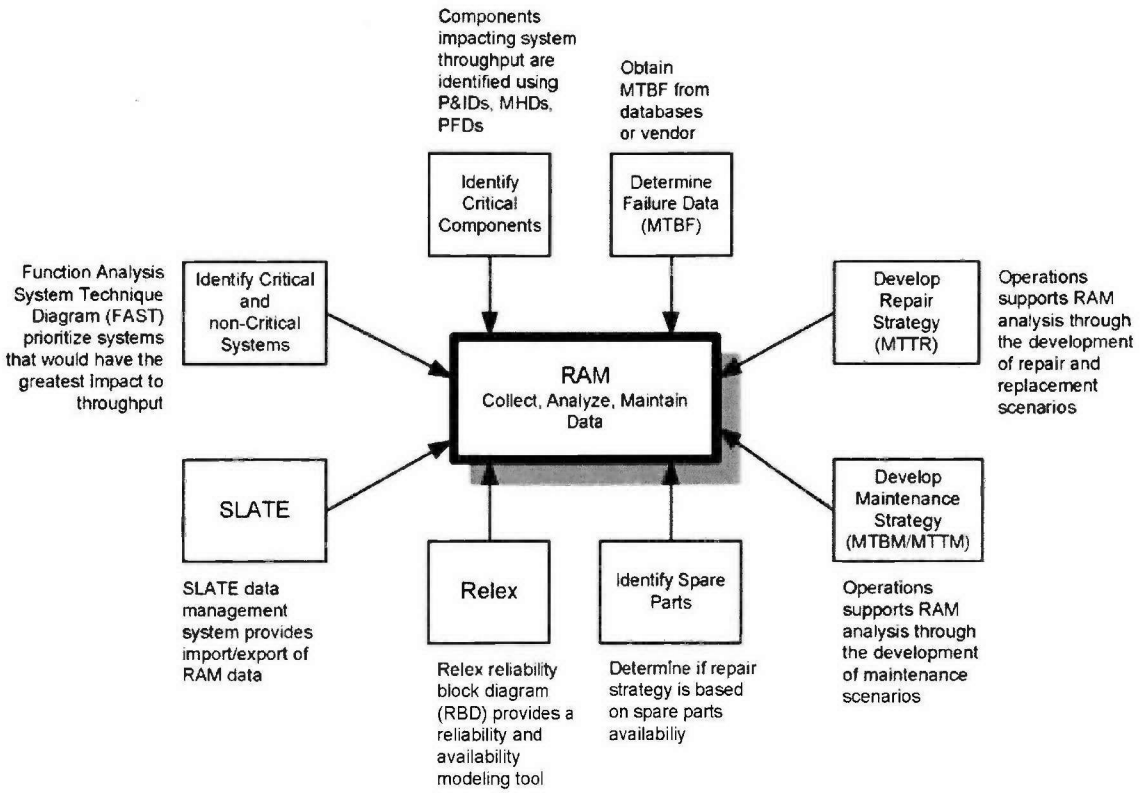
Reliability is the probability that a system will perform its intended function satisfactorily for its intended life under specified environmental and operating conditions. Maintainability is a measure of the ability of an item to be retained in, or restored to, a specified condition when maintenance or repair is performed by personnel having specified skill levels. It reflects the ease and efficiency of performing both corrective and scheduled maintenance on a system. Availability is the probability that the system is operating satisfactorily at any time, and it depends on the reliability and the maintainability. The reliability, availability, and maintainability (RAM) evaluation consists of reviewing a system to determine if the system will be ready for use when required, will successfully perform assigned or designed (intended) functions, and can be maintained in its operation state over its specified useful life. The RAM evaluation of the Pretreatment (PT) Facility, High-Level Waste (HLW) Facility, Low-Activity Waste (LAW) Facility, Balance of Facilities (BOF), and Analytical Laboratory (Lab) is based on a numerical quantity or figure-of-merit value; mean time between failures (MTBF), mean time to repair (MTTR), mean time between maintenance (MTBM), and mean time to maintain (MTTM). Those components that were identified as affecting the system and availability, should they fail, were added to the RAM data collection. The RAM data were incorporated into the WTP Operations Research (OR) Model, which was developed using Lanner's WITNESS software.

The DOE Contract, DE-AC27-01RV14136, C.6 Standard 2(b)(1) identifies the requirements for the RAM data collection and WTP OR Model to include the equipment reliability, time estimates for maintenance and repair of facility and process systems, estimated spare equipment inventory, and recommendations to improve reliability and availability of the production facilities. The RAM data was collected through multi-discipline cross-functional meetings that analyzed each system and component to develop the pertinent RAM data. The team reviewed available design documents, including process flow diagrams, mechanical flow diagrams, piping and instrumentation diagrams, and system descriptions, to develop the RAM data.

10.2 Approach, Bases, and Assumptions

There are many functions to the RAM data collection, as depicted in Figure 10-1. The functions range from determining which systems to analyze, to managing the RAM data collected. Each system was evaluated to determine the system's affect on the facility throughput. Relex software is used to validate the systems deemed not critical by determining system availability through redundancy. A team of multi-discipline engineers reviewed available design documents to determine which components are critical to the system availability. The MTBF values are obtained from available databases and vendor information. The Operations group develops the MTTR, MTBM, and MTTM based on their knowledge and experience of similar facilities. Consideration to spare parts availability is part of the MTTR development.

Figure 10-1 RAM Data Collection



The bases for RAM information revisions include ongoing and planned design detail and evolution, industry and research and technology information, other RAM assessments, and vendor information. In WTP, RAM data are applied to the OR Model to determine individual and integrated plant availability. Some key RAM assumptions used for availability determination were established during development of the RAM information, as described below:

Assumption 10.1. Components that have redundancy or work-around alternatives will be repaired prior to failure of the alternative and are not critical to WTP availability. The RAM repair scenario considered crane utilization, which included the crane travel time and crane usage time. The repair scenario considered tasks that could be performed at the same time.

Assumption 10.2. Resolved.

Assumption 10.3. Qualified spares, procedures, and personnel will be readily available for failed critical components such that replacement is not delayed. The RAM evaluation identified spare components that must be on hand to minimize the breakdown effects on plant availability, and identified those components by vendor and model designators, as the information became available.

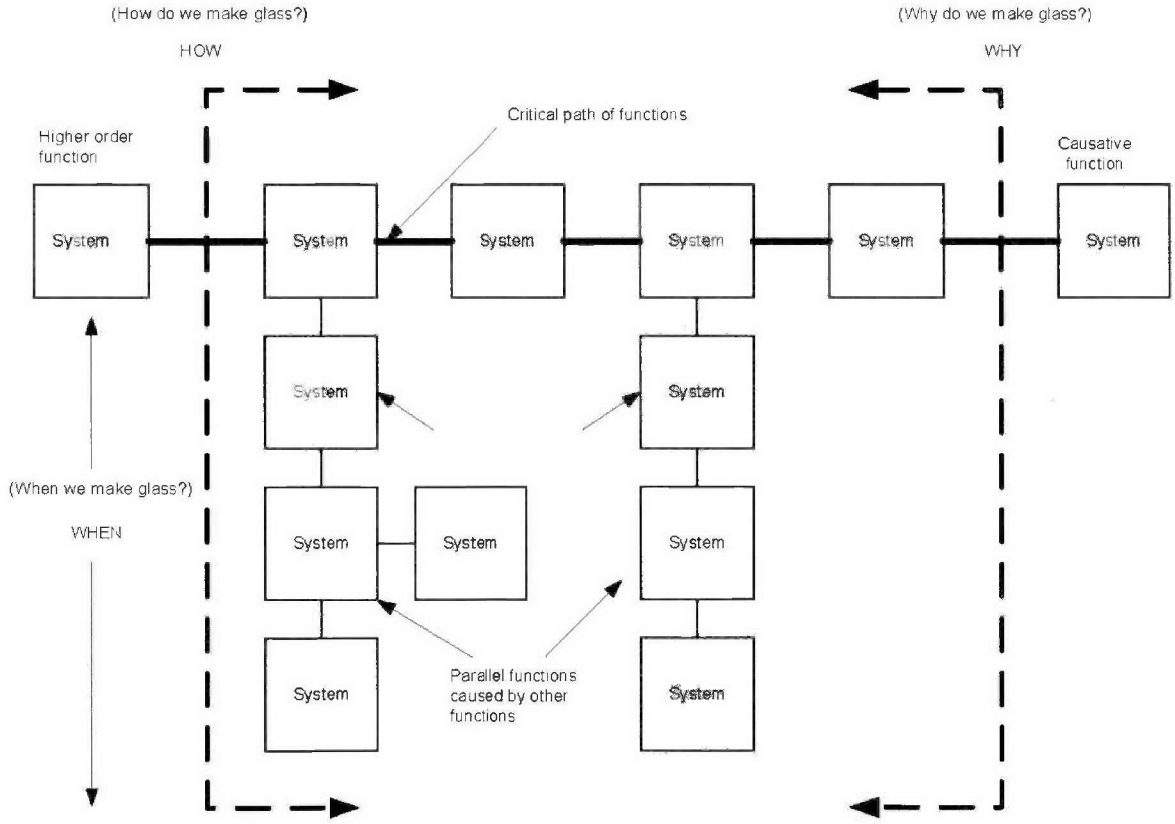
Assumption 10.4. WTP external interfaces, such as the supply of chemical reagents, will be highly available and will not impact the WTP availability. The Relex software was used to determine the availability of these interface systems and their impact to the WTP throughput.

RAM assessments are a process, not a one-time activity. The RAM assessments should begin in the early design development and continue throughout the life of the system, with different methods used at varying times. The RAM assessments were performed under the guidance of the *Reliability, Availability, Maintainability, and Inspectability (RAMI)*, 24590-WTP-GPG-ENG-009. The next sections describe methods used for RAM analysis.

10.2.1 Systems and Components Strategy

The Functional Analysis System Technique Diagram was used as a systematic method to help prioritize the systems analyzed for RAM, as depicted in Figure 10-2. This approach allowed an examination of a system's function and the functional interactions by asking: How is this function accomplished? Why is this function performed? When is this function performed? This method provided the logical arrangement of the higher-level and lower-level functions, as well as, supporting functions to determine those systems that are critical to availability and the supporting systems required to make availability.

Figure 10-2 Functional Analysis System Technique Diagram



10.2.2 Failure Strategy

The failure of a component or MTBF was formulated through the evaluation of the system configuration to determine redundancy, design life, impact to system functionality, and sub-components of the system.

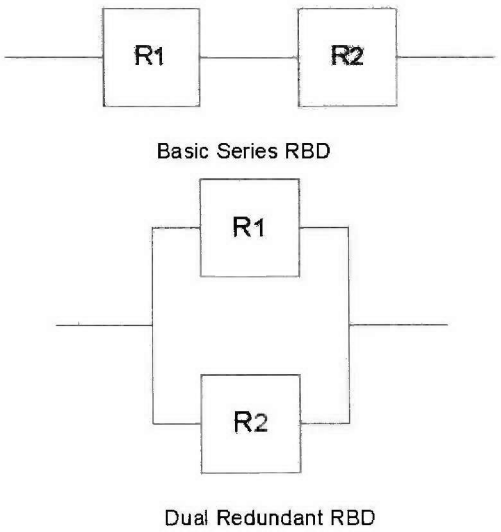
Assumption 10.1 states that components that have redundancy or work-around alternatives will be repaired prior to failure of the alternative. The MTBF data was derived from various databases; *WTP Operational Risk Analysis - Risk Goal Confirmation*, 24590-WTP-RPT-ENS-03-007; *SRS Generic Data Base Development*, WSRC-TR-93-262; *Report on Reliability Survey of Industrial Plant Part I: Reliability of Electrical Equipment,* IEEE 493-1997, Appendix A, Nonelectronic Parts Reliability Database (NPRD) for equivalent or similar equipment (RAC-STD-6200-NPRD-95); and vendor data.

10.2.3 Relex Reliability Software

The Relex software reliability black diagram (RBD) was used to determine system availability. The RBDs are a graphical representation of how the components of a system are connected, as depicted in Figure 10-3. In order to construct an RBD, the configuration of the components must be determined. That configuration can be as simple as units arranged in a pure series (such that a failure of any component results in failure for the entire system), or parallel configuration also known as redundant configuration. Redundancy is a very important aspect of system design and reliability in that adding redundancy is one of several methods to improve system reliability.

Relex was used to evaluate availability for non-critical systems, and the results of the Relex analysis were documented in the *Technical Report - RAMI Analysis Supporting Resolution of External Flowsheet Review Team (EFRT) Issue M15 and Pretreatment Non-Critical Systems*, 24590-WTP-RPT-ENG-07-006. Relex was also used to combine the pulse jet mixer fluidic controller instrumentation and control loops into a single MTBF. The results of this analysis is documented in the *Technical Report - RAM Analysis Supporting Resolution of External Flowsheet Review Team (EFRT) Issue M15 Pulse Jet Mixer Fluidic Controller Subsystem,* 24590-WTP-RPT-PE-07-002.

Figure 10-3 Reliability Block Diagram



10.2.4 Repair Strategy

The repair of a component or MTTR was formulated by the WTP Operations group. The MTTR data took into account the development of work packages, lock-out tag-out of electrical power, source term, building a protective hut for worker safety, flushing, or any function required to return the component to a working state. The MTTR considered external effects, such as a crane, required to do the repair. The crane time includes crane travel and actual crane usage. The MTTR took into account repair tasks that can be completed at the same time or parallel to one another. It is desirable to restore the failed component to a working state in a fast, safe, and economical manner.

10.2.5 Maintenance Strategy

Maintenance or MTBM and MTTM were considered a planned repair or downtime performed within a given period in accordance with prescribed procedures and resources. In many cases maintenance activities do not affect availability because they are a planned activity performed during periods that the equipment is not needed for operation. In cases involving LAW maintenance, activities are evaluated and performed during the melter outage to minimize the impact to availability. Daily maintenance activities (such as daily rope inspections for cranes) were also reviewed for production impact.

10.2.6 Spare Parts Strategy

The WTP Operations Research (OR) model is structured on the assumption that adequate spare parts are available, such that critical repairs are not delayed due to the lack of replacement parts. (*Assumption 10.3* states that qualified spares, procedures, and personnel will be readily available for failed critical components such that replacement is not delayed.) The OR model output may be used to support WTP Operations in developing a spare parts inventory list.

10.3 Operations Research Flowsheet RAM Data

The WTP OR flowsheet model is one of the tools developed to perform flowsheet analyses and pre-operational assessments of the Hanford Tank Waste Treatment and Immobilization Plant. The RAM data provided in Appendix D, unless stated otherwise, is part of the OR model release 6.0. Details on the model implementation of the RAM data can be found in the *Operations Research (WITNESS) Model Design Document*, 24590-WTP-MDD-PR-01-001.

The basis for the RAM data is documented in 24590-WTP-RPT-PET-07-003, *Waste Treatment Plant Reliability Availability Maintainability (RAM) Basis Report*, 24590-LAB-RPT-ENG-03-003, *LAB First Order RAM Data Development and Preliminary Assessment Report: October 2002 Baseline*, and the latest RAM updates included in the model change requests used to create versions 5 and 6 of the OR model.

10.4 References

24590-LAB-RPT-ENG-03-003, Rev 0, *LAB First Order RAM Data Development and Preliminary Assessment Report: October 2002 Baseline.*

24590-WTP-GPG-ENG-009, Rev 2, *Reliability, Availability, Maintainability, and Inspectability (RAMI).*

24590-WTP-MDD-PR-01-001, Rev 11, *Operations Research (WITNESS) Model Design Document,*

24590-WTP-RPT-ENG-07-006, Rev 1, *Technical Report - RAMI Analysis Supporting Resolution of External Flowsheet Review Team (EFRT) Issue M15 and Pretreatment Non-Critical Systems.*

24590-WTP-RPT-ENS-03-007, Rev 00A, *WTP Operational Risk Analysis (ORA) - Risk Goal Confirmation.*

24590-WTP-RPT-PE-07-002, Rev 0, *Technical Report - RAM Analysis Supporting Resolution of External Flowsheet Review Team (EFRT) Issue M15 Pulse Jet Mixer Fluidic Controller Subsystem.*

24590-WTP-RPT-PET-07-003, Rev 0, *Waste Treatment Plant Reliability Availability Maintainability (RAM) Basis Report.*

DOE. 2000. *DOE Statement of Work,* DE-AC27-01RV14136. US Department of Energy, Office of River Protection, Richland, WA, as amended.

IEEE 493-1997, *Report on Reliability Survey of Industrial Plant Part I: Reliability of Electrical Equipment Appendix A.*

RAC-STD-6200-NPRD-95, *The Nonelectronic Parts Reliability Database (NPRD) for equivalent or similar equipment (MIL-HDBK) from the Reliability Analysis Center.*

WSRC-TR-93-262, *Savannah River Site Generic Data Base Development.*

Appendix A

List of PFDs, P&IDs, DCAs (old), and DCNs Incorporated/Applied

Appendix A
List of PFDs, P&IDs, DCAs (old), and DCNs Incorporated/Applied

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-BOF-M5-V17T-00001	A	*Process Flow Diagram Reagent Bulk Storage and Dilution Nitric Acid Reagent System (NAR)*
24590-BOF-M5-V17T-00002	A	*Process Flow Diagram Reagent Bulk Storage and Dilution Sodium Hydroxide System (SHR)*
24590-BOF-M5-V17T-00003	A	*Process Flow Diagram Reagent Bulk Storage Sodium Permanganate and Strontium Nitrate Reagent Systems (SPR/STR)*
24590-BOF-M6-AMR-00002001	0	*P&ID - BOF Ammonia Reagent System Truck Unloading Station*
24590-BOF-M6-AMR-00002002	0	*P&ID - BOF Ammonia Reagent System Storage Vessel AMR-VSL-00003*
24590-BOF-M6-AMR-00003001	0	*P&ID - BOF Anhydrous Ammonia Reagent System Vaporizers and Appurtenances AMR-VPR-00002/3*
24590-BOF-M6-AMR-00003002	0	*P&ID - BOF Anhydrous Ammonia Reagent System Safety Shower and Eye Wash Units*
24590-BOF-M6-AMR-00005001	0	*P&ID - BOF Ammonia Reagent System Storage Vessel AMR-VSL-00004*
24590-BOF-M6-CHW-00001001	0	*P&ID - BOF Chilled Water System Yard Distribution Piping*
24590-BOF-M6-CHW-00001002	0	*P&ID - BOF Chilled Water System CHW-PMP-00008A/B and CHW-PMP-00012A/B*
24590-BOF-M6-CHW-00001003	0	*P&ID - BOF Chilled Water System CHW-PMP-00010A/B and CHW-PMP-00011A/B*
24590-BOF-M6-PCW-00002001	0	*P&ID - BOF Plant Cooling Water System Chiller Compressor Plant Distribution Piping*
24590-HLW-M6-HDH-00002	0	*P&ID - HLW Canister Decontamination Handling System*
24590-BOF-M6-DFO-00001001	0	*P&ID - BOF Diesel Fuel Oil System Unloading and Storage DFO-TK-0001*
24590-BOF-M6-DFO-00001002	0	*P&ID - BOF Diesel Fuel Oil System Boiler Feed DFO-PMP-00001A/B.*
24590-BOF-M6-HPS-00009002	0	*P&ID - BOF Steam Plant Facility Continuous Blow Down Heat Exchanger and Water Softeners*
24590-BOF-M6-DFO-00002	1	*P&ID - BOF Fuel Oil System ITS Emergency Diesel Gen Fuel Oil Storage Vessels*
24590-BOF-M6-DFO-00003	1	*P&ID - BOF Fuel Oil System Standby Diesel Generator Fuel Oil Day Tank*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-BOF-M6-HPS-00001001	0	*P&ID - BOF-High Pressure Steam System Distribution Header*
24590-BOF-M6-PCW-00001001	0	*P&ID - BOF Plant Cooling Water System Cooling Tower -Distribution Piping*
24590-BOF-M6-PSA-00001001	0	*P&ID - BOF Plant Service Air System Yard Distribution Piping*
24590-BOF-M6-PSA-00002001	0	*P&ID - BOF Plant Service Air System Centrifugal Compressor Stage 1 PSA-CMP-00001A*
24590-BOF-M6-PSA-00003001	0	*P&ID - BOF Plant Service Air System Rotary Screw Compressor PSA-CMP-00002A*
24590-BOF-M6-PSA-00004001	0	*P&ID - BOF Plant Service Air System Heat-of-Compression Dryer Air Supply Headers*
24590-BOF-M6-PSA-00005001	0	*P&ID - BOF Plant Service Air Receivers PSA-VSL-00004/5*
24590-BOF-M6-PSA-00006001	0	*P&ID - BOF Plant Service Air System Yard Distribution Piping to BOF Facilities*
24590-PTF-M6-PSA-00045	2	*P&ID - PTF Plant Service Air System PSA-VSL-00137/138*
24590-BOF-M6-DIW-00001001	0	*P&ID-BOF Demineralized Water System Storage and Distribution System*
24590-HLW-DCA-M-02-019	0	*HLW Elimination of Pour Tunnel Lid Stations*
24590-HLW-DCA-PR-02-008	0	*Increase in Thermal Efficiency for the Booster Fan Preheater (HOP-HX-00002)*
24590-HLW-DCA-PR-02-009	0	*Updates to the HLW Canister Decontamination System (HDH) Process Equipment*
24590-HLW-DCA-PR-02-010	2	*Removal of Decon Effluent Collection Vessel (RLD-VSL-00001)*
24590-HLW-DCA-PR-02-011	0	*Removal of Redundant Pumps for HLW Systems NAR and SHR*
24590-HLW-M5-V17T-00001	6	*Process Flow Diagram-HLW Receipt & Feed Preparation (System HCP, GFR, & HFP)*
24590-HLW-M5-V17T-00002	5	*Process Flow Diagram-HLW Vitrification Melter 1 (System HMP and HOP)*
24590-HLW-M5-V17T-00003	5	*Process Flow Diagram HLW Vit Melter 1 Primary Offgas Treatment (System HOP)*
24590-HLW-M5-V17T-00004	5	*Process Flow Diagram HLW Vitrification Melter 1 Secondary Offgas Treatment (System HOP)*
24590-HLW-M5-V17T-00005	4	*Process Flow Diagram HLW Vitrification Pulse Jet Ventilation Treatment (System PJV)*
24590-HLW-M5-V17T-00006	6	*Process Flow Diagram HLW Vitrification HLW Canister Decon (System HDH)*
24590-HLW-M5-V17T-00007001	5	*Process Flow Diagram HLW Vitrification Liquid Waste Effluent (System RLD) (Sheet 1)*
24590-HLW-M5-V17T-00007002	5	*Process Flow Diagram HLW Vitrification Liquid Waste Effluent (System RLD) (Sheet 2)*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-HLW-M5-V17T-00008	5	*Process Flow Diagram-HLW Vitrification Reagents (System NAR, SHR, AMR, AFR, and DIW)*
24590-HLW-M5-V17T-00009	5	*Process Flow Diagram HLW C2 Drains Collection (System NLD)*
24590-HLW-M5-V17T-20002	1	*Process Flow Diagram HLW Vitrification Melter 2 (System HMP and HOP)*
24590-HLW-M5-V17T-20003	1	*Process Flow Diagram HLW Vit Melter 2 Primary Offgas Treatment (System HOP)*
24590-HLW-M5-V17T-20004	1	*Process Flow Diagram HLW Vitrification Melter 2 Secondary Offgas Treatment (System HOP)*
24590-HLW-M5N-V17T-00040	NA	*Hold Removal, Stream Number Addition, and TBD Removal*
24590-HLW-M5N-V17T-00041	NA	*Hold Removal, Stream Number Addition, and TBD Removal*
24590-HLW-M5N-V17T-00047	NA	*Updates to Venting and Simplification of Control Strategy on HLW Melter PFDs 24590-HLW-M5-V17T-00002/20002*
24590-HLW-M5N-V17T-00048	NA	*Update of HOP Instrumentation and Vendor Package on 24590-HLW-M5-V17T-00004/20004*
24590-HLW-M6-CHW-00001	1	*P&ID - HLW Chilled Water System Distribution*
24590-HLW-M6-DIW-00001001	0	*P&ID - HLW Demineralized Water System, Demineralized Water Distribution*
24590-HLW-M6-DIW-00001002	0	*P&ID - HLW Demineralized Water System, Demineralized Water Distribution*
24590-HLW-M6-DIW-00001003	0	*P&ID - HLW Demineralized Water System, Demineralized Water Distribution*
24590-HLW-M6-DIW-00001004	0	*P&ID - HLW Demineralized Water System, Demineralized Water Distribution*
24590-HLW-M6-HDH-00001	4	*P&ID HLW Canister Decontamination Handling System*
24590-HLW-M6-HDH-00002	4	*P&ID - HLW Canister Decontamination Handling System*
24590-HLW-M6-HDH-00003	3	*P&ID - HLW Canister Decontamination Area Steam Rack HDH-RK-00009*
24590-HLW-M6-HDH-00004	0	*P&ID - HLW Canister Decontamination Handling System HDH-HX-00001*
24590-HLW-M6-HDH-20001	3	*P&ID - HLW Canister Decontamination Handling System*
24590-HLW-M6-HDH-20002	0	*P&ID - HLW Canister Decontamination Handling System HDH-HX-00002*
24590-HLW-M6-HMP-00002	5	*P&ID - HLW Melter 1 System Film Cooler and Offgas Connection*
24590-HLW-M6-HMP-20002	6	*P&ID - HLW Melter 2 Film Cooler and Offgas Connection*
24590-HLW-M6-HOP-00001	5	*P&ID - HLW Melter Offgas System Melter 1 Primary Offgas Scrubber*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-HLW-M6-HOP-00002	5	*P&ID - HLW Melter Offgas System Melter 1 Primary Offgas WESP*
24590-HLW-M6-HOP-00003	2	*P&ID - HLW Melter Offgas System Melter 1 Secondary Offgas Treatment Sheet 1 of 3*
24590-HLW-M6-HOP-00004	4	*P&ID - HLW Melter 1 Offgas Fluidics Air Rack HOP-RK-00025*
24590-HLW-M6-HOP-00006	5	*P&ID - HLW Melter Offgas System Melter 1 Primary Offgas Scrubber Condensate Vessel*
24590-HLW-M6-HOP-00007	3	*P&ID - HLW Melter Offgas System Melter 1 Steam Rack HOP-RK-00047*
24590-HLW-M6-HOP-00008	2	*P&ID - HLW Melter Offgas System Melter 1 Secondary Offgas Treatment Sheet 2 of 3*
24590-HLW-M6-HOP-00009	5	*P&ID - HLW Melter Offgas System Melter 1 Primary Offgas HEME*
24590-HLW-M6-HOP-00010	3	*P&ID - HLW Melter Offgas System Melter 1 Primary Offgas HEPA Filters*
24590-HLW-M6-HOP-00011	0	*P&ID - HLW Melter Offgas System Melter 1 Secondary Offgas Treatment Sheet 3 of 3*
24590-HLW-M6-HOP-20001	6	*P&ID - HLW Melter Offgas System Melter 2 Primary Offgas Scrubber*
24590-HLW-M6-HOP-20002	6	*P&ID - HLW Melter Offgas System Melter 2 Primary Offgas WESP*
24590-HLW-M6-HOP-20003	2	*P&ID - HLW Melter Offgas System Melter 2 Secondary Offgas Treatment Sheet 1 of 3*
24590-HLW-M6-HOP-20004	5	*P&ID - HLW Melter 2 Offgas Fluidics Air Rack HOP-RK-00048*
24590-HLW-M6-HOP-20006	6	*P&ID - HLW Melter Offgas System Melter 2 Primary Offgas Scrubber Condensate Vessel*
24590-HLW-M6-HOP-20008	2	*P&ID - HLW Melter Offgas System Melter 2 Secondary Offgas Treatment Sheet 2 of 3*
24590-HLW-M6-HOP-20009	6	*P&ID - HLW Melter Offgas System Melter 2 Primary Offgas HEME*
24590-HLW-M6-HOP-20010	4	*P&ID - HLW Melter Offgas System Melter 2 Primary Offgas HEPA Filters*
24590-HLW-M6-HOP-20011	0	*P&ID - HLW Melter Offgas System Melter 2 Secondary Offgas Treatment Sheet 3 of 3*
24590-HLW-M6-NLD-00002	3	*P&ID - HLW Non-radioactive Liquid Waste Disposal System Non-active Effluent Collection*
24590-HLW-M6-PJV-00001	4	*P&ID - HLW Pulse Jet Ventilation System Collection & Conditioning*
24590-HLW-M6-PJV-00002	4	*P&ID - HLW Pulse Jet Ventilation System Filtration & Monitoring*
24590-LAW-DCA-M-02-006	0	*Elimination of Container Storage Facility*
24590-LAW-DCA-PR-02-004	0	*Deletion of CDG Compressed Air Equipment*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-LAW-DCA-PR-02-005	0	*Sugar Addition to Melter Feed Vessel and Melter*
24590-LAW-M5-V17T-00001	5	*Process Flow Diagram LAW Concentrate Receipt and Melter 1 Feed (System LCP, GFR, and LFP)*
24590-LAW-M5-V17T-00002	5	*Process Flow Diagram LAW Concentrate Receipt and Melter 2 Feed (System LCP, GFR, and LFP)*
24590-LAW-M5-V17T-00004	4	*Process Flow Diagram-LAW Vitrification Melter 1 (System LMP & LOP)*
24590-LAW-M5-V17T-00005	4	*Process Flow Diagram-LAW Vitrification Melter 2- (System LMP & LOP)*
24590-LAW-M5-V17T-00007	4	*Process Flow Diagram Melter 1 Primary Offgas Treatment System (System LOP)*
24590-LAW-M5-V17T-00008	4	*Process Flow Diagram Melter 2 Primary Offgas Treatment System (System LOP)*
24590-LAW-M5-V17T-00010	4	*Process Flow Diagram LAW Vitrification Ammonia & Secondary Offgas (System AMR & LVP)*
24590-LAW-M5-V17T-00011	5	*Process Flow Diagram LAW Vit Secondary Offgas Treatment (System LVP)*
24590-LAW-M5-V17T-00013	3	*Process Flow Diagram-LAW Vitrification Container Decontamination (System CDG)*
24590-LAW-M5-V17T-00014	5	*Process Flow Diagram LAW Liquid Effluent (System RLD)*
24590-LAW-M5-V17T-00016	4	*Process Flow Diagram-LAW Cold Chemical Supply (Systems SHR)*
24590-LAW-M5N-V17T-00011	NA	*Delete Offsheet Connector*
24590-LAW-M5N-V17T-00015	NA	*Change HEPA Filter Configuration, Renumber Ammonia Holding Vessels*
24590-LAW-M5N-V17T-00017	NA	*Rename NH3 Vaporization Heater, Change Batch Capacity for AMR-VSL-00003 & -00004, Change Offsheet Connector to LAW Selective Catalytic Reducer*
24590-LAW-M5N-V17T-00019	NA	*Add HEPA Filters Before the Inlets to LVP Fans in LVP-SKID-00003*
24590-LAW-M5N-V17T-00020	NA	*Change LFP Melter Feed Preparation Vessels' Overflow Lines (LFP-VSL-00002, LFP-VSL-00004)*
24590-LAW-M5N-V17T-00021*	NA	*Correct Stream Numbers*
24590-LAW-M5N-V17T-00023	NA	*Change Fan Symbol to LVP-FAN-00001/2*
24590-LAW-M5N-V17T-00024*	NA	*Delete Steam From Film Coolers*
24590-LAW-M6-CDG-00001001	0	*P&ID - LAW Carbon Dioxide Gas System CDG-VSL-00001.*

* Applies to LAW Melters 1 and 2

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-LAW-M6-CDG-00001002	0	*P&ID - LAW Carbon Dioxide Gas System CDG-PMP-00001A/B, -00002 A/B.*
24590-LAW-M6-CDG-00002001	0	*P&ID - LAW Carbon Dioxide Gas System CDG-SKID-00004A & 00005A*
24590-LAW-M6-CDG-00002002	0	*P&ID - LAW Carbon Dioxide Gas System CDG-SKID-00004B & 00005B*
24590-LAW-M6-LOP-00001001	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-SCB-00001*
24590-LAW-M6-LOP-00001002	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-VSL-00001*
24590-LAW-M6-LOP-00001003	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-BULGE-00001*
24590-LAW-M6-LOP-00001004	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-WESP-00001*
24590-LAW-M6-LOP-00001005	0	*P&ID - LAW Primary Offgas Process System Melter 1 Film Cooler Offgas*
24590-LAW-M6-LOP-00001006	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-PMP-00003A/B*
24590-LAW-M6-LOP-00002001	0	*P&ID - LAW Primary Offgas Process System Melter 2 LOP-SCB-00002*
24590-LAW-M6-LOP-00002002	0	*P&ID - LAW Primary Offgas Process System Melter 2 LOP-VSL-00002*
24590-LAW-M6-LOP-00002003	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-BULGE-00001*
24590-LAW-M6-LOP-00002004	0	*P&ID - LAW Primary Offgas Process System Melter 2 LOP-WESP-00002*
24590-LAW-M6-LOP-00002005	0	*P&ID - LAW Primary Offgas Process System Melter 2 Film Cooler Offgas*
24590-LAW-M6-LOP-00002006	0	*P&ID - LAW Primary Offgas Process System Melter 2 LOP-PMP-00006A/B*
24590-LAW-M6-LOP-00004001	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-FCLR-00002*
24590-LAW-M6-LOP-00004002	0	*P&ID - LAW Primary Offgas Process System Melter 1 LOP-FCLR-00001*
24590-LAW-M6-LOP-00005001	0	*P&ID - LAW Primary Offgas Process System Melter 2 LOP-FCLR-00004*
24590-LAW-M6-LOP-00005002	0	*P&ID - LAW Primary Offgas Process System Melter 2 LOP-FCLR-00003*
24590-LAW-M6-LVP-00001	3	*P&ID - LAW Secondary Offgas/Vessel Vent Process System Melters Secondary Offgas*
24590-LAW-M6-LVP-00002	3	*P&ID - LAW Secondary Offgas/Vessel Vent Process System and Stack Discharge Monitoring System*
24590-LAW-M6-LVP-00003	2	*P&ID - LAW Secondary Offgas / Vessel Vent Process System Equipment Vents*
24590-LAW-M6-LVP-00004	1	*P&ID - LAW Melters Secondary Offgas Vessel Vent Process System Mercury Mitigation Equipment*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-LAW-M6-LVP-00005	1	*P&ID - LAW Melters Secondary Offgas Vessel Vent Process System SCR, VOC & Ammonia Dilution Packages*
24590-PTF-DCA-M-02-017	0	*Modification of PJM Quantity for HLP-VSL-00022 / (12) PJMs in Lieu of (10)*
24590-PTF-DCA-M-03-003	0	*Replacement of PWD Steam Ejectors (PWD EJCTR-00119/00120) with Fluid Ejectors*
24590-PTF-M5-V17T-00003	2	*Process Flow Diagram Waste Feed Receipt- System FRP*
24590-PTF-M5-V17T-00004001	3	*Process Flow Diagram Waste Feed Evaporation-Sheet 1 of 2- System FEP*
24590-PTF-M5-V17T-00004002	3	*Process Flow Diagram Waste Feed Evaporation-Sheet 2 of 2- System FEP*
24590-PTF-M5-V17T-00005	2	*Process Flow Diagram Treated LAW Evaporation System TLP*
24590-PTF-M5-V17T-00006	1	*Process Flow Diagram Treated LAW Concentrate Storage- System TCP*
24590-PTF-M5-V17T-00007	2	*Process Flow Diagram HLW Feed Receipt System HLP*
24590-PTF-M5-V17T-00008	3	*Process Flow Diagram HLW Lag Storage and Feed Blending System HLP*
24590-PTF-M5-V17T-00009	2	*Process Flow Diagram Ultrafiltration Feed Preparation System UFP*
24590-PTF-M5-V17T-00011	2	*Process Flow Diagram Ultrafiltration Permeate Collection System UFP*
24590-PTF-M5-V17T-00012	3	*Process Flow Diagram Cesium Ion Exchange Process Vessels System CXP*
24590-PTF-M5-V17T-00013	3	*Process Flow Diagram Cesium Ion Exchange Process Columns System CXP*
24590-PTF-M5-V17T-00014	2	*Process Flow Diagram Cesium Nitric Acid Recovery Process System CNP*
24590-PTF-M5-V17T-00018	2	*Process Flow Diagram Cesium Resin Addition Process System CRP*
24590-PTF-M5-V17T-00020	2	*Process Flow Diagram Spent Resin Collection and Dewatering Process System RDP*
24590-PTF-M5-V17T-00021001	2	*Process Flow Diagram Pretreatment Vessel Vents (PVP/PVV) Process Systems PVP/PVV/PJV*
24590-PTF-M5-V17T-00021002	2	*Process Flow Diagram Pretreatment RFP/PJM Exhaust(PJV)-Systems PVP/PVV/PJV*
24590-PTF-M5-V17T-00021003	2	*Process Flow Diagram Pretreatment Vessel Passive Purge Air Inlets (PVP) Systems PVP/PVV/PJV*
24590-PTF-M5-V17T-00021004	2	*Process Flow Diagram Pretreatment Vessels Vent Exhaust Header (PAP) Systems PVP/PVV/PJV*
24590-PTF-M5-V17T-00022001	2	*Process Flow Diagram-Pretreatment Effluent, Plant Wash and Drain-System PWD*
24590-PTF-M5-V17T-00022002	2	*Process Flow Diagram Pretreatment Plant Wash and Disposal System PWD*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-PTF-M5-V17T-00022003	2	*Process Flow Diagram Pretreatment Radioactive Liquid Disposal System RLD Sheet 3 of 4*
24590-PTF-M5-V17T-00022004	2	*Process Flow Diagram Pretreatment Radioactive Liquid Disposal/Recycle System RLD Sheet 4 of 4*
24590-PTF-M5-V17T-00023001	2	*Process Flow Diagram Pretreatment Process Reagents System NAR*
24590-PTF-M5-V17T-00023002	2	*Process Flow Diagram Pretreatment Process Reagents System SHR*
24590-PTF-M5-V17T-00023003	2	*Process Flow Diagram Pretreatment Process Reagents System DIW*
24590-PTF-M5-V17T-00023004	2	*Process Flow Diagram Pretreatment Process Reagents Systems AFR/STR/SPR*
24590-PTF-M5-V17T-00025	1	*Process Flow Diagram Cesium Ion Exchange Process Collection Vessels System CXP*
24590-PTF-M5-V17T-00026	0	*Process Flow Diagram Pretreatment Process Reagents PWD Flush System PWD*
24590-PTF-M5-V17T-00032001	0	*Process Flow Diagram Ultrafiltration System UFP*
24590-PTF-M5-V17T-00032002	0	*Process Flow Diagram Ultrafiltration System UFP*
24590-PTF-M5N-V17T-00018	NA	*AB Update by Revision of the PT/BOF PSAR and Implementation of 24590-PTF-DCA-M-03-012*
24590-PTF-M5N-V17T-00026	NA	*Update this Drawing to Reflect Elimination of the TXP System and a Stream Number Change*
24590-PTF-M5N-V17T-00032	NA	*Incorporate 24590-PTF-DCA-PR-03-004, Rev 0 Removal of Technetium Ion Exchange from the Pretreatment Facility*
24590-PTF-M5N-V17T-00036	NA	*The Ejectors in PWD-VSL-00033 and PWD-VSL-00043 Will Be Driven by Process Condensate instead of Steam (See 24590-PTF-DCA-M-03-003, Rev 0)*
24590-PTF-M5N-V17T-00040	0	*The Need for Off-spec Resin to be Disposed of in the HLP System Has Been Eliminated Due to Two Factors. 1) Increases the*
24590-PTF-M5N-V17T-00045	NA	*The Justification for Each of the Changes is: 1. Pump Added and Piping Rerouted to Reflect Vendor's Design Change (See 24590-PTF-M6N-CNP-00021) 2. Temperature Instrument Removed by Vendor from Their Design. (See 24590-PTF-M6N-CNP-00021) 3. Sample Point*
24590-PTF-M5N-V17T-00047	0	*Incorporation of Vendor Information. Also, Solids Analyzer (AL) on the Inlet Line to Spent Resin Disposal Container Is Deleted Because this Instrument Is Not Noted. the AL Instrument Is Not Required Because the Solids Level Indication (Via Camera) Will*
24590-PTF-M5N-V17T-00048	NA	*Design Changes Associated with the Control of the Pressure in the CNP Evaporator Separator Vessel*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-PTF-M5N-V17T-00052	NA	*Removal of Process Condensate Immersion Heaters Due to Calculation Revision and Modifications to Vessel Vent System Due to Rheology Changes*
24590-PTF-M5N-V17T-00053	NA	*Deletion of Redundant Instrumentation and Changing Vessel Designator to Tank Designator. Contract Requirements for Performance Testing Can Be Achieved with a Single LAW Vitrification Facility*
24590-PTF-M5N-V17T-00078	NA	*General Update and Clarification for Current Design*
24590-PTF-M5N-V17T-00084	NA	*Add Evaporator Concentrate Transfer Line to FRP-VSL-00002A*
24590-PTF-M5N-V17T-00086	NA	*Add Flag for CRP and Delete Note 10*
24590-PTF-M5N-V17T-00088	NA	*Revision of Drawing Index for PFD 24590-PTF-M5-V17T-00022001*
24590-PTF-M6-CNP-00001	2	*P&ID-PTF Cesium Nitric Acid Recovery Process System Eluate Contingency Storage Vessel*
24590-PTF-M6-CRP-00001	3	*P&ID - PTF Cesium Ion Exchange Fresh Resin Addition*
24590-PTF-M6-CXP-00001001	0	*P&ID - PTF Cesium Ion Exchange Process System CXP-VSL-00001*
24590-PTF-M6-CXP-00001002	0	*P&ID - PTF Cesium Ion Exchange Process System CXP-PMP-00001B*
24590-PTF-M6-CXP-00001003	0	*P&ID - PTF Cesium Ion Exchange Process System CXP-PMP-00001A*
24590-PTF-M6-CXP-00001004	0	*P&ID - PTF Cesium Ion Exchange Process System CXP-VSL-00004*
24590-PTF-M6-CXP-00001005	0	*P&ID - PTF Cesium Ion Exchange Process System CXP-VSL-00005*
24590-PTF-M6-FRP-00001	3	*P&ID - PTF Waste Feed Receipt Vessels FRP-VSL-00002A and FRP-VSL-00002B*
24590-PTF-M6-FRP-00002	3	*P&ID - PTF Waste Feed Receipt Vessels FRP-VSL-00002C and FRP-VSL-00002D*
24590-PTF-M6-FRP-00003	3	*P&ID - PTF Waste Feed Receipt Process System FRP-PMP-00001 and FRP-PMP-00002A*
24590-PTF-M6-HLP-00001001	0	*P&ID - PTF HLW Lag Storage and Feed Blending Process System Vessel HLP-VSL-00027A*
24590-PTF-M6-HLP-00001002	0	*P&ID - PTF HLW Lag Storage and Feed Blending Process System Vessel HLP-VSL-00027B*
24590-PTF-M6-HLP-00001003	0	*P&ID - PTF HLW Lag Storage and Feed Blending Process System Pumps HLP-PMP-00017A/B*
24590-PTF-M6-HLP-00002001	0	*P&ID - PTF HLP System HLW Feed Receipt Vessel HLP-VSL-00022*
24590-PTF-M6-HLP-00002002	0	*P&ID - PTF HLP System HLW Feed Receipt Transfer Pump HLP-PMP-00021*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-PTF-M6-HLP-00003001	0	*P&ID - PTF HLW Lag Storage and Feed Blending Process System Vessel HLP-VSL-00028*
24590-PTF-M6-HLP-00003002	0	*P&ID - PTF HLW Lag Storage and Feed Blending Process System HLW Melter Feed Pump HLP-PMP-00019A*
24590-PTF-M6-HLP-00003003	0	*P&ID - PTF HLW Lag System HLW Melter Feed Pump HLP-PMP-00019B*
24590-PTF-M6-PJV-00001	3	*P&ID Pulse Jet Ventilation System Air Racks to Demisters.*
24590-PTF-M6-PJV-00002	3	*P&ID - PTF Pulse Jet Ventilation System Inlet Header to Demister Outlet.*
24590-PTF-M6-PJV-00004	3	*P&ID-PTF Pulse Jet Ventilation System Utility Services Plant Wash Rack.*
24590-PTF-M6-PJV-00007	1	*P&ID - PTF Pulse Jet Ventilation System Primary HEPA Exhaust Filters Elevation 56 FT-0 IN.*
24590-PTF-M6-PJV-00008	1	*P&ID - PTF Pulse Jet Ventilation System Primary HEPA Exhaust Filters Elevation 56FT-0IN.*
24590-PTF-M6-PJV-00009	1	*P&ID - PTF Pulse Jet Ventilation System Secondary HEPA Exhaust Filters Elevation 77FT-0IN.*
24590-PTF-M6-PJV-00010	1	*P&ID - PTF Pulse Jet Ventilation System Secondary HEPA Exhaust Filters Elevation 77FT-0IN.*
24590-PTF-M6-PJV-00011	1	*P&ID - PTF Pulse Jet Ventilation System In-Bleed Hot Air Injection System Elevation 56FT-0IN.*
24590-PTF-M6-PJV-00012	1	*P&ID - PTF Pulse Jet Ventilation System Exhaust Fans.*
24590-PTF-M6-PWD-00002001	0	*P&ID - PTF Plant Wash & Disposal System Effluent Collection PWD-VSL-00044*
24590-PTF-M6-PWD-00002002	0	*P&ID - PTF Plant Wash & Disposal System Effluent Collection PWD-VSL-00033/00043*
24590-PTF-M6-PWD-00003	4	*P&ID - PTF Plant Wash Disposal System Effluent Collection PWD-VSL-00015 and 00016*
24590-PTF-M6-PWD-00040	3	*P & ID - PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 0-0 Thru 56-0)*
24590-PTF-M6-PWD-00041	3	*P&ID - PTF Plant Wash & Disposal System C2 Area Floor Drains Collection Vessel*
24590-PTF-M6-PWD-00042	3	*P&ID - PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 0-0 Thru 56-0)*
24590-PTF-M6-PWD-00043	3	*P&ID - PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 0-0 Thru 56-0)*
24590-PTF-M6-PWD-00044	3	*P&ID - PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 0-0 Thru 56-0)*
24590-PTF-M6-PWD-00060001	0	*P&ID-PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 77-0 Thru 109-0)*
24590-PTF-M6-PWD-00061001	0	*P&ID-PTF Plant Wash & Disposal System C2 Area Floor Drains (EL 77-0 Thru EL 98-0)*
24590-PTF-M6-PWD-00062	1	*P&ID - PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 77-0)*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-PTF-M6-PWD-00063001	0	*P&ID-PTF Plant Wash & Disposal System C3 Area Floor Drains (EL 77-0 Thru EL 98-0)*
24590-PTF-M6-PWD-00064	0	*P&ID - PTF Process Reagent Flush System PWD-VSL-00150*
24590-PTF-M6-PWD-00065	0	*P&ID - PTF Process Reagent Flush System PWD-VSL-00148*
24590-PTF-M6-PWD-00066	0	*P&ID - PTF Process Reagent Flush System PWD-VSL-00151*
24590-PTF-M6-PWD-00067	0	*P&ID - PTF Process Reagent Flush System PWD-VSL-00149*
24590-PTF-M6-RDP-00001	3	*P&ID - PTF Ion Exchange Spent Resin Collection & Dewatering Process*
24590-PTF-M6-RLD-00001	2	*P&ID - PTF Radioactive Liquid Waste Disposal System Process Condensate RLD-TK-00006A/B*
24590-PTF-M6-RLD-00003001	0	*P&ID - PTF Radioactive Liquid Waste Disposal System Effluent Collection RLD-VSL-00017A*
24590-PTF-M6-RLD-00003002	0	*P&ID - PTF Radioactive Liquid Waste Disposal System Effluent Collection RLD-VSL-00017B*
24590-PTF-M6-UFP-00001001	0	*P&ID - PTF Ultrafiltration Process System Feed Preparation Vessel UFP-VSL-00001A*
24590-PTF-M6-UFP-00001002	0	*P&ID - PTF Ultrafiltration Process System Bubblers UFP-VSL-00001A*
24590-PTF-M6-UFP-00001003	0	*P&ID - PTF Ultrafiltration Process System UFP-PMP-00041A and UFP-HX-00041A*
24590-PTF-M6-UFP-00001004	0	*P&ID - PTF Ultrafiltration Process System Feed Preparation Vessel UFP-VSL-00001B*
24590-PTF-M6-UFP-00001005	0	*P&ID - PTF Ultrafiltration Process System Bubblers UFP-VSL-00001B*
24590-PTF-M6-UFP-00001006	0	*P&ID - PTF Ultrafiltration Process System UFP-PMP-00041B and UFP-HX-00041B*
24590-PTF-M6-UFP-00001007	0	*P&ID - PTF Ultrafiltration Process System Feed Preparation Header UFP-VSL-00001A/1B*
24590-PTF-M6-UFP-00002001	0	*P&ID - PTF Ultrafiltration Process System Feed Vessel UFP-VSL-00002A*
24590-PTF-M6-UFP-00002002	0	*P&ID - PTF Ultrafiltration Process System Bubblers UFP-VSL-00002A*
24590-PTF-M6-UFP-00002003	0	*P&ID - PTF Ultrafiltration Process System Feed Vessel UFP-PMP-00042A and UFP-PMP-00043A*
24590-PTF-M6-UFP-00002004	0	*P&ID - PTF Ultrafiltration Process System UFP-FILT-00001A/ -00002A/ -00003A/ -00004A*
24590-PTF-M6-UFP-00002005	0	*P&ID - PTF Ultrafiltration Process System UFP-FILT-00005A UFP-HX-00001A*
24590-PTF-M6-UFP-00002006	0	*P&ID - PTF Ultrafiltration Process System UFP-PP-00001A UFP-PP-00002A*
24590-PTF-M6-UFP-00002007	0	*P&ID - PTF Ultrafiltration Process System UFP-PP-00003A*

List of PFDs P&IDs and DCAs

Document #	Revision	Title
24590-PTF-M6-UFP-00002008	0	*P&ID - PTF Ultrafiltration Process System UFP-PMP-00044A*
24590-PTF-M6-UFP-00003001	0	*P&ID - PTF Ultrafiltration Process System Feed Vessel UFP-VSL-00002B*
24590-PTF-M6-UFP-00003002	0	*P&ID - PTF Ultrafiltration Process System Bubblers UFP-VSL-00002B*
24590-PTF-M6-UFP-00003003	0	*P&ID - PTF Ultrafiltration Process System UFP-PMP-00042B and UFP-PMP-00043B*
24590-PTF-M6-UFP-00003004	0	*P&ID - PTF Ultrafiltration Process System UFP-FILT-00001B/ -00002B/ -00003B/ -00004B*
24590-PTF-M6-UFP-00003005	0	*P&ID - PTF Ultrafiltration Process System UFP-FILT-00005B UFP-HX-00001B*
24590-PTF-M6-UFP-00003006	0	*P&ID - PTF Ultrafiltration Process System UFP-PP-00001B UFP-PP-00002B*
24590-PTF-M6-UFP-00003007	0	*P&ID - PTF Ultrafiltration Process System UFP-PP-00003B*
24590-PTF-M6-UFP-00003008	0	*P&ID - PTF Ultrafiltration Process System UFP-PMP-00044B*
24590-PTF-M6-UFP-00004001	0	*P&ID - PTF Ultrafiltration Process System Permeate Collection UFP-VSL-00062A*
24590-PTF-M6-UFP-00004002	0	*P&ID - PTF Ultrafiltration Process System Permeate Collection UFP-VSL-00062B*
24590-PTF-M6-UFP-00004003	0	*P&ID - PTF Ultrafiltration Process System Permeate Collection UFP-VSL-00062C*

Appendix B

Batch Volume and Setpoint Tables

Appendix B
Batch Volume and Setpoint Tables

The Vessel Datasheet contains information that reflects the current design. The information applies to PT, HLW, and LAW Facility vessels and tanks. The following information is provided in the data sheet:

System – Provides the system designation for the vessel.

Vessel (Bechtel Number) – The current Bechtel Plant Item Number.

Name or Description – The Plant Item Description.

Overflow Volume – The volume of liquid contained in a vessel to the bottom of the overflow nozzle with all the internals flooded.

Overflow Point – Where the excess volume flows when the vessel volume exceeds the overflow volume.

Filled Volume (Batch + Heel) – The volume of the heel volume added to the batch volume. Given in gallons.

Batch Volume – Portion of liquid volume available for processing. Given in gallons.

Heel Volume – Volume of liquid remaining after normal batch transfer. Given in gallons.

Maximum Effluent Rate – The maximum flow rate which effluent leaves the vessel/tank. Given in gallons per minute.

Total Holdup Time – The total time allowed for collection, delivery, and analysis of a sample. Given in hours.

Figures B-1 through B-4 provide information defining tank levels and volumes used by various WTP disciplines. Table B-1 provides additional definitions.

System	Vessel (Bechtel Number)	Name or Description	Overflow Volume[g]	Overflow Point	Filled Volume (Batch + Heel) (Gallons)	Batch Volume (Gallons)[h]	Heel Volume (Gallons)[i]	Maximum Effluent Rate (gpm)[c]	Total Model Holdup Time (hr)[o]
AMR	AMR-TK	Anhydrous Ammonia Storage Tank	6000						
AMR	AMR-TK	Anhydrous Ammonia Storage Tank	6000						
CDG	CDG-VSL-00001	LAW Container Decon CO2 Storage	TBD	N/A	28,400	28,400	0	TBD	None
CNP	CNP-EVAP-00001	Evaporator	N/A	N/A	2130	2000	130	20	None
CNP	CNP-DISTC-00001	Rectifier	N/A	N/A	N/A	N/A	N/A	N/A	None
CNP	CNP-VSL-00004	Nitric Recovery	10,064	PWD-VSL-00033	7342	6000	1342	20	None
CNP	CNP-VSL-00003	Cont. Storage	18,750	PWD-VSL-00033	16,127	12,500	3627	62	None
CRP	CRP-VSL-00001	Resin Add	2500	Bermed Area	2146	2146	0	60	None
CRP	CRP-VSL-00002	Air Gap	TBD	RDP-VSL-00002A	N/A	N/A	N/A	N/A	None
CXP	CXP-IXC-00001-4	IX Columns	TBD	TBD	Variable	Variable	N/A	30	None
CXP	CXP-VSL-00004	Caustic Rinse	8907	PWD-VSL-00033	7840	6000	1840	30	None
CXP	CXP-VSL-00005	Reagent	1003	PWD-VSL-00033	454	150	304	30	None
CXP	CXP-VSL-00026A	Collection	33,335	PWD-VSL-00033	29,768	27,500	2268	34	4.8
CXP	CXP-VSL-00026B	Collection	33,335	CXP-VSL-00026A	29,768	27,500	2268	34	4.8
CXP	CXP-VSL-00026C	Collection	33,335	CXP-VSL-00026B	29,768	27,500	2268	34	4.8
DIW	DIW-TK-00003	LAW Demineralized Water Tank	11,159	N/A	10,161	8759	1722	300	None
DIW	DIW-TK-00002	Demin Water Tank	3789	berm	2551	427	2124	198	None
FEP	FEP-VSL-00017A/B	Evap. Feed	69,292	PWD-VSL-0033	55,692	50,000	5692	50	None
FEP	FEP-SEP-00001A/B	Evaporator	N/A	N/A	N/A	N/A	N/A	45	None
FEP	FEP-VSL-00005	Evap. Cond.	4144	PWD-VSL-00033	1280	970	310	60	None
FRP	FRP-VSL-00002A/B/C/D	Feed Receipt	403,592	PWD-VSL-00033	379,391	375,000[a]	4391	125	37.8
GFR	GFR-TK-00022	LAW Melter 1 Glass Former Feed Hopper	N/A	N/A	3516	3516	0	49	None
GFR	GFR-TK-00023	LAW Melter 2 Glass Former Feed Hopper	N/A	N/A	3516	3516	0	49	None
GFR	GFR-TK-00025	HLW Melter Glass Former Feed Hopper	N/A	N/A	2394	2394	0	33.3	None
GFR	GFR-TK-00031	HLW Melter Glass Former Feed Hopper	N/A	N/A	2394	2394	0	33.3	None
HDH	HDH-VSL-00002[r]	Canister Decon Vessel	210	HDH-VSL-00003	204	204	0	48	None
HDH	HDH-VSL-00004[r]	Canister Decon Vessel	213	HDH-VSL-00003	207	207	0	48	None
HDH	HDH-VSL-00003	Waste Neutralization Vessel	4142	SUMPS	2752	2172	580	58	1
HDH	HDH-VSL-00001	Canister Decon Bogie Vessel	360	N/A	360	360	0	80	None
HDH	HDH-TK-00002	Cerium-4 Addition Tank	25	N/A	25	25	0	TBD	None
HFP	HFP-VSL-00001	Feed Preparation Vessel	7650l	HFP-SUMP-00002	5661	4305	1356	44	11.7/25.3
HFP	HFP-VSL-00005	Feed Preparation Vessel	7650l	HFP-SUMP-00002	5661	4305	1356	44	11.7/25.3
HFP	HFP-VSL-00002	Melter Feed Vessel	7646l	HFP-SUMP-00002	7208	5665	1543	2.53	None
HFP	HFP-VSL-00006	Melter Feed Vessel	7646l	HFP-SUMP-00002	7208	5665	1543	2.53	None
HLP	HLP-VSL-00022	HLW Receipt	232,261	PWD-VSL-00033	174,763	145,000	29,763	150[n]	43.7
HLP	HLP-VSL-00027A	HLW Lag	112,082	PWD-VSL-00033	91,418	82,000	9,418	90	None
HLP	HLP-VSL-00027B	HLW Lag	112,082	PWD-VSL-00033	91,418	82,000	9,418	90	None

System	Vessel (Bechtel Number)	Name or Description	Overflow Volume[g]	Overflow Point	Filled Volume (Batch + Heel) (Gallons)	Batch Volume (Gallons)[h]	Heel Volume (Gallons)[i]	Maximum Effluent Rate (gpm)[c]	Total Model Holdup Time (hr)[o]
HLP	HLP-VSL-00028	HLW Blend	124,750	PWD-VSL-00033	101,863	81,000	20,863	56 (90)[p]	24.8
HMP	HMP-MLTR-00001/2	HLW Melter	1217	Discharge Trough 5" above bath	1092	25	1067	Offgas/Glass	None
HOP	HOP-SCB-00001	Submerged Bed Scrubber (SBS) Column	3329	HOP-VSL-00903	3329	3329	0	80	None
HOP	HOP-SCB-00002	Submerged Bed Scrubber (SBS) Column	3329	HOP-VSL-00904	3329	3329	0	80	None
HOP	HOP-VSL-00903	SBS Condensate Receiver Vessel	7898	N/A	5808	4050	1758	80	None
HOP	HOP-VSL-00904	SBS Condensate Receiver Vessel	7898	N/A	5808	4050	1758	80	None
LCP	LCP-VSL-00001	Concentrate Receipt Vessel 1	14,877	RLD-VSL-00004	12,855	9115	3740	88	10.5
LCP	LCP-VSL-00002	Concentrate Receipt Vessel 2	14,877	RLD-VSL-00004	12,855	9115	3740	88	10.5
LFP	LFP-VSL-00001	LAW Melter 1 Feed Preparation Vessel	7489	RLD-VSL-00004	5132	3400	1732	50	None
LFP	LFP-VSL-00002	LAW Melter 1 Feed Vessel	5786	LFP-VSL-00001	4377	3400	977	3.5	None
LFP	LFP-VSL-00004	LAW Melter 2 Feed Vessel	5786	LFP-VSL-00003	4377	3400	977	3.5	None
LFP	LFP-VSL-00003	LAW Melter 2 Feed Preparation Vessel	7489	RLD-VSL-00004	5132	3400	1732	50	None
LMP	LMP-MLTR-00001	LAW Melter 1	2318L	Discharge Trough 8" above bath[M]	2016	141	1875	Offgas/Glass	None
LMP	LMP-MLTR-00002	LAW Melter 2	2318L	Discharge Trough 8" above bath[M]	2016	141	1875	Offgas/Glass	None
LOP	LOP-VSL-00001	Melter 1 SBS Condensate Vessel	6806	N/A	6651	6200	451	80	None
LOP	LOP-SCB-00001	Melter 1 SBS Column	3329	LOP-VSL-00001	3329	3329	0	82	None
LOP	LOP-VSL-00002	Melter 2 SBS Condensate Vessel	6806	N/A	6651	6200	451	80	None
LOP	LOP-SCB-00002	Melter 2 SBS Column	3329	LOP-VSL-00002	3329	3329	0	82	None
LVP	LVP-TK-00001	LAW Caustic Collection Vessel	7325	RLD-VSL-00017A/B	6032	4000	2032	200	None
MXR	MXR-TK-00001	Misc Cold Chemical Mix Tank	1029	Berm/sump	794	625	169	TBD	None
NAR	NAR-TK-00001	Nitric Acid Tank	1333	berm	1265	600	89	100	None
NLD	NLD-VSL-00005	C1/C2 Drains & Sump Collection Tank	15,100	SUMPS	14,107	11,331	2776	100	None
NLD	NLD-TK-00006	C1/C2 Drains/Sump Collection Vessel	1585	Fire Collection Area	1220	750	470	30	None
PVP	PVP-SCB-00002	Scrubber	3564	PWD-VSL-00033	1960	1960	0	120	None
PVP	PVP-VSL-00001	HEME	1650	PWD-VSL-00033	1547	800	747	50	None
PWD	PWD-VSL-00015/16	Acidic/Alk	105,864	PWD-VSL-00033	87,148	75,000	12,148	108	None
PWD	PWD-VSL-00044	Plant Wash	88,631	PWD-VSL-00033	73,644	60,000	13,644	111	None
PWD	PWD-VSL-00033	Plant Overflow	31,476	PWD-VSL-00043	20,386	15,000	5386	83	None
PWD	PWD-VSL-00043	HLW Transfer	26,504	PWD-VSL-00033/ PWD-SUMP-00040	20,301	15,000	5301	79	None
PWD	PWD-VSL-00148	Process Reagent Flush System	569.3	N/A	550.3	442	108.3	48	None
PWD	PWD-VSL-00149	Process Reagent Flush System	569.3	N/A	550.3	442	108.3	48	None
PWD	PWD-VSL-00150	Process Reagent Flush System	569.3	N/A	550.3	442	108.3	48	None

System	Vessel (Bechtel Number)	Name or Description	Overflow Volume[g]	Overflow Point	Filled Volume (Batch + Heel) (Gallons)	Batch Volume (Gallons)[h]	Heel Volume (Gallons)[i]	Maximum Effluent Rate (gpm)[c]	Total Model Holdup Time (hr)[o]
PWD	PWD-VSL-00151	Process Reagent Flush System	569.3	N/A	550.3	442	108.3	48	None
RDP	RDP-VSL-00002A/B/C	Spent Resin	12,688	PWD-VSL-00033	7525	7517	8	140	5.5
RDP	RDP-VSL-00004	Dewatering	N/A	N/A	80	80	0	265	None
RLD	RLD-VSL-00017A/B	Alkaline	28,075	PWD-VSL-00033	21,870	20,000	1870	130	8.4
RLD	RLD-TK-00006A	Condensate	313,500	RLD-SUMP-00027	292,500	265,000	27,500	1000	None
RLD	RLD-TK-00006B	Condensate	313,500	RLD-SUMP-00027	292,500	265,000	27500	170	None
RLD	RLD-VSL-00005	SBS Condensate Collection Vessel	23,264	RLD-VSL-00003	20,300	16,000	4300	175	None
RLD	RLD-VSL-00003	Plant Wash Vessel	23,400	RLD-VSL-00004	19,164	16,000	3164	175	None
RLD	RLD-VSL-00004	C3/C5 Drain/Sump Collection Vessel	6456	SUMPS	5887	4500	1387	75	None
RLD	RLD-VSL-00007	Acid Waste Storage Vessel	14,612	RLD-VSL-00008	11,662	9868	1794	47	7.8
RLD	RLD-VSL-00008	Plant Wash & Drains Vessel	10,624	SUMPS	8721	6865	1856	45	7.8
RLD	RLD-VSL-00002	Offgas Drains Collection Vessel	260	Sump	226	90	136	23	None
SHR	SHR-TK-00009	Flush	DELETED	---	---	---	---	---	None
SHR	SHR-TK-00003	Caustic Cold Chemical Mix Tank	4809	Berm/sump	3949	3400	549	60	None
SHR	SHR-TK-00002	Sodium Hydroxide Tank	1403	berm	1262	750	447	25	None
TCP	TCP-VSL-00001	Conc. Buffer	130,234	PWD-VSL-00033	103,430	96,000	7430	88	None
TLP	TLP-SEP-00001	Evaporator	N/A	N/A	N/A	N/A	N/A	30	None
TLP	TLP-VSL-00009A/B	SBS	114,064	PWD-VSL-00033	87,450	80,000	7450	46	None
TLP	TLP-VSL-00002	Cond.	1705	PWD-VSL-00033	495	364	131	34	None
UFP	UFP-VSL-00001A/B	UF Feed Prep.	64,373	PWD-VSL-00033	52,704	45,000	7704	140	None
UFP	UFP-VSL-00002A/B	UF Feed	36,510	PWD-VSL-00033	27,292	26,792	500[d]	94	16.9[q]
UFP	UFP-VSL-00062A/B/C	UF Permeate / Solid Wash	29,993	PWD-VSL-00033	23,645	21,800	3305	70	None

[a] Volume given is a working volume for 2 PJM operation. Working volume for 12 PJM operation is 363,700 gallons (24590-PTF-MTE-FRP-00004).

[b] Frequency of sampling set by ICD-06.

[c] Flow rate is the maximum flow rate, which may represent reagent flow rates and not normal operation flow rates. These values are from vessel sizing calculations.

[d] The estimated heel volume is the level that positive displacement pumps UFP-PMP-00044A/B can lower UFP-VSL-00002A/B. Engineering is currently determining the minimum vessel volume for recirculation.

[f] This vessel empties completely upon transfer.

[g] Overflow volumes are from vessel sizing calculations.

[h] Batch volumes are from vessel sizing calculations.

[I] Heel volumes are from vessel sizing calculations.

[j] This batch volume comes from CCN 040099.

[k] These are operating volumes.

[l] Maximum effluent values from pump sizing calculations (24590-PTF-M6C-UFP-00014).

[n] Per 24590-PTF-M6C-HLP-00007, Rev C

[o] Sample turn-around times were obtained from the *Integrated Sampling and Analysis Requirements Document (ISARD)*, 24590-WTO-PL-PR-04-0001, Rev 2.

[p] 56 gpm transfer rate to HLW and 90 gpm transfer rate for transfers within PT.

[q] Sample hold-up time begins after initial transfer of slurry.

[r] These volumes do not include the HLW canister displacement volume. The working volume represents the high liquid level (2" below the overflow nozzle), as described in 24590-HLW-M6C-HDH-00008.

Table B-1 Tank Level and Volume Definitions Used by Various WTP Disciplines

	Description	Definition	Value (ft.)	Vol. (ft^3)	Vol. (gal)
V_{L1}	Heel (Minimum)	Volume of liquid remaining after total pump out.			
V_{L2}	Lo-Lo Level Margin	Minimum height required to achieve 0.2 c/t ratio for agitator/mixer clearance minus V_{L1}-(provides additional pump protection or dipped leg seal).			
V_{L3}	Operator Response Time-Low Level	Operator response volume allowance between the Low Alarm Level (L) and Lo-Lo Level Interlock (LL) if required by ITS. Equivalent to the greater of 10 minutes of outflow or 2 % of the Maximum Operating Volume (V_{L17}). Not required for this Vessel.			
V_{L4}	Lower Operating Volume	Volume required to avoid nuisance tripping of the Low Alarm Level (L). Equivalent to the greater of 10 minutes of pump discharge flow rate or 2 % of the Maximum Operating Volume (V_{L17}).			
V_{L5}	Mixing Volume-Low Level	Volume required for effective mixing operating at low level. Equivalent to 15 % of the volume below the Low Alarm (L). Volume required for effective mixing operating at low level. Equivalent to 6 inches of vessel height.			
V_{L6}	Lower Instrumentation Volume	Volume required to accommodate instrumentation level uncertainty. Equivalent to 2 % of the Maximum Operating Volume (V_{L17}).			
V_{L7}	Heel (Normal)	Volume of liquid remaining after normal batch transfer.			
V_{L8}	Batch Volume	Portion of liquid volume available for processing. Batch volume includes the volume of liquid contained within the flooded internals. The top of the batch volume sets the Upper Operating Level (UOL).			
V_{L9}	Upper Instrumentation Volume	Volume required to accommodate instrumentation level uncertainty. Equivalent to 2 % of the Maximum Operating Volume (V_{L17}).			
V_{L10}	Mixing Volume-Hi Level	Volume required for effective mixing operating at high level. Equivalent to 15 % of the volume below the Upper Operating Level (UOL). Volume required for effective mixing operating at high level. Equivalent to 6 inches of vessel height.			
V_{L11}	Operator Response Time-Hi Level	Operator response allowance above the Upper Operating Level (UOL)-High Level Alarm (H). Sets the High Level Alarm (H) to trip in the event of continued filling while mixing-the greater of 10 minutes of inflow or 2 % of the Maximum Operating Volume (V_{L17}).			

Table B-1 Tank Level and Volume Definitions Used by Various WTP Disciplines

	Description	Definition	Value (ft.)	Vol. (ft^3)	Vol. (gal)
V_{L12}	Operating Response Time-HiHi Level	Operator response allowance above the Upper Operating Level (UOL). If required by ITS sets the HiHi Level Interlock (HH) to trip in the event of continued filling beyond the High Alarm (H) level while mixing. The greater of 30 minutes of inflow for draining tanks and 20 min of inflow above the Upper Operating Level (UOL) for all others or 2 % of the Maximum Operating Volume (V_{L17}). Not required for this Vessel.			
V_{L13}	Overflow Reserve	The greater of 2 inches of vessel height or 5 minutes of inflow or 2 % of the Maximum Operating Volume (V_{L17}) above the HiHi Level Interlock (HH) or the High Level Alarm (H) in absence of the HiHi Level Interlock (HH).			
V_{L14}	Overflow Range	Level range between top and bottom of overflow nozzle.			
V_{L15}	Vapor Space	Volume of vapor contained between the top of the overflow nozzle and the top of the vessel.			
V_{L16}	Internals Displacement Vol.	Volume occupied by internal piping and structural elements.			
V_{L17}	Maximum Operating Volume	Volume of liquid contained in the vessel up to the bottom of the overflow nozzle with all the internals flooded.			
V_{L18}	Total Vessel Volume	Total internal vessel volume including shell and both heads. (Calculated According Build-Up Method)			
V_{L19}	Overflow Nozzle Clearance	Distance from upper tangent line to top of overflow nozzle. This distance assures that the nozzle and its reinforcement are entirely below the tangent line. Additionally, nozzle and reinforcement welds should avoid the head-shell seam. Overflow Nozzle Clearance should be the greater of 4 inches or one half the nominal diameter of the overflow nozzle (Based on Self-Reinforced Nozzle).			
$L_{T\text{-}T}$	Tangent Length	Length between tangent lines.			
L_{SLN}	Pump Suction Lift (Normal)	Normal operating volume attributed to pump suction lift.			
L_{SLM}	Pump Suction Lift (Maximum)	Maximum volume attributed to pump suction lift.			
D_i	Inside Diameter	Inside diameter of vessel.			

Figure B-1 VIT Vessel Volume Diagram for Models

Constant Volumes

V_{OF} (Overflow Volume)

V_F (Filled Volume)

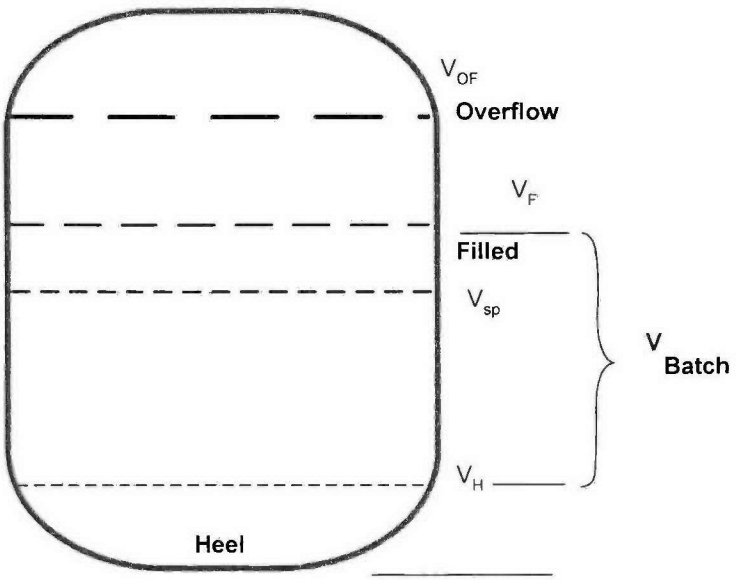
V_B (Batch Volume)

V_H (Heel Volume)

Variable Volumes

Vsp (Set Point)

The model is triggered to do a particular task when Vsp is reached. Value for Vsp may vary, but Vsp shall not exceed V_F.



Process Tech	Mechanical Systems	Process Engineering	OR	G2
V_{OF}	Maximum Operating Volume	Maximum Capacity @	Modeled $	Modeled
V_F	Batch + Heel	Batch + Heel	N/A	Modeled
V_B	Batch	Batch Volume	Modeled	N/A
V_H	Heel Normal	Heel Normal	N/A	Modeled
V_{SP} *	N/A	N/A	N/A	Modeled (Trigger for Model)

Notes:

1. * - G2 Specific
2. @ - Max Capacity = Maximum Operating Volume + Overflow Range
3. $ - Only used for Buffer Vessels

Figure B-2 Vessel Volume Diagram for Models

Constant Volumes

V_H (Volume of Heel)

V_F (Filled Volume)

V_{OF} (Overflow Volume)

V_B (Batch Volume)

V_F = Batch + Heel

V_B = Batch Operated Volume

V_{OF} = Value at Overflow Nozzle

V_H = Heel

Variable Volumes

V_{sp} (Set Point)

The model is triggered to do a particular task when Vsp is reached. Value for Vsp may vary, but Vsp shall not exceed V_F.

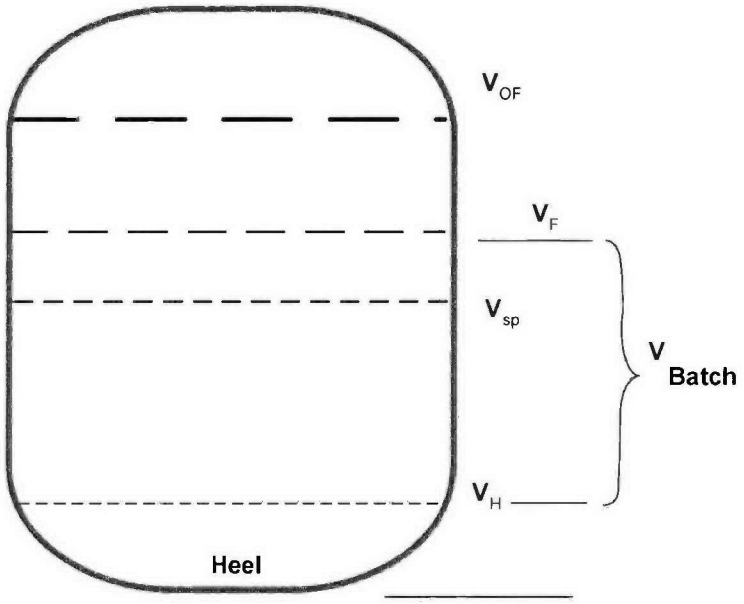
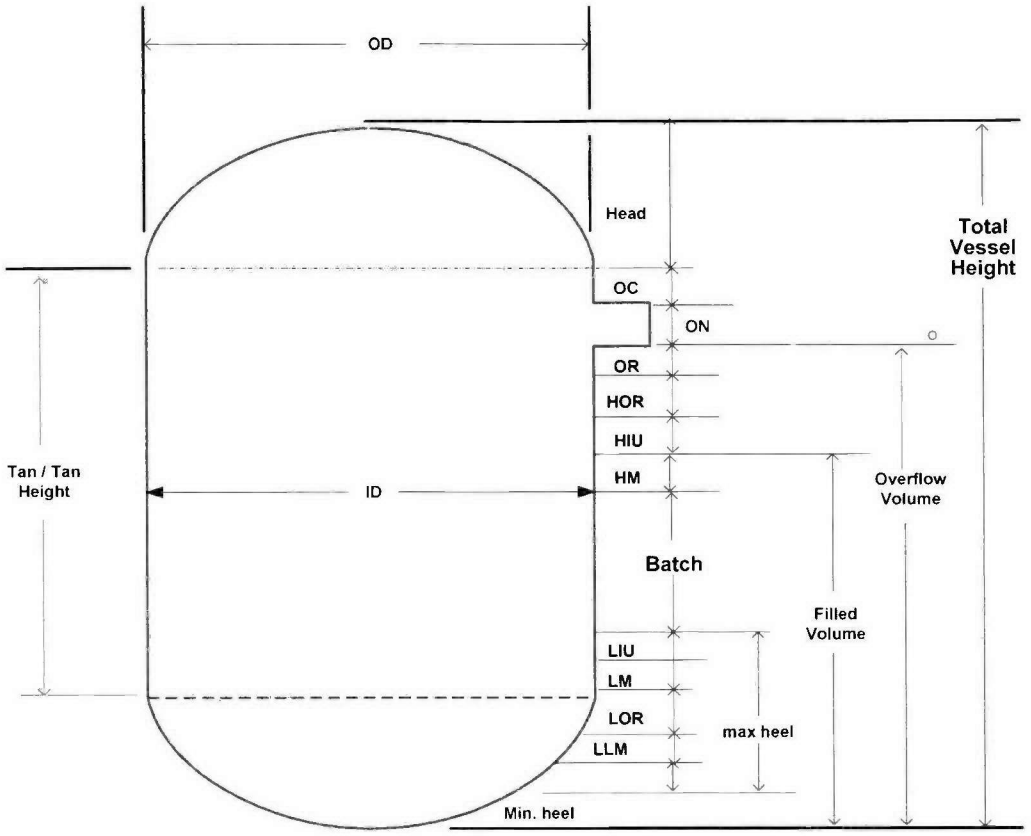


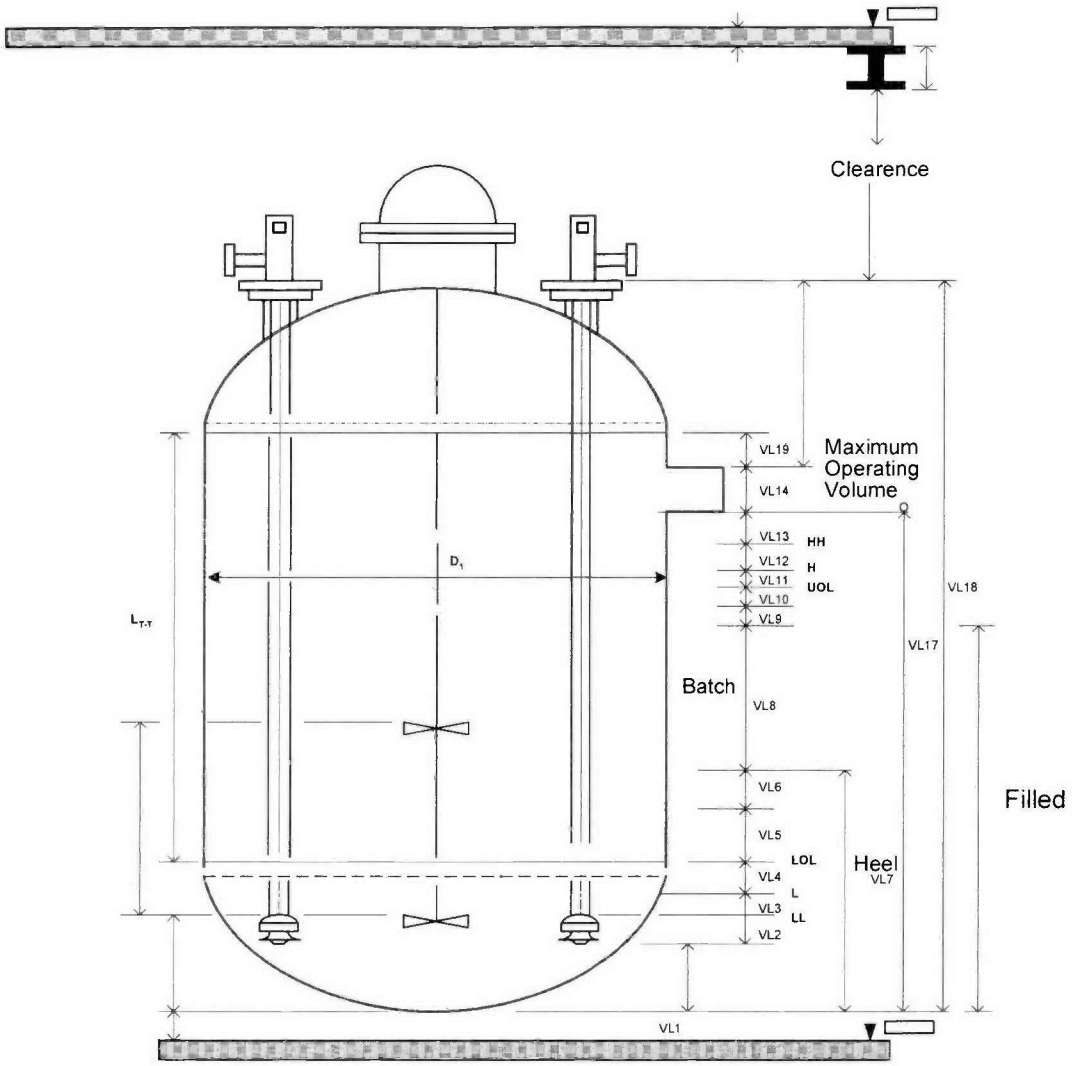
Figure B-3 Calculation Sheet



NOT TO SCALE

ID = inside diameter
OD = outside diameter
LLM = low level margin
LOR = low operator response
LM = low mixing
LIU = low instrument uncertainty
HM = high mixing
HIU = high instrument uncertainty
HOR = high operator response
OR = overflow reserve
ON = overflow nozzle
OC = overflow clearance

Figure B-4 Vessel Diagram



Appendix C

List of Assumptions

Appendix C
List of Assumptions

Introduction to Appendix C

Appendix C provides a summary of all the assumptions listed in the main body of the BARD. It is divided into three distinct sections: unresolved, resolved and status sections. The unresolved assumptions are assumptions that conclusive data is not available to close the assumption. The resolved section contains assumptions that a basis has been developed that contains strong supporting evidence that is considered fact. Lastly, the assumption status section list all assumptions past and present and states its current condition or final disposition.

UNRESOLVED

Assumption 2.2.1. Assumptions made in the reference calculation define some of the DF values for radionuclides and chemical components as having similar values to calculated values for which constituent information is available. Assumptions used to establish DF values are provided in the referenced calculation and summarized in Tables 2.2-1 and 2.2-2. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data.....2.2-8

Assumption 2.12.2. Assumptions are made in defining the DF values for organic components as having similar values to calculated values for formate, oxalate, and other test compounds as detailed in CCN 027646. Assumptions used to establish values are summarized in Table 2.12-5. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data.....2.2-7

Assumption 2.3.2. Each ultrafilter train is chemically cleaned following the next solids discharge when 500 hr of operating time or has elapsed since the last cleaning or after every fourth UFP-VSL-00002A/B batch, whichever comes first. Chemical cleaning involves two 2000 gal power flushes, three 6000 gal 2 M nitric acid cleaning cycles, draining the acid to PWD and neutralization of the vessel heel with 2 M sodium hydroxide. The time provided in the model to perform these activities is 18 hr. 2.3-21

Assumption 2.3.3. The general form of the leaching reaction used is $C_x(OH)_y(s) + x\ NaOH(\ell) \rightarrow x\ NaC(OH)_{x+y}(\ell)$ where C = component. 2.3-21

Assumption 2.3.4. The WTP process will produce similar results as TFCOUP or TWINS supplied leach factors.....2.3-21

Assumption 2.3.6. The exact mechanism and solid products for the reactions have not been determined. The research to date suggests that the Sr reaction is a good representation of the process, but the TRU is not likely precipitating as discrete hydroxide phases, as published in Project R&T results. Additional hydroxide did not improve the TRU decontamination as would be expected in a simple formation of metal hydroxide (24590-101-TSA-W000-0004-101-02 Rev 00A). The TRU is likely precipitating as a coprecipitated birnessite crystal. Although the compounds that are precipitating are not entirely understood, the overall process removes sufficient quantities of Sr and TRU so that the liquid can be processed into ILAW. 2.3-27

Assumption 2.5.2. The process can accommodate the variations in resin bed volume indicated by test data over the process cycles. 2.5-8

Assumption 2.5.4. Spherical RF will be supplied in the quantities needed and future production scale resin batch performance is conservatively bounded by the selected benchmark resin properties. 2.5-6

Assumption 2.5.5. The relative impact of radiation degradation on spherical RF performance observed in material used by the Pretreatment Facility is assumed to be similar to that determined using material from resin lot BRF-14 (produced using different fabrication parameters than the final reference resin lot). 2.5-10

Assumption 2.5.6. The impact of combined radiolytic and chemical degradation rate is assumed to be additive as was observed during testing of SuperLig 644. ..... 2.5-16

Assumption 2.5.7. The presence of organics in waste is assumed to have no measurable impact on spherical RF loading or elution performance since testing performed using organic spiked material did not impact the loading and elution performance of SuperLig 644. ..... 2.5-22

Assumption 2.5.8. A model based on ideal stirred tank mixing of the column head space liquid volume is assumed to be applicable to all cycles processed down flow as a conservative estimate of transmitting residual ions in the liquid phase from one cycle to the next. 2.5-46

Assumption 2.9.2. The resorcinol formaldehyde resin will retain adequate performance and capacity stability for 40 loading and elution cycles. 2.9-2

Assumption 2.12.1. Assumptions are made in the reference calculation that define some of the DF values for radionuclides and chemical components as having similar values to calculated values for which constituent information is available. Assumptions used to establish DF values are provided in the referenced calculation and briefly summarized in Table 2.12-1 and 2.12-2. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data. 2.12-3

Assumption 2.12.2. Assumptions are made in defining the DF values for organic components as having similar values to calculated values for formate, oxalate, and other test compounds as detailed in CCN 027646. Assumptions used to establish values in the calculation are briefly summarized in Table 2.12-3. Comparisons to these DF values may be made using vapor-liquid equilibrium data, pilot-scale test data, and commissioning data. 2.12-4

Assumption 2.13.1. The forced purge air and passive purge air flow rates listed in Table 2.13-1 are unverified assumptions for hydrogen mitigation. Additional calculations (e.g., hydrogen generation, passive purge inlet line sizing, forced purge inlet line sizing) are needed to verify these assumptions for hydrogen mitigation..... 2.13-4

Assumption 3.1.5. The amount of water added for dusting control is 3 wt % for all LAW glass former batches (CCN 077705)..... 3.1-5

Assumption 3.3.1. Heavy organics, such as PCBs, are commonly removed from gas streams with activated carbon. These molecules compete with other contaminants for active sites in the carbon beds, which may increase the carbon changeout frequency. No credit is assumed for removal of these organics within the carbon beds, nor are competing contaminants considered in the models. This presents a more challenging case for the offgas systems and provides a bounding emissions estimate. 3.3-14

Assumption 4.1.5. The exact quantity of water needed to control melter feed water is waste specific. The assumption will be that melter feeds will have acceptable rheology if the glass yield is below 550 grams of oxide per liter. Water must be added to bring the glass yield below this value and this will be added to the HLW melter feed preparation vessels. The operating contractor may choose to add this water to some other location upstream of the melter feed preparation vessels. 4.1-19

Assumption 4.3.1. Heavy organics are assumed to have minimal removal (DF = 10) in the carbon adsorption beds and their contribution as competing contaminants is not considered in the models..... 4.3-15

Assumption 4.4.3. The contamination release fraction per constituent in the emissions stream of the HLW PJV system is assumed 1.0E-10..... 4.4-2

Assumption 10.1. Components that have redundancy or work-around alternatives will be repaired prior to failure of the alternative and are not critical to WTP availability. The RAM repair scenario considered crane utilization, which included the crane travel time and crane usage time. The repair scenario considered tasks that could be performed at the same time..... 10.2-2

Assumption 10.3. Qualified spares, procedures, and personnel will be readily available for failed critical components such that replacement is not delayed. The RAM evaluation identified spare components that must be on hand to minimize the plant availability, and identified those components by vendor and model designators, as the information became available..... 10.2-2

Assumption 10.4. WTP external interfaces, such as the supply of chemical reagents, will be highly available and will not impact the WTP availability. The Relex software was used to determine the availability of these interface systems and their impact to the WTP throughput..... 10.2-3

RESOLVED

Assumption 2.3.1. The ultrafilter solids removal efficiency is 99.99 %. The Envelope A/B/D solids can be concentrated to 20 wt % solids and the Envelope C solids can be concentrated to 15 wt % solids with ultrafiltration. The variable flux equation used in the flowsheet depends on the waste envelope. The flux rate at a given time is based on the wt % solids and the sodium molarity of the filter feed, at that time. The flux multiplied by the effective surface area of the filters, gives the permeate flowrate (gpm) through the ultrafilters.

Assumption 2.3.5. The dynamic flowsheet dissolution of Cr is 87 % and Pu is 1 % for batches that are oxidative leached and is based on the SX-101 test data (test #3 24590-101-TSA-W000-0004-00012)

Assumption 2.5.1. SuperLig 644 will be supplied in the quantities needed and future production scale resin batch performance is conservatively bounded by the selected benchmark resin properties.

Assumption 2.5.3. The loading cycle test data obtained from a two-column system, using essentially fresh resin, conservatively describes the loading performance of a three column system over a minimum of 10 cycles where chemical and radiolytic resin degradation has occurred.

Assumption 2.7.1. SuperLig 639 will be supplied in the quantities needed and perform as expected in the flowsheet.

Assumption 2.7.2. It is assumed that loading cycle test data obtained from a two column system, using essentially fresh resin, conservatively describes the loading performance of a three column system over a minimum of 10 cycles where chemical and radiolytic resin degradation has occurred.

Assumption 2.9.1. The SuperLig 644 resin will retain adequate performance and capacity stability for 10 loading and elution cycles.

Assumption 2.13.2. The forced and passive purge air inlet conditions are assumed to be 25 °C, 1 atm with a dewpoint of 12 °C throughout the flowsheets, unless specifically called out elsewhere. The assumption is based on engineering judgment. Incorrect values for this assumption will slightly affect energy requirement results for some offgas equipment and the amount of water lost to the ventilation system.

Assumption 3.2.1. Relationships derived for data presented in the tables within the VSL report 42590-101-TSA-W000-0009-111-02 are assumed to be correct. The report is currently in the review process and all data will be validated and the information reconciled.

Assumption 3.3.1. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data. Pump failures are not provided, as they are still to be determined.

Assumption 3.3.2. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data. Pump failures are not provided, as they are still to be determined.

Assumption 3.3.3. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.4. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.5. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.6. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.7. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.8. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.9. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.10. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.11. RAM data used for LAW components is assumed to be consistent with HLW RAM data for the HOP system (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of LAW RAM data.

Assumption 3.3.12. The vessel ventilation retention factors shown in the table below are an assumption that was originally based on a proprietary design guide from British Nuclear Fuels, Limited, when that company had the contract for the WTP (BNFL 1996). That guide has not been available to the project since Bechtel and Washington Group International won the contract. The assumption does not require verification because entrainment from the calm surface of liquid in the LAW vessels is extremely small and within the range of engineering uncertainty inherent within project models and calculations. The value assumed bounds anticipated entrainment.

Assumption 3.4.2.	Transfer line is flushed following each transfer with an assumed two line volumes. Vessel wash volumes and the frequency have not yet been determined
Assumption 3.5.1.	The Reliability Availability Maintainability (RAM) data used is the same as for pumps in the HDH system (24590-HLW-RPT-ENG-02-001) as shown below. This data will be updated as LAW RAM data is determined.
Assumption 3.5.2.	The RAM data below is based on specification requirements being issued for bid proposals. This data will be updated as LAW RAM data is determined.
Assumption 3.5.3.	The RAM data is the same as for HEPA filters in the HOP system (24590-HLW-RPT-ENG-02-001) as shown below. This data will be updated as LAW RAM data is determined.
Assumption 3.5.4.	The RAM data is the same as for HEPA filters in the HOP system (24590-HLW-RPT-ENG-02-001) as shown below. This data will be updated as LAW RAM data is determined.
Assumption 3.6.1.	RAM data used for the LAW cold chemicals supply system components is assumed to be consistent with RAM data for similar equipment (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of future RAM data updates.
Assumption 3.7.1.	All of the following RAM data are preliminary values assumed to be the same as HLW RAM data.
Assumption 4.1.4.	Up to one weight percent spinel at 950 °C is tolerable in the melter. This assumption is consistent with glass formulation strategy adopted for the DM 1200 Pilot melter glasses (24590-101-TSA-W000-0009-82-02). Likewise, this assumption is consistent with the assertion made by Hrma and others (2002), that zero percent crystals is too constraining for small crystals such as spinel, because they do not settle appreciably.
Assumption 4.4.1.	The reliability, availability, maintainability (RAM) values for the heaters, filters, and fans are the same values as for similar equipment within the HLW melter offgas treatment process system (24590-HLW-RPT-ENG-02-001).
Assumption 4.5.1.	RAM data for PJMs assumed to be similar to RFDs.
Assumption 4.5.2.	(Note: system description silent on flush and wash and HLW water balance does not include)
Assumption 4.7.1.	RAM data used for the HLW reagent system components is assumed to be consistent with RAM data for similar equipment (24590-HLW-RPT-ENG-02-001). These assumptions will be verified upon determination of future RAM data updates.

Assumption 10.2. ITS components and systems were evaluated for their impacts to the WTP throughput. Repair times within the LCO periods were considered and RAM data for ITS components were determined and submitted for implementation into the OR Model.

Status

Assumption	Status (Resolved/ Unresolved)	Proposed Resolution	Disposition	Comments
1.3.1.	Resolved	Verify assumption when RAM data for LAW Process Reagent systems is developed.	The RAM analysis of WTP facility-specific cold chemical systems is not planned since the design of reliable cold chemical systems is well understood.	Originally Assumption 3.6.1. This assumption is closed.
1.3.2.	Resolved	Verify assumption when RAM data for the PJV system components is developed.	Systems Engineering to complete development of RAM Data. The RAM analysis of WTP PJV is not planned since the PJV system has not been identified as a critical system.	Incorporates Assumption 4.4.1. This assumption is closed.
1.3.3.	Resolved	Verify assumption when RAM data for Pulse Jet Mixers is developed.	Systems Engineering to complete development of RAM Data. The RAM analysis of WTP PJMs is not planned since their design is projected to be life-of the-plant.	Incorporates Assumption 4.5.1. This assumption is closed.
1.3.4.	Resolved	Verify assumption when RAM data for HLW Process Reagent systems is developed.	The RAM analysis of WTP facility-specific cold chemical systems is not planned since the design of reliable cold chemical systems is well understood.	Incorporates Assumption 4.7.2. This assumption is closed.
1.3.1.	Unresolved	Verify assumption when RAM data for LAW Process Reagent systems is developed.	Systems Engineering to complete development of RAM Data.	Originally Assumption 3.6.1.
1.3.2.	Unresolved	Verify assumption when RAM data for the PJV system components is developed.	Systems Engineering to complete development of RAM Data.	Incorporates Assumption 4.4.1.
1.3.3.	Unresolved	Verify assumption when RAM data for Pulse Jet Mixers is developed.	Systems Engineering to complete development of RAM Data.	Incorporates Assumption 4.5.1.
1.3.4	Unresolved	Verify assumption when RAM data for HLW Process Reagent systems is developed.	Systems Engineering to complete development of RAM Data.	Incorporates Assumption 4.7.2
2.2.1.	Unresolved	The Decontamination Factors provided are based on information from the 242-A Evaporator and other design references. However, these references do not contain all of the components that are tracked in the flowsheet. Some assumptions are made that components that have no information will split in a similar manner to components that information is available (e.g., Ce is given the same DF as 238U). These assumptions cannot be proven since many of the components are present in quantities that so small that they are not measured.	Evaluation of DFs and performance of the process will be completed by Process Operations during commissioning.	None
2.2.2.	Unresolved	The Decontamination Factors provided are based on information from the 242-A Evaporator and other design references. However, these references do not contain all of the components that are tracked in the flowsheet. Some assumptions are made that components that have no information will split in a similar manner to components that information is available (e.g., Ce is given the same DF as 238U). These assumptions cannot be proven since many of the components are present in quantities that so small that they are not measured.	Evaluation of DFs and performance of the process will be completed by Process Operations during commissioning.	None

Status

Assumption	Status (Resolved/ Unresolved)	Proposed Resolution	Disposition	Comments
2.3.1.	Resolved	Verification of the assumption will be completed through reconciliation of R&T test data and during commissioning.	Pretreatment Engineering Platform (PEP) testing confirmed that the ultrafiltration process can concentrate wastes to greater than 20 wt% solids, see 24590-QL-HC9-WA49-00001-03-00040, *Pretreatment Engineering Platform Phase 1 Final Test Report.* The only solids observed in PEP permeate were the result of precipitation. No solids crossed the 0.1 μm sintered ultrafilters, see 24590-QL-HC9-WA49-00001-03-00036, *Laboratory Tests on Post-Filtration Precipitation in the WTP Pretreatment Process.*	None.
2.3.2.	Unresolved	Verification of the assumption will be completed through reconciliation of R&T test data and operational performance during commissioning.	Process Operations to complete during flowsheet development and commissioning.	None
2.3.3.	Unresolved	The assumption will be closed through development of a rigorous model.	Process Operations to complete during flowsheet development.	None
2.3.4.	Unresolved	The assumption will be closed through development of a rigorous model and operations performance during commissioning.	Process Operations to complete during flowsheet development and commissioning.	None
2.3.5.	Resolved	Evaluate oxidative leach factors of experiments performed using Tank Farm wastes.	An average chromium conversion factor of 0.876 was determined from a review of oxidative leaching experiments (24590-WTP-MCR-PO-08-0014).	None
2.3.6.	Unresolved	The precipitation reactions are presumed as those occurring within the Sr/TRU precipitation processes. Reaction extents are known, however, verification of actual reactions is pending and may not be completely determined.	Process Operations to close with DOE during commissioning.	
2.5.1.	Resolved	Cancel	Process Operations to complete during flowsheet development and commissioning.	It was closed because SuperLig will no longer be used. Assumption 2.5.4 replaces it.
2.5.2.	Unresolved	Verification of the assumption will occur during commissioning by quantifying the available headspace in the column during the loading/elution/regeneration cycles during the lifetime of the resin bed	Process Operations to complete during flowsheet development and commissioning.	None
2.5.3.	Resolved	Verification of the assumption will be completed as reconciliation of R&T test work on Ion Exchange processes and design of the CXP system develops.	Additional column loading cycle tests with newer resin batches have been performed and summarized in section 2.5.3.4.1, "Cesium Removal Column Test Data Summary" and shown on Figure 2.5-12. These tests provide assurance that the loading performance of the IX columns will be adequate.	This assumption is closed.
2.5.4.	Unresolved	Verification of the assumption will be completed during commissioning.	Process Operations to complete during flowsheet development and commissioning.	This Assumption replaced Assumption 2.5.1 to incorporate RF resin.
2.5.5.	Unresolved	Process Operations to close after hot commissioning		None

Status

Assumption	Status (Resolved/ Unresolved)	Proposed Resolution	Disposition	Comments
2.5.6.	Unresolved	Closed during reconciliation of hot commissioning results		None
2.5.7.	Unresolved	Verification is expected from testing being performed to mature cesium removal to a technical readiness level of 6.		None
2.5.8.	Unresolved	During commissioning, if plugged flow proves to be adequate, the model will be updated. This is a conservative assumption for the time being.		None
2.7.1.	Resolved	Cancel	Assumption deleted as it pertained to the Technetium Ion Exchange Process System which has been removed from the flowsheet.	This assumption is closed.
2.7.2.	Resolved	Cancel	Assumption deleted as it pertained to the Technetium Ion Exchange Process System which has been removed from the flowsheet.	This assumption is closed.
2.9.1.	Resolved	Cancel	The resin type was replaced. SuperLig 644 was replaced with Resorcinol Formaldehyde.	None
2.9.2.	Unresolved	Evaluation of the performance of the RF resin will be conducted throughout commissioning operations. Data compiled during commissioning will verify this assumption.	Process Operations to evaluate during commissioning.	None
2.12.1.	Unresolved	The Decontamination Factors provided are based on information from the 242-A Evaporator and other design references. However, these references do not contain all of the components that are tracked in the flowsheet. Some assumptions are made that components that have no information will split in a similar manner to components that information is available (e.g., Ce is given the same DF as 238U). These assumptions cannot be proven since many of the components are present in quantities that so small that they are not measured.	Evaluation of DFs and performance of the process will be completed by Process Operations during commissioning.	None
2.12.2.	Unresolved	The Decontamination Factors provided are based on information from the 242-A Evaporator and other design references. However, these references do not contain all of the components that are tracked in the flowsheet. Some assumptions are made that components that have no information will split in a similar manner to components that information is available (e.g., Ce is given the same DF as 238U). These assumptions cannot be proven since many of the components are present in quantities that so small that they are not measured.	Evaluation of DFs and performance of the process will be completed by Process Operations during commissioning.	None
2.13.1.	Unresolved	Additional calculations (e.g., hydrogen generation, passive purge inlet line sizing, forced purge inlet line sizing) are needed to verify these assumptions for hydrogen mitigation.	Process Operation to reconcile R&T reports and Central Engineering calculations on hydrogen mitigation. Hydrogen generation calculation routine has been incorporated into the dynamic G2 model to determine hydrogen generation rate. Process operation to evaluate during commissioning.	None

Status

Assumption	Status (Resolved/ Unresolved)	Proposed Resolution	Disposition	Comments
2.13.2.	Unresolved	Verification of the assumption will occur during commissioning by determining total inlet conditions for forced and passive purges.	Process Operations to evaluate during commissioning.	None
3.1.1.	Resolved	Assumptions on washing vessels are not used in flowsheets	Need for model vessel washing will be determined after commissioning during reconciliation	This assumption is closed.
3.1.2.	Resolved	Assumptions on washing vessels are not used in flowsheets	Need for model vessel washing will be determined after commissioning during reconciliation	This assumption is closed.
3.1.3.	Resolved	Flushing requirements for ADS pumps are based on ADS pump tests performed by Duratek	Flushing is based on testing results	This assumption is closed.
3.1.4.	Resolved	Assumptions on washing vessels are not used in flowsheets.	Need for model vessel washing will be determined after commissioning during reconciliation	This assumption is closed.
3.1.5.	Unresolved	The amount of water added for dusting control is 3 wt % for all LAW glass former batches (CCN 077705).	This assumption will be evaluated during operations from operational experience.	None
3.2.1.	Resolved	Review final report.	The report has been accepted by the project and the data has been reconciled (RTC-218).	This assumption is closed
3.3.1.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.2.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.3.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.4.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.5.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.6.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.7.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.

Status

Assumption	Status (Resolved/ Unresolved)	Proposed Resolution	Disposition	Comments
3.3.8.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.9.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.10.	Resolved	Verify assumption when RAM data for LAW offgas components is developed.	RAM Data for LAW Offgas was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.3.11.	Resolved	Assumption will be closed upon approval of design for Mercury abatement systems.	Sulfur impregnated activated carbon is now in WTP baseline	This assumption is closed.
3.3.12.	Resolved	TBD	TBD	This assumption is closed.
3.4.1.	Resolved	Assumption not needed for flowsheets.	Plant wash vessel currently does not receive wash in flowsheets	This assumption is closed.
3.4.2.	Resolved	Close the assumption upon design confirmation of line flush volume and the development of confirmed line flush and vessel wash strategies.	Currently the models don't assume any line flushes for the vessels in this section (RLD-VSL-00003, RLD-VSL-00004, and RLD-VSL-00005). The System Description (24590-LAW-3YD-RLD-00001, Rev 2) states that "a typical flush is one pipe volume to remove residual" which will be put into the model when this volume calculation is done. Since there is no calculation for this volume, it can't be put into the models at this time. Need for model vessel washing will be determined after commissioning during reconciliation.	This assumption is closed.
3.5.1.	Resolved	Verify assumption when RAM data for LAW CDG system components is developed.	RAM Data for LAW Mechanical Handling systems was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.5.2.	Resolved	Verify assumption when RAM data for LAW CDG system components is developed.	RAM Data for LAW Mechanical Handling systems was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.5.3.	Resolved	Verify assumption when RAM data for LAW CDG system components is developed.	RAM Data for LAW Mechanical Handling systems was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.5.4.	Resolved	Verify assumption when RAM data for LAW CDG system components is developed.	RAM Data for LAW Mechanical Handling systems was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
3.6.1.	Resolved	Verify assumption when RAM data for LAW Process Reagent systems is developed.	Renamed as Assumption 1.3.1.	This assumption was moved to section 1.3 and is now numbered Assumption 1.3.1.

Status

Assumption	Status (Resolved/ Unresolved)	Proposed Resolution	Disposition	Comments
3.7.1.	Resolved	Verify assumption when RAM data for LAW Mechanical Handling systems is developed.	RAM Data for LAW Mechanical Handling systems was developed in *LAW First-Order RAM Data Development and Assessment* (24590-LAW-RPT-ENG-02-004)	This assumption is closed.
4.1.1.	Resolved	Equipment impacted by this assumption has been removed from the design.	Assumption was used for vessel and process line now removed from WTP baseline	This assumption is closed.
4.1.2.	Resolved	Closed the assumption with committed flush volumes provided in calculation 24590-HLW-M4C-30-00003 Rev B. Vessel washing is an off-normal event to be performed as required by operations.	Changes have been incorporated in the flowsheet through MCRs 04-0045, 04-0047 and line flush volume is now based on a calculation	This assumption is closed.
4.1.3.	Resolved	Closed the assumption with committed flush volumes provided in calculation 24590-HLW-M4C-30-00003 Rev B. Vessel washing is an off-normal event to be performed as required by operations.	Line flush volume is now based on a calculation	This assumption is closed.
4.1.4.	Resolved	Very thorough R&T testing with pilot melters show that 1 percent spinel in glass has not caused problems. They expect the same with full sized melter operation.	Very thorough R&T testing with pilot melters show that 1 percent spinel in glass has not caused problems. They expect the same with full sized melter operation.	None
4.1.5.	Unresolved	Resolved as Part of Operating Plan for Commission and Balance of Mission by the Operating contractor.	Close by Operating Contractor	None
4.3.1.	Resolved	Assumption removed, mercury abatement is now included in baseline design	Sulfur impregnated activated carbon is now in the baseline design	This assumption is closed.
4.4.1.	Resolved	Verify assumption when RAM data for the PJV system components is developed.	Systems Engineering to complete development of RAM Data.	This assumption was moved to Section 1.3 and is now consolidated under Assumption 1.3.2.
4.4.3	Unresolved	Verify the contamination release fraction per constituent in the emissions stream is 1.0E-10.	Testing is required to close this assumption	This assumption is listed as "not requiring verification" in 24590-WTP-M4C-V11T-00010.
4.5.1.	Resolved	Verify assumption when RAM data for Pulse Jet Mixers is developed.	Systems Engineering to complete development of RAM Data.	This assumption was moved to Section 1.3 and is now consolidated under Assumption 1.3.3.
4.5.2.	Resolved	Line flush volume is now based on a calculation	Line flush volume is now based on a calculation	This assumption is closed.
4.5.3.	Resolved	Line flush volume is now based on a calculation	Line flush volume is now based on a calculation	This assumption is closed.
4.7.1.	Resolved	Verify assumption when RAM data for HLW Process Reagent systems is developed.	Systems Engineering to complete development of RAM Data.	This assumption was moved to Section 1.3 and is now consolidated under Assumption 1.3.4.
4.7.2.	Resolved	The AMR process for HLW has been removed from the baseline. Anhydrous ammonia is now being provided from the LAW Facility.	AMR for HLW is no longer in the baseline	This assumption is closed.

Status

Assumption	Status (Resolved/ Unresolved)	Proposed Resolution	Disposition	Comments
4.8.1.	Resolved	Testing has been completed	Pour testing completed	This assumption is closed.
10.1.	Unresolved	Verify assumption for the PTF hot cell and other potential areas of risk when detailed design, maintenance, and operations information is available.	PTF hotcell has been reviewed for pumps and valves.	This assumption was updated with additional information for clarity.
10.2.	Resolved	Verify assumption when LCOs have been established.	ITS components and systems were evaluated for their impacts to the WTP throughput. Repair times within the LCO periods were considered and RAM data for ITS components were determined and submitted for implementation into the OR Model.	This assumption is closed. Appendix D contains all components evaluated for RAM data.
10.3.	Unresolved	Verify assumption when spares planning information is available.	The RAM evaluation identified spare components that must be on hand to minimize the plant availability, and identified those components by vendor and model designators, as the information became available.	This assumption was updated with additional information for clarity.
10.4.	Unresolved	Verify assumption through RAM assessment of external interfaces.	The RAM evaluation reviewed external interfaces, such as the supply of chemical reagents.	This assumption was updated with additional information for clarity.

Appendix D

Reliability, Availability, and Maintainability Data

Appendix D
Reliability, Availability, and Maintainability Data

2 Pretreatment RAM Data

2.1 System FRP: Waste Feed Receipt Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
FRP-PMP-00001	FRP-YV-0306	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0311	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0326	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0327	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0328	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0366	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FRP-PMP-00001	FRP-YV-0301	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
FRP-PMP-00002-A	FRP-YV-0318	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
FRP-PMP-00002-A	FRP-YV-0347	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0348	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0349	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0350	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0354	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0356	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0360	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0368	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	FRP-YV-0369	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FRP-VSL-00002A	FRP-PJM-00061_0511 Subsystem	WST FD REC VLS A PJM 61	55,455	42	
	FRP-PJM-00062_0501 Subsystem	WST FD REC VSL A PJM 62	55,455	42	
	FRP-PJM-00063_0502 Subsystem	WST FD REC VSL A PJM 63	55,455	42	
	FRP-PJM-00064_0503 Subsystem	WST FD REC VSL A PJM 64	55,455	42	
	FRP-PJM-00065_0504 Subsystem	WST FD REC VSL A PJM 65	55,455	42	
	FRP-PJM-00066_0505 Subsystem	WST FD REC VLS A PJM 66	55,455	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FRP-PJM-00067_0506 Subsystem	WST FD REC VLS A PJM 67	55,455	42	
	FRP-PJM-00068_0507 Subsystem	WST FD REC VLS A PJM 68	55,455	42	
	FRP-PJM-00069_0508 Subsystem	WST FD REC VLS A PJM 69	55,455	42	
	FRP-PJM-00070_0509 Subsystem	WST FD REC VLS A PJM 70	55,455	42	
	FRP-PJM-00071_0510 Subsystem	WST FD REC VLS A PJM 71	55,455	42	
	FRP-PJM-00072_0512 Subsystem	WST FD REC VLS A PJM 72	55,455	42	
	FRP-DT-0104/FRP-LT-0103 Assembly	WST FD REC VSL A	28,855	42	
	FRP-YV-0330	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0331	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0332	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0362	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
FRP-VSL-00002A/B/C/D	FRP-PCJ-PNL	PROGRAMMABLE PROTECTION (PPJ) I/O MODULES FOR FRP-VSL-00002A/B/C/D	17,159	8	
	FRP-PMP-00001	WASTE FEED RETURN PUMP - VERTICAL CENTRIFUGAL PUMP API 610 - 125 GPM 150 HP	9636	63 / PIH crane usage 36	
	FRP-PMP-00002-A	WASTE FEED TRANSFER PUMP - VERTICAL CENTRIFUGAL PUMP API 610 - 100 GPM 20 HP	9636	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	FRP-PPJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES FOR FRP-VSL-00002A/B/C/D	2,027,064	8	
	FRP-VSL-00002-A	WASTE FEED RECEIPT VESSELS	350,400		
	FRP-YV-0302 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0303 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0304 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0305 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0333 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0334 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0335 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0336 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FRP-YV-0345 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0346 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0353 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0358 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FRP-VSL-00002B	FRP-PJM-00017_0601 Subsystem	WST FD REC VSL B PJM 17	55,455	42	
	FRP-PJM-00018_0602 Subsystem	WST FD REC VSL B PJM 18	55455	42	
	FRP-PJM-00019_0603 Subsystem	WST FD REC VSL B PJM 19	55,455	42	
	FRP-PJM-00020_0604 Subsystem	WST FD REC VSL B PJM 20	55,455	42	
	FRP-PJM-00021_0605 Subsystem	WST FD REC VSL B PJM 21	55,455	42	
	FRP-PJM-00022_0606 Subsystem	WST FD REC VSL B PJM 22	55,455	42	
	FRP-PJM-00023_0607 Subsystem	WST FD REC VSL B PJM 23	55,455	42	
	FRP-PJM-00024_0608 Subsystem	WST FD REC VSL B PJM 24	55,455	42	
	FRP-PJM-00025_0609 Subsystem	WST FD REC VSL PJM 25	55,455	42	
	FRP-PJM-00026_0610 Subsystem	WST FD REC VSL B PJM 26	55,455	42	
	FRP-PJM-00027_0611 Subsystem	WST FD REC VSL B PJM 27	55,455	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FRP-PJM-00028_0612 Subsystem	WST FD REC VSL B PJM 28	55,455	42	
	FRP-DT-0109/FRP-LT-0108 Assembly	WST FD REC VSL B	28,855	42	
	FRP-VSL-00002-B	WASTE FEED RECEIPT VESSELS	350,400		
	FRP-YV-0363	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
FRP-VSL-00002C	FRP-PJM-00001_0701 Subsystem	WST FD REC VSL C PJM 1	55,455	42	
	FRP-PJM-00002_0702 Subsystem	WST FD REC VSL C PJM 2	55,455	42	
	FRP-PJM-00003_0703 Subsystem	WST FD REC VSL C PJM 3	55,455	42	
	FRP-PJM-00004_0704 Subsystem	WST FD REC VSL C PJM 4	55,455	42	
	FRP-PJM-00029_0705 Subsystem	WST FD REC VSL C PJM 29	55,455	42	
	FRP-PJM-00030_0706 Subsystem	WST FD REC VSL C PJM 30	55,455	42	
	FRP-PJM-00031_0707 Subsystem	WST FD REC VSL PJM 31	55,455	42	
	FRP-PJM-00032_0708 Subsystem	WST FD REC VSL C PJM 32	55,455	42	
	FRP-PJM-00033_0709 Subsystem	WST FD REC VSL C PJM 33	55,455	42	
	FRP-PJM-00034_0710 Subsystem	WST FD REC VSL C PJM 34	55,455	42	
	FRP-PJM-00035_0711 Subsystem	WST FD REC VSL C PJM 35	55,455	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FRP-PJM-00036_0712 Subsystem	WST FD REC VSL C PJM 36	55,455	42	
	FRP-DT-0204/FRP-LT-0203 Assembly	WST FD REC VSL C	28,855	42	
	FRP-VSL-00002-C	WASTE FEED RECEIPT VESSELS	350,400		
	FRP-YV-0364	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
FRP-VSL-00002D	FRP-PJM-00005_0802 Subsystem	WST FD REC VSL D PJM 5	55,455	42	
	FRP-PJM-00006_0803 Subsystem	WST FD REC VSL D PJM 6	55,455	42	
	FRP-PJM-00007_0804 Subsystem	WST FD REC VSL D PJM 7	55,455	42	
	FRP-PJM-00008_0805 Subsystem	WST FD REC VSL D PJM 8	55,455	42	
	FRP-PJM-00009_0806 Subsystem	WST FD REC VSL D PJM 9	55,455	42	
	FRP-PJM-00010_0807 Subsystem	WST FD REC VSL D PJM 10	55,455	42	
	FRP-PJM-00011_0808 Subsystem	WST FD REC VSL D PJM 11	55,455	42	
	FRP-PJM-00012_0809 Subsystem	WST FD REC VSL D PJM 12	55,455	42	
	FRP-PJM-00013_0810 Subsystem	WST FD REC VSL D PJM 13	55,455	42	
	FRP-PJM-00014_0811 Subsystem	WST FD REC VSL PJM 14	55,455	42	
	FRP-PJM-00015_0812 Subsystem	WST FD REC VSL D PJM 15	55,455	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FRP-PJM-00016_0801 Subsystem	WST FD REC VSL D PJM 16	55,455	42	
	FRP-DT-0209/FRP-LT-0208 Assembly	WST FD REC VSL D	28,855	42	
	FRP-VSL-00002-D	WASTE FEED RECEIPT VESSELS	350,400		
	FRP-YV-0344	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FRP-YV-0365	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

2.2 System FEP: Feed Evaporator Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
FEP-PMP-00006A/B	FEP-YV-0331	VALVE - ON/OFF BALL (2 WAY)	43,800	12	
FEP-PMP-00007-A	FEP-YV-0140	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FEP-PMP-00008-A	FEP-YV-0222	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0225	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0226	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0240	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
FEP-PMP-00008-B	FEP-YV-0425	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0426	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0440	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0464	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
FEP-PMP-00009-B	FEP-YV-0422	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FEP-SEP-00001-A	FEP-SEP-00001-A	WASTE FEED EVAPORATOR SEPARATOR VESSEL	350,400		
	FEP-VSL-00021	REBOILER CONDENSATE TRANSFER VESSEL	350,400		
	FEP-YV-0128	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0242	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0264	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	FEP-YV-0265	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
FEP-SEP-00001A/B	FEP-COND-00001-A	WASTE FEED EVAPORATOR PRIMARY CONDENSER	254,040	192	
	FEP-COND-00001-B	WASTE FEED EVAPORATOR PRIMARY CONDENSER	254,040	192	
	FEP-COND-00002-A	WASTE FEED EVAPORATOR INTER-CONDENSER	254,040	192	
	FEP-COND-00002-B	WASTE FEED EVAPORATOR INTER-CONDENSER	254,040	192	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FEP-COND-00003-A	WASTE FEED EVAPORATOR AFTER-CONDENSER	254,040	192	
	FEP-COND-00003-B	WASTE FEED EVAPORATOR AFTER-CONDENSER	254,040	192	
	FEP-PMP-00008-A	WASTE FEED EVAPORATOR CONCENTRATE PUMP - VERTICAL CENTRIFUGAL PUMP API 610 - 34 GPM 20 HP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	FEP-PMP-00008-B	WASTE FEED EVAPORATOR CONCENTRATE PUMP - VERTICAL CENTRIFUGAL PUMP API 610 - 34 GPM 20 HP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	FEP-PMP-00009-A	WASTE FEED EVAPORATOR RECIRCULATION PUMP - VERTICAL AXIAL PUMP API 610 - 8200 GPM 200 HP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	FEP-PMP-00009-B	WASTE FEED EVAPORATOR RECIRCULATION PUMP - VERTICAL AXIAL PUMP API 610 - 8200 GPM 200 HP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	FEP-PMP-00010-A	REBOILER CONDENSATE TRANSFER PUMP	43,800	48	
	FEP-PMP-00010-B	REBOILER CONDENSATE TRANSFER PUMP	43,800	48	
	FEP-PMP-00011-A	REBOILER CONDENSATE TRANSFER PUMP	43,800	48	
	FEP-PMP-00011-B	REBOILER CONDENSATE TRANSFER PUMP	43,800	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FEP-RBLR-00001A	WASTE FEED EVAPORATOR REBOILER	350,400		Deactivated in OR model (MTBF=10,000,000)
	FEP-RBLR-00001-B	WASTE FEED EVAPORATOR REBOILER	350,400		Deactivated in OR model (MTBF=10,000,000)
FEP-SEP-00001-B	FEP-SEP-00001-B	WASTE FEED EVAPORATOR SEPARATOR VESSEL	350,400		
	FEP-VSL-00022	REBOILER CONDENSATE TRANSFER VESSEL	350,400		
	FEP-YV-0129	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0442	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0465	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
FEP-VSL-00002-A	FEP-YV-0131	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0139	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FEP-VSL-00005	FEP-PMP-00006-A	WASTE FEED EVAPORATOR CONDENSATE PUMP - VERTICAL CENTRIFUGAL PUMP ASME B73.1 - 75 GPM 5 HP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	FEP-PMP-00006-B	WASTE FEED EVAPORATOR CONDENSATE PUMP - VERTICAL CENTRIFUGAL PUMP ASME B73.1 - 75 GPM 5 HP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	FEP-VSL-00005	WASTE FEED EVAPORATOR CONDENSATE VESSEL	350,400		
	FEP-YV-0357- Critical Valve	VALVE - GLOBE	43,800	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
FEP-VSL-00017A	FEP-DT-0104/FEP-LT-0103 Assembly	WST FD EVAP FD VSL A	28,855	42	
	FEP-PJM-00001_0601 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-PJM-00002_0602 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-PJM-00003_0603 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-PJM-00004_0604 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-PJM-00005_0605 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-PJM-00006_0606 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-PJM-00007_0607 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-PJM-00017_0608 Subsystem	WST FD EVAP VSL A PJM	53,534	42	
	FEP-VSL-00017-A	WASTE FEED EVAPORATOR FEED VESSEL	350,400		
	FEP-YV-0111	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0137	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FEP-VSL-00017A/B	FEP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES FOR FEP-VSL-00017A/B	17,159	8	
	FEP-PMP-00007-A	WASTE FEED EVAPORATOR FEED PUMP - VERTICAL CENTRIFUGAL PUMP API 610 - 50 GPM 20 HP	9636	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FEP-PMP-00007-B	WASTE FEED EVAPORATOR FEED PUMP - VERTICAL CENTRIFUGAL PUMP API 610 - 50 GPM 20 HP	9636	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	FEP-PPJ-PNL	PROGRAMMABLE PROTECTION (PPJ) I/O MODULES FOR FEP-VSL-00017A/B	2,027,064	8	
	FEP-YV-0126	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
FEP-VSL-00017B	FEP-DT-0109/FEP-LT-0108 Assembly	WST FD EVAP FD VSL B	28,855	42	
	FEP-PJM-00008_0701 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-PJM-00009_0702 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-PJM-00010_0703 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-PJM-00011_0704 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-PJM-00012_0705 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-PJM-00013_0706 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-PJM-00014_0707 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-PJM-00015_0708 Subsystem	WST FD EVAP VSL B PJM	53,534	42	
	FEP-VSL-00017-B	WASTE FEED EVAPORATOR FEED VESSEL	350,400		

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	FEP-YV-0112	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	FEP-YV-0138	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

2.3 System UFP: Ultrafiltration Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00001-A	UFP-PDV-0135 - Critical Valve	UFLTR PP 3A PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 1A. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train A, while the valve is being repaired.
	UFP-YV-0134	UFLTR PP 3A PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. The failure of this valve would reduce ultrafiltration efficiency over time. If this valve fails, decrease the filtration rate of Train A by 10 %. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZE-0135	UFLTR PP 3A PRMT IN	100,000	88 / PIH crane usage 40	Valve failure impacts the associated filter UFP-FILT-00001A. Reduce flow by 20 %.
	UFP-ZSL-0134/UFP-ZSH-0134	UFLTR PP 3A PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train A by 10 %.
UFP-FILT-00001-B	UFP-PDV-0235 - Critical Valve	UFLTR PP 3B PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 1B. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train B, while the valve is being repaired.
	UFP-YV-0234	UFLTR PP 3B PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. Can't flush backpulse limited process. Failure of this valve would reduce the Train B filtering rate by 10 %, and require the use of the PIH Crane. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0235 - Critical Valve	UFLTR PP 3B PRMT IN	100,000	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 1B. Reduce flow by 20 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0234/UFP-ZSH-0234	UFLTR PP 3B PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train B by 10 %.
UFP-FILT-00002-A	UFP-PDV-0141 - Critical Valve	UFLTR PP 2A PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UPF Filter 2A. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train A, while the valve is being repaired.
	UFP-YV-0140	UFLTR PP 2A PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. The failure of this valve would reduce ultrafiltration efficiency over time. If this valve fails, decrease the filtration rate of Train A by 10 %. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0141	UFLTR PP 2A PRMT IN	100,000	88 / PIH crane usage 40	Valve failure impacts the associated filter UFP-FILT-00002A. Reduce flow by 20 %.
	UFP-ZSL-0140/UFP-ZSH-0140	UFLTR PP 2A PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train A by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00002-B	UFP-PDV-0241 - Critical Valve	UFLTR PP 2B PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 2B. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train B, while the valve is being repaired.
	UFP-YV-0240	UFLTR PP 2B PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. Can't flush backpulse limited process. Failure of this valve would reduce the Train B filtering rate by 10 %, and require the use of the PIH Crane. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0241 - Critical Valve	UFLTR PP 2B PRMT IN	100,000	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 2B. Reduce flow by 20 %.
	UFP-ZSL-0240/UFP-ZSH-0240	UFLTR PP 2B PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train B by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00003-A	UFP-PDV-0148 - Critical Valve	UFLTR PP 1A PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 3A. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train A, while the valve is being repaired.
	UFP-YV-0147	UFLTR PP 1A PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. The failure of this valve would reduce ultrafiltration efficiency over time. If this valve fails, decrease the filtration rate of Train A by 10 %. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0148	UFLTR PP 1A PRMT IN	100,000	88 / PIH crane usage 40	Valve failure impacts the associated filter UFP-FILT-00003A. Reduce flow by 20 %.
	UFP-ZSL-0147/UFP-ZSH-0147	UFLTR PP 1A PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train A by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00003-B	UFP-PDV-0248 - Critical Valve	UFLTR PP 1B PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 3B. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train B, while the valve is being repaired.
	UFP-YV-0247	UFLTR PP 1B PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. Can't flush backpulse limited process. Failure of this valve would reduce the Train B filtering rate by 10 %, and require the use of the PIH Crane. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0248 - Critical Valve	UFLTR PP 1B PRMT IN	100,000	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 3B. Reduce flow by 20 %.
	UFP-ZSL-0247/UFP-ZSH-0247	UFLTR PP 1B PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train B by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00004-A	UFP-PDV-0409	UFLTR PP 2A PRMT IN	43,800	88 / PIH crane usage 40	Valve failure impacts the associated filter 4A. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train A, while the valve is being repaired.
	UFP-YV-0406	UFLTR PP2A PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. The failure of this valve would reduce ultrafiltration efficiency over time. If this valve fails, decrease the filtration rate of Train A by 10 %. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0409	UFLTR PP 2A PRMT IN	100,000	88 / PIH crane usage 40	Valve failure impacts the associated filter UFP-FILT-00004A. Reduce flow by 20 %.
	UFP-ZSL-0406/UFP-ZSH-0406	UFLTR PP 2A PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train A by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00004-B	UFP-PDV-0373 - Critical Valve	UFLTR PP 2B PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 4B. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train B, while the valve is being repaired.
	UFP-YV-0370	UFLTR PP2B PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. Can't flush backpulse limited process. Failure of this valve would reduce the Train B filtering rate by 10 %, and require the use of the PIH Crane. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0373 - Critical Valve	UFLTR PP 2B PRMT IN	100,000	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 4B. Reduce flow by 20 %.
	UFP-ZSL-0370/UFP-ZSH-0370	UFLTR PP 2B PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train B by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00005-A	UFP-PDV-0414	UFLTR PP 1A PRMT IN	43,800	88 / PIH crane usage 40	Valve failure impacts the associated filter 5A. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train A, while the valve is being repaired.
	UFP-YV-0411	UFLTR PP1A PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. The failure of this valve would reduce ultrafiltration efficiency over time. If this valve fails, decrease the filtration rate of Train A by 10 %. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0414	UFLTR PP 1A PRMT IN	100,000	88 / PIH crane usage 40	Valve failure impacts the associated filter UFP-FILT-00005A. Reduce flow by 20 %.
	UFP-ZSL-0411/UFP-ZSH-0411	UFLTR PP 1A PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train A by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-FILT-00005-B	UFP-PDV-0378 - Critical Valve	UFLTR PP 1B PRMT IN	43,800	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 5B. EXTERNAL EFFECTS on PIH Crane. As the worst case scenario, decrease rate of all concentration steps by 20 % of Train B, while the valve is being repaired.
	UFP-YV-0375	UFLTR PP1B PRMT IN	43,800	88 / PIH crane usage 40	Backpulse lines power flush. Can't flush backpulse limited process. Failure of this valve would reduce the Train B filtering rate by 10 %, and require the use of the PIH Crane. EXTERNAL EFFECT on PIH Crane.
	UFP-ZE-0378 - Critical Valve	UFLTR PP 1B PRMT IN	100,000	88 / PIH crane usage 40	Valve failure prevents backpulse of UFP Filter 5B. Reduce flow by 20 %.
	UFP-ZSL-0375/UFP-ZSH-0375	UFLTR PP 1B PRMT IN	499,320	56 / PIH crane usage 28	Decrease the filtration rate of Train B by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-HX-00001-A/B	UFP-YV-0298	UF FD VSL A/B ISOL VLV	43,800	88 / PIH crane usage 40	This valve ties vessels UFP-VSL-00001A/B and UFP-VSL-00002A/B common header. Valve failure impacts feed forward.
	UFP-ZSL-0298/UFP-ZSH-0298	UF FD VSL A/B ISOL VLV	499,320	56 / PIH crane usage 28	This valve ties vessels UFP-VSL-00001A/B and UFP-VSL-00002A/B common header. Valve failure impacts feed forward.
UFP-PMP-00041-A	UFP-ASD-00041-A	ADJUSTABLE SPEED DRIVE FOR CONCENTRATE TRANSFER PUMP	312,500	24	Pump is located in the hotcell. Pump failure stops transfer out from UFP-VSL-00001-A
	UFP-IT-0427/UFP-JY-0427-A	POWER SOURCE FOR CONCENTRATE TRANSFER PUMP - HPAV	116,667	42	Instrument loops is required for HPAV; the UFP-PMP-00041A should fail, resulting in stop transfer out from UFP-VSL-00001A.
	UFP-IT-0427/UFP-JY-0427-B	POWER SOURCE FOR CONCENTRATE TRANSFER PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00041A should fail, resulting in stop transfer out from UFP-VSL-00001A.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-TE-0125/UFP-TT-0125	HIGH TEMP SHUTDOWN PUMP	66,667	42	Temperature loop shuts down pump 41A will impact associated vessel UFP-VSL-00001A. Cannot transfer out from UFP-VSL-00001A.
UFP-PMP-00041-B	UFP-ASD-00041-B	ADJUSTABLE SPEED DRIVE FOR CONCENTRATE TRANSFER PUMP	312,500	24	Pump is located in the hotcell. Pump failure stops transfer out from UFP-VSL-00001-B
	UFP-IT-0443/UFP-JY-0443-A	POWER SOURCE FOR CONCENTRATE TRANSFER PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00041B should fail. Cannot transfer out from UFP-VSL-00001B
	UFP-IT-0443/UFP-JY-0443-B	POWER SOURCE FOR CONCENTRATE TRANSFER PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00041B should fail. Cannot transfer out from UFP-VSL-00001B
UFP-PMP-00042-A	UFP-ASD-00042-A	ULTRAFILTRATION RECIRCULATION PUMP	312,500	24	Pumps are located in the hotcell. Pump failure stops transfer out from UFP-VSL-00002A.
	UFP-FE-0153/UFP-FT-0153	UFLTR FD PMP A DISCH	66,667	42 / PIH crane usage 12	The instrument failure resulting in not able to transfer out from UFP-VSL-2A.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-IT-0428/UFP-JY-0428-A	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00042A should fail, resulting in stop transfer out from UFP-VSL-00002A
	UFP-IT-0428/UFP-JY-0428-B	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00042A should fail, resulting in stop transfer out from UFP-VSL-00002A
UFP-PMP-00042-A UFP-PMP-00043-A	UFP-YV-0404	ITS PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0404 and YV/ZSL/ZSH-0405) the UFP-PMP-00042A and 43A should fail. UFP-PMP-42A and UFP-PMP-43A failure would stop the Train A concentration steps.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0405	ITS PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0404 and YV/ZSL/ZSH-0405) the UFP-PMP-00042A and 43A should fail. UFP-PMP-42A and UFP-PMP-43A failure would stop the Train A concentration steps.
	UFP-ZSL-0404/UFP-ZSH-0404	ITS PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0404 and YV/ZSL/ZSH-0405) the UFP-PMP-00042A and 43A should fail. 1 out of 2 is required after HPAV.
	UFP-ZSL-0405/UFP-ZSH-0405	ITS PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0404 and YV/ZSL/ZSH-0405) the UFP-PMP-00042A and 43A should fail. 1 out of 2 is required after HPAV.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PMP-00042-B	UFP-ASD-00042-B	ULTRAFILTRATION RECIRCULATION PUMP	312,500	24	Pumps are located in the hotcell. Pump failure stops transfer out from UFP-VSL-00002B.
	UFP-FE-0253/UFP-FT-0253	UFLTR FD PMP B DISCH	66,667	42 / PIH crane usage 12	The instrument failure resulting in not able to transfer out from UFP-VSL-2B.
	UFP-IT-0441/UFP-JY-0441-A	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00042B should fail. Cannot transfer out from UFP-VSL-00002B.
	UFP-IT-0441/UFP-JY-0441-B	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00042B should fail. Cannot transfer out from UFP-VSL-00002B.
UFP-PMP-00042-B UFP-PMP-00043-B	UFP-YV-0438	ITS PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0438 and YV/ZSL/ZSH-0439) the UFP-PMP-00042B and 43B should fail. Failure of UFP-PMP-42B and UFP-PMP-43B would stop the Train B concentrating steps.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0439	ITS PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0438 and YV/ZSL/ZSH-0439) the UFP-PMP-00042B and 43B should fail. Failure of UFP-PMP-42B and UFP-PMP-43B would stop the Train B concentrating steps.
	UFP-ZSL-0438/UFP-ZSH-0438	ITS PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0438 and YV/ZSL/ZSH-0439) the UFP-PMP-00042B and 43B should fail. 1 out of 2 is required after HPAV.
	UFP-ZSL-0439/UFP-ZSH-0439	ITS PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0438 and YV/ZSL/ZSH-0439) the UFP-PMP-00042B and 43B should fail. 1 out of 2 is required after HPAV.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PMP-00043-A	UFP-ASD-00043-A	ULTRAFILTRATION RECIRCULATION PUMP	312,500	24	Pumps are located in the hotcell. Pump failure stops transfer out from UFP-VSL-00002A.
	UFP-IT-0429/UFP-JY-0429-A	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00043A should fail, resulting in stop transfer out from UFP-VSL-00002A.
	UFP-IT-0429/UFP-JY-0429-B	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00043A should fail, resulting in stop transfer out from UFP-VSL-00002A.
UFP-PMP-00043-B	UFP-ASD-00043-B	ULTRAFILTRATION RECIRCULATION PUMP	312,500	24	Pumps are located in the hotcell. Pump failure stops transfer out from UFP-VSL-00002B.
	UFP-IT-0442/UFP-JY-0442-A	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00043B should fail. Cannot transfer out from UFP-VSL-00002B.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-IT-0442/UFP-JY-0442-B	POWER SOURCE FOR ULTRAFILTRATION RECIRCULATION PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00043B should fail. Cannot transfer out from UFP-VSL-00002B.
UFP-PMP-00044-A	UFP-IT-0431/UFP-JY-0431-A	SOLID TRANSFER POSITIVE DISPLACEMENT PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00044A should fail. Cannot transfer out from UFP-VSL-00002A only during solid transfer or cleaning steps.
	UFP-IT-0431/UFP-JY-0431-B	SOLID TRANSFER POSITIVE DISPLACEMENT PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00044A should fail. Cannot transfer out from UFP-VSL-00002A only during solid transfer or cleaning steps.
	UFP-PSE-0425	RUPTURE DISK	333,333	42	Cannot transfer out from UFP-VSL-002A during solid transfer step, and cleaning steps.
	UFP-PT-0424	RUPTURE DISK - FAILURE OF PRESSURE TRANSMITTER	333,333	8	Cannot transfer out from UFP-VSL-002A during solid transfer step, and cleaning steps.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PMP-00044-B	UFP-IT-0437/UFP-JY-0437-A	SOLID TRANSFER POSITIVE DISPLACEMENT PUMP - HPAV	116,667	42	Instrument loops is required for HPAV; the UFP-PMP-00044B should fail. Cannot transfer out from UFP-VSL-00002B only during solid transfer or cleaning steps.
	UFP-IT-0437/UFP-JY-0437-B	SOLID TRANSFER POSITIVE DISPLACEMENT PUMP - HPAV	116,667	42	Instrument loop is required for HPAV; the UFP-PMP-00044B should fail. Cannot transfer out from UFP-VSL-00002B only during solid transfer or cleaning steps.
	UFP-PSE-0436	RUPTURE DISK	333,333	42	Cannot transfer out from UFP-VSL-002B during solid transfer step, and cleaning steps.
	UFP-PT-0435	RUPTURE DISK - FAILURE OF PRESSURE TRANSMITTER	333,333	8	Cannot transfer out from UFP-VSL-002B during solid transfer step, and cleaning steps.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PP-00001-A	UFP-YV-0137	UFLTR PP 1A PA IN	43,800	88 / PIH crane usage 40	Apply failure to associated filters UFP-FILT-00003/5A. For simplicity, decrease the train A filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0138	UFLTR PP 1A REAGT IN	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0176 - Critical Valve	UFLTR PP 1A PRMT OUT	43,800	88 / PIH crane usage 40	Valve failure prevents permeate flow from filter UFP-FILT-00003/5A to UFP-VSL-000062ABC, and prevent backpulsing for PP 1A. Since the valve fails to open, reduce filtration rate by 20 % to prevent backpulsing. EXTERNAL AFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0319	UF PP 1A TO UF FD VSL B XFR VLV	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Failure impacts reagent back pulsing. Reduce Train A filtering rate by 20 %. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0320	UF PP 1A OUT DVTR VLV	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP1A. Reduce filtration rate by 40 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0137/UFP-ZSH-0137 B	UFLTR PP 1A PA IN	499,320	56 / PIH crane usage 28	Apply failure to associated filters UFP-FILT-00003/5A. For simplicity, decrease the train A filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0138/UFP-ZSH-0138 B	UFLTR PP 1A REAGT IN	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-ZSL-0176/UFP-ZSH-0176	UFLTR PP 1A PRMT OUT	499,320	56 / PIH crane usage 28	Failure prevents permeate flow from filter UFP-FILT-00003/5A only. Reduce flow by 20 %.
	UFP-ZSL-0319/UFP-ZSH-0319 B	UF PP 1A TO UF FD VSL B XFR VLV	499,320	56 / PIH crane usage 28	Valve failure prevents permeate flow to vessels 62A,B,C from FILT-Train A, PP1A. Reduce flow by 20 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0320/UFP-ZSH-0320	UF PP 1A OUT DVTR VLV	499,320	56 / PIH crane usage 28	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP1A. Reduce filtration rate by 40 %. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PP-00001-B	UFP-YV-0237	UFLTR PP 1B PA IN	43,800	88 / PIH crane usage 40	Apply failure to associated filters UFP-FILT-00003/5B. For simplicity, decrease the train B filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0238	UFLTR PP 1B REAGT IN	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0276 - Critical Valve	UFLTR PP 1B PRMT OUT	43,800	88 / PIH crane usage 40	Valve failure prevents permeate flow from filter UFP-FILT-00003/5B to UFP-VSL-000062ABC, and prevent backpulsing for PP 1B. Since the valve fails to open, reduce filtration rate by 20 % to prevent backpulsing. EXTERNAL AFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0307	UF PP 1B TO UF FD VSL B XFR VLV	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Failure impacts reagent back pulsing. Reduce Train B filtering rate by 20 %. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0308	UF PP 1B OUT DVTR VLV	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP1B. Reduce filtration rate by 40 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0237/UFP-ZSH-0237 B	UFLTR PP 1B PA IN	499,320	56 / PIH crane usage 28	Apply failure to associated filters UFP-FILT-00003/5B. For simplicity, decrease the train B filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0238/UFP-ZSH-0238 B	UFLTR PP 1B REAGT IN	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-ZSL-0276/UFP-ZSH-0276	UFLTR PP 1B PRMT OUT	499,320	56 / PIH crane usage 28	Failure prevents permeate flow from filter UFP-FILT-00003/5B only. Reduce flow by 20 %.
	UFP-ZSL-0307/UFP-ZSH-0307 B	UF PP 1B TO UF FD VSL B XFR VLV	499,320	56 / PIH crane usage 28	Valve failure prevents permeate flow to vessels 62A,B,C from FILT-Train B. Reduce flow by 20 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0308/UFP-ZSH-0308	UF PP 1B OUT DVTR VLV	499,320	56 / PIH crane usage 28	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP1B. Reduce filtration rate by 40 %. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PP-00002-A	UFP-YV-0143	UFLTR PP 2A PA IN	43,800	88 / PIH crane usage 40	Apply failure to associated filters UFP-FILT-00002/4A. For simplicity, decrease the train A filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0144	UFLTR PP 2A REAGT IN	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0178 - Critical Valve	UFLTR PP 2A PRMT OUT	43,800	88 / PIH crane usage 40	Valve failure prevents permeate flow from filter UFP-FILT-00002/4A to UFP-VSL-000062ABC, and prevent backpulsing for PP 2A. Since the valve fails to open, reduce filtration rate by 20 % to prevent backpulsing. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0321	UF PP 2A TO UF FD VSL B XFR VLV	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Failure impacts reagent back pulsing. Reduce Train A filtering rate by 20 %. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0322	UF PP 2A OUT DVTR VLV	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP2A. Reduce filtration rate by 40 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0143/UFP-ZSH-0143 B	UFLTR PP 2A PA IN	499,320	56 / PIH crane usage 28	Apply failure to associated filters UFP-FILT-00002/4A. For simplicity, decrease the train A filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0144/UFP-ZSH-0144 B	UFLTR PP 2A REAGT IN	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-ZSL-0178/UFP-ZSH-0178	UFLTR PP 2A PRMT OUT	499,320	56 / PIH crane usage 28	Failure prevents permeate flow from filter UFP-FILT-00002/4A only. Reduce flow by 20 %.
	UFP-ZSL-0321/UFP-ZSH-0321 B	UF PP 1A TO UF FD VSL B XFR VLV	499,320	56 / PIH crane usage 28	Not included in the WTP OR Model. Valve failure prevents permeate flow to vessels 62A,B,C from FILT-Train A, PP2A. Reduce flow by 20 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0322/UFP-ZSH-0322	UF PP 2A OUT DVTR VLV	499,320	56 / PIH crane usage 28	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP2A. Reduce filtration rate by 40 %. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PP-00002-B	UFP-YV-0243	UFLTR PP 2B PA IN	43,800	88 / PIH crane usage 40	Apply failure to associated filters UFP-FILT-00002/4B. For simplicity, decrease the train B filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0244	UFLTR PP 2B REAGT IN	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0278 - Critical Valve	UFLTR PP 2B PRMT OUT	43,800	88 / PIH crane usage 40	Valve failure prevents permeate flow from filter UFP-FILT-00002/4B to UFP-VSL-000062ABC, and prevent backpulsing for PP 2B. Since the valve fails to open, reduce filtration rate by 20 % to prevent backpulsing. EXTERNAL AFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0309	UF PP 2B TO UF FD VSL B XFR VLV	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Failure impacts reagent back pulsing. Reduce Train B filtering rate by 20 %. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0310	UF PP 2B OUT DVTR VLV	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP2B. Reduce filtration rate by 40 %. EXTERNAL AFFECTS on PIH Crane.
	UFP-ZSL-0243/UFP-ZSH-0243 B	UFLTR PP 2B PA IN	499,320	56 / PIH crane usage 28	Apply failure to associated filters UFP-FILT-00002/4B. For simplicity, decrease the train B filtration rate by 20 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0244/UFP-ZSH-0244 B	UFLTR PP 2B REAGT IN	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-ZSL-0278/UFP-ZSH-0278	UFLTR PP 2B PRMT OUT	499,320	56 / PIH crane usage 28	Failure prevents permeate flow from filter UFP-FILT-00002/4B only. Reduce flow by 20 %.
	UFP-ZSL-0309/UFP-ZSH-0309 B	UF PP 2B TO UF FD VSL B XFR VLV	499,320	56 / PIH crane usage 28	Valve failure prevents permeate flow to vessels 62A,B,C from FILT-Train B. Reduce flow by 20 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0310/UFP-ZSH-0310	UF PP 2B OUT DVTR VLV	499,320	56 / PIH crane usage 28	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP2B. Reduce filtration rate by 40 %. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PP-00003-A	UFP-YV-0150	UFLTR PP 3A PA IN	43,800	88 / PIH crane usage 40	Apply failure to associated filters UFP-FILT-00001A. For simplicity, decrease the train A filtration rate by 10 %. These items require the PT PIH Crane for repair. The failure of these items do not impact the process throughput directly and are consider
	UFP-YV-0151	UFLTR PP 3A REAGT IN	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0180 - Critical Valve	UFLTR PP 3A PRMT OUT	43,800	88 / PIH crane usage 40	Valve failure prevents permeate flow from filter UFP-FILT-00001A to UFP-VSL-000062ABC, and prevent backpulsing for PP 3A. Since the valve fails to open, reduce filtration rate by 10 % to prevent backpulsing. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0323	UF PP 3A TO UF FD VSL B XFR VLV	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Failure impacts reagent back pulsing. Reduce Train A filtering rate by 10 %. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0324	UF PP 3A OUT DVTR VLV	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected Valve failure prevents permeate flow to vessels 62A,B,C from PP3A. Reduce filtration rate by 20 %. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0150/UFP-ZSH-0150 B	UFLTR PP 3A PA IN	499,320	56 / PIH crane usage 28	Apply failure to associated filters UFP-FILT-00001A. For simplicity, decrease the train A filtration rate by 10 %. These items require the PT PIH Crane for repair. The failure of these items do not impact the process throughput directly, and are conside[ajg1]d low priority repair work for the PIH Crane.
	UFP-ZSL-0151/UFP-ZSH-0151 B	UFLTR PP 3A REAGT IN	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-ZSL-0180/UFP-ZSH-0180	UFLTR PP 2A PRMT OUT	499,320	56 / PIH crane usage 28	Failure prevents permeate flow from filter UFP-FILT-00001A only. Reduce flow by 10 %.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0323/UFP-ZSH-0323 B	UF PP 3A TO UF FD VSL B XFR VLV	499,320	56 / PIH crane usage 28	Not included in the WTP OR Model. Valve failure prevents permeate flow to vessels 62A,B,C from FILT-Train A, PP3A. Reduce flow by 10 %. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0324/UFP-ZSH-0324	UF PP 3A OUT DVTR VLV	499,320	56 / PIH crane usage 28	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP3A. Reduce filtration rate by 20 %. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-PP-00003-B	UFP-YV-0247 E Jumper	UFLTR PP 3B PRMT IN ELEC JMPP	323,100	88 / PIH crane usage 40	This item requires the PIH crane (PIH-CRN-00004) for repair. The failure does not impact the process throughput directly, therefore is considered low priority repair work for the PIH Crane. Electrical Jumper does not need to be associated with an operat[ajg2]ing unit in the OR Model, as it does not impact the process flow.
	UFP-YV-0250	UFLTR PP 3B PA IN	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0251	UFLTR PP 3B REAGT IN	43,800	88 / PIH crane usage 40	Apply failure to associated filters UFP-FILT-00001B. For simplicity, decrease the train B filtration rate by 10 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0280 - Critical Valve	UFLTR PP 3B PRMT OUT	43,800	88 / PIH crane usage 40	Valve failure prevents permeate flow from filter UFP-FILT-00001B to UFP-VSL-000062ABC, and prevent backpulsing for PP 3B. Since the valve fails to open, reduce filtration rate by 10 % to prevent backpulsing. EXTERNAL AFFECTS on PIH
	UFP-YV-0311	UF PP 3B TO UF FD VSL B XFR VLV	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. Failure impacts reagent back pulsing. Reduce Train B filtering rate by 10 %. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0312	UF PP 3B OUT DVTR VLV	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP3B. Reduce filtration rate by 20 %. EXTERNAL AFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0250/UFP-ZSH-0250 B	UFLTR PP 3B PA IN	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. Reagent can be added via wash ring. No impact to process. EXTERNAL EFFECT on PIH Crane.
	UFP-ZSL-0251/UFP-ZSH-0251 B	UFLTR PP 3B REAGT IN	499,320	56 / PIH crane usage 28	Apply failure to associated filters UFP-FILT-00001B. For simplicity, decrease the train B filtration rate by 10 %. These items require the PT PIH Crane for repair. EXTERNAL EFFECT on PIH Crane.
	UFP-ZSL-0280/UFP-ZSH-0280	UFLTR PP 3B PRMT OUT	499,320	56 / PIH crane usage 28	Failure prevents permeate flow from filter UFP-FILT-00001B only. Reduce flow by 10 %.
	UFP-ZSL-0311/UFP-ZSH-0311 B	UF PP 3B TO UF FD VSL B XFR VLV	499,320	56 / PIH crane usage 28	Valve failure prevents permeate flow to vessels 62A,B,C from FILT-Train B. Reduce flow by 10 %. EXTERNAL EFFECTS on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0312/UFP-ZSH-0312	UF PP 3B OUT DVTR VLV	499,320	56 / PIH crane usage 28	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected. Valve failure prevents permeate flow to vessels 62A,B,C from PP3B. Reduce filtration rate by 20 %. EXTERNAL EFFECTS on PIH Crane.
UFP-VSL-00001-A	UFP-HX-00041-A	HEAT EXCHANGER	87,600	120	For UFP 1 leaching: upon failure stopped transfer out from UFP-VSL-00001A. No impact for UFP 2 leaching (other than crane time).
	UFP-LT-0107/UFP-DT-0104	UFLTR FD PREP VSL A	28,855	42	Instrument loop is the regular, non-ITS process level for the fluidic controllers. This UFP failure should be assigned to UFP-VSL-00001A (stop transfer in or out of UFP-VSL-00001A).

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-LT-0121/UFP-DT-0118/UFP-YY-0121/UFP-YV-0121-A/B	UFLTR FD PREP VSL A - HPAV	28,855	42	Instrument loop is required for HPAV. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-LT-0195/UFP-DT-0194/UFP-YY-0195/UFP-YV-0195-A/B	UFLTR FD PREP VSL A - HPAV	28,855	42	Instrument loop is required for HPAV. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-PJM-00001_0701 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	
	UFP-PJM-00002_0702 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	
	UFP-PJM-00003_0703 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	
	UFP-PJM-00004_0704 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	
	UFP-PJM-00044_0705 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	
	UFP-PJM-00053_0706 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	
	UFP-PJM-00105_0707 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	
	UFP-PJM-00106_0708 Subsystem	UFLTR FD PREP VSL A PJM CTRL	53,534	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-PJM-TEMP-01	UFLTR FD PREP VSL A PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.
	UFP-PJM-TEMP-02	UFLTR FD PREP VSL A PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.
	UFP-PJM-TEMP-03	UFLTR FD PREP VSL A PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.
	UFP-PJM-TEMP-04	UFLTR FD PREP VSL A PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.
	UFP-PMP-00041-A	CONCENTRATE TRANSFER PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. Pump failure wills stop transfer out from UFP-VSL-00001A.
	UFP-TE-0103/UFP-TT-0103	UFLTR FD PREP VSL A	66,667	42	Instrument is located in hotcell will require crane and remove of jumper. The instrument failure should be assigned to UFP-VSL-00001A.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-TV-0125	HIGH TEMP SHUTDOWN PUMP	333,333	12	Temperature valve shuts down pump 41A will impact associated vessel UFP-VSL-00001A. Cannot transfer out from UFP-VSL-00001A.
	UFP-VSL-00001-A	ULTRAFILTRATION FEED PREPARATION VESSEL	350,400		
	UFP-YV-0108 - Critical Valve	CONC XFR PMP A SUCT	43,800	88 / PIH crane usage 40	Valve failure prevents transfer from UFP-VSL-0001A only. EXTERNAL EFFECTS on PIH Crane.
	UFP-YV-0110 - Critical Valve	CONC XFR TO UF FD VSL B	43,800	88 / PIH crane usage 40	Valve failure prevents (feed forward) transfer to UFP-VSL-0002B only. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0115 - Critical Valve	CONC XFR TO UF FD VSL A	43,800	88 / PIH crane usage 40	Valve failure prevents (feed forward) transfer to UFP-VSL-0002A only. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0172 - Critical Valve	CONC XFR PMP A RECRC	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. For UFP 1 leaching: if the valve fails, cannot perform the cooling step at UFP-VSL-00001A. EXTERNAL EFFECT on PIH Crane.
	UFP-YV-0197 - Critical Valve	UF FD PREP VSL A XFR HDR MN VLV	43,800	88 / PIH crane usage 40	Valve failure prevents transfer from UFP-VSL-0001A only. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0108/UFP-ZSH-0108	CONC XFR PMP A SUCT	499,320	56 / PIH crane usage 28	Failure should be applied to the UFP-VSL-00001-A.
	UFP-ZSL-0115/UFP-ZSH-0115	CONC XFR TO UF FD VSL B	499,320	56 / PIH crane usage 28	Valve or switch failure prevents (feed forward) transfer to UFP-VSL-0002B only.
	UFP-ZSL-0172/UFP-ZSH-0172	CONC XFR PMP A RECRC	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. For UFP 1 leaching: if the valve fails, cannot perform the cooling step at UFP-VSL-00001A. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0197/UFP-ZSH-0197	UF FD PREP VSL A XFR HDR MN VLV	499,320	56 / PIH crane usage 28	Valve failure prevents transfer from UFP-VSL-0001A to UFP-VSL-0002A/B EXTERNAL AFFECTS on PIH Crane.
UFP-VSL-00001-A/B UFP-VSL-00002-A/B	UFP-PPJ-PNL	PROGRAMMABLE PROTECTION (PPJ) I/O MODULES UFP-VSL-00002A/B OR UFP-VSL-00001A/B	2,027,064	8	Use 25 % uniform distribution to fail UFP-VSL-1A/1B/2A/2B. Variable update is hardcoded in the WITNESS model logic.
UFP-VSL-00001-A/B UFP-VSL-00002-A/B UFP-VSL-00062-A/B/C	UFP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES	17,159	8	Use 14.3 % uniform distribution to fail UFP VSL 1A/1B/2A/2B/62A/62B/62C. Variable update is hardcoded in the WITNESS model logic.
UFP-VSL-00001-B	UFP-HX-00041-B	HEAT EXCHANGER	87,600	120	For UFP 1 leaching: upon failure stopped transfer out from UFP-VSL-00001B. No impact for UFP 2 leaching (other than crane time).
	UFP-LT-0207/UFP-DT-0204	UFLTR FD PREP VSL B	28,855	42	This UFP failure should be assigned to UFP-VSL-00001B.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-LT-0221/UFP-DT-0218/UFP-YY-0221/UFP-YV-0221-A/B	UFLTR FD PREP VSL B	28,855	42	Instrument loop is required for HPAV. The UFP-VSL-00001B should fail.
	UFP-LT-0295/UFP-DT-0294/UFP-YY-0295/UFP-YV-0295-A/B	UFLTR FD PREP VSL B	28,855	42	Instrument loop is required for HPAV. The UFP-VSL-00001B should fail.
	UFP-PJM-00045_0801 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-00046_0802 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-00047_0803 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-00048_0804 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-00049_0805 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-00050_0806 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-00101_0807 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-00102_0808 Subsystem	UFLTR FD PREP VSL B PJM CTRL	53,534	42	
	UFP-PJM-TEMP-05	UFLTR FD PREP VSL B PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-PJM-TEMP-06	UFLTR FD PREP VSL B PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.
	UFP-PJM-TEMP-07	UFLTR FD PREP VSL B PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.
	UFP-PJM-TEMP-08	UFLTR FD PREP VSL B PJM CTRL	53,534	42	Operating philosophy is to be determined (12 PJMs per vessel). Use phantom tag.
	UFP-PMP-00041-B	CONCENTRATE TRANSFER PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. Pump failure wills stop transfer out from UFP-VSL-00001B.
	UFP-TE-0203/UFP-TT-0203	UFLTR FD PREP VSL B	66,667	42	Instrument is located in hotcell will require crane and remove of jumper. The instrument failure should be assigned to UFP-VSL-00001B.
	UFP-TE-0225/UFP-TT-0225	HIGH TEMP SHUTDOWN PUMP	66,667	42	Temperature loop shuts down pump 41B will impact associated vessel UFP-VSL-00001B. Cannot transfer out from UFP-VSL-00001B.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-TV-0225	HIGH TEMP SHUTDOWN PUMP	333,333	12	Temperature valve shuts down pump 41B will impact associated vessel UFP-VSL-00001B. Cannot transfer out from UFP-VSL-00001B.
	UFP-VSL-00001-B	ULTRAFILTRATION FEED PREPARATION VESSEL	350,400		
	UFP-YV-0208 - Critical Valve	CONC XFR PMP B SUCT	43,800	88 / PIH crane usage 40	Valve failure prevents transfer from UFP-VSL-0001B only. EXTERNAL EFFECTS on PIH Crane.
	UFP-YV-0272	CONC XFR PMP B RECRC	43,800	88 / PIH crane usage 40	These items require the PT PIH Crane for repair. For UFP 1 leaching: if the valve fails, cannot perform the cooling step at UFP-VSL-00001B. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0296	UF FD PREP VSL B ASMPLR IN	43,800	88 / PIH crane usage 40	The failure of these items do not impact the process throughput directly, and are considered low priority repair work for the PIH Crane. Valve and position switches are used for sampling of UFP-VSL-00001B.
	UFP-YV-0297 - Critical Valve	UF FD PREP VSL B XFR HDR MN VLV	43,800	88 / PIH crane usage 40	Valve failure prevents transfer from UFP-VSL-0001B only. EXTERNAL EFFECTS on PIH Crane.
	UFP-ZSL-0110/UFP-ZSH-0110	CONC XFR TO UF FD VSL B	499,320	56 / PIH crane usage 28	Valve or switch failure prevents (feed forward) transfer to UFP-VSL-0002B only.
	UFP-ZSL-0208/UFP-ZSH-0208	CONC XFR PMP B SUCT	499,320	56 / PIH crane usage 28	Failure should be applied to the UFP-VSL-00001-B.
	UFP-ZSL-0272/UFP-ZSH-0272	CONC XFR PMP B RECRC	499,320	56 / PIH crane usage 28	These items require the PT PIH Crane for repair. For UFP 1 leaching: if the valve fails, cannot perform the cooling step at UFP-VSL-00001B. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0296/UFP-ZSH-0296	UF FD PREP VSL B ASMPLR IN	499,320	56 / PIH crane usage 28	The failure of these items do not impact the process throughput directly, and are considered low priority repair work for the PIH Crane. Valve and position switches are used for sampling of UFP-VSL-00001B.
	UFP-ZSL-0297/UFP-ZSH-0297	CONC XFR PMP A RECRC	499,320	56 / PIH crane usage 28	Valve failure prevents transfer from UFP-VSL-0001B to UFP-VSL-00002A/B EXTERNAL AFFECTS on PIH Crane.
UFP-VSL-00002-A	UFP-ASD-00044-A	ULTRAFILTRATION RECIRCULATION PUMP	312,500	24	Pumps are located in the hotcell. Pump failure will impact the solid transfer step and the cleaning steps of the UFP cycles. Associate with transfer out from UFP-VSL-00002A.
	UFP-FILT-00001/2/3/4/5-A	ULTRAFILTER	87,600	353	All five filters on the same train are replaced together.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-LT-0119/UFP-DT-0120/UFP-YY-0119/UFP-YV-0119-A/B	UFLTR FD VSL A	28,855	42	Item required for safety, 2 SC mix/1 operate. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-LT-0209/UFP-DT-0210/UFP-YY-0209/UFP-YV-0209-A/B	UFLTR FD VSL A	28,855	42	Item required for safety, 2 SC mix/1 operate. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-LT-0211/UFP-DT-0212/UFP-YY-0211/UFP-YV-0211-A/B	UFLTR FD VSL A	28,855	42	Item required for safety, 2 SC mix/1 operate. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-PJM-00006_1007 Subsystem	UFLTR FD VSL A PJM CTRL	53,534	42	
	UFP-PJM-00007_1008 Subsystem	UFLTR FD VSL A PJM CTRL	53,534	42	
	UFP-PJM-00008_1009 Subsystem	UFLTR FD VSL A PJM CTRL	53,534	42	
	UFP-PJM-00009_1010 Subsystem	UFLTR FD VSL A PJM CTRL	53,534	42	
	UFP-PJM-00010_1011 Subsystem	UFLTR FD VSL A PJM CTRL	53,534	42	
	UFP-PJM-00011_1012 Subsystem	UFLTR FD VSL A PJM CTRL	53,534	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-PMP-00042-A	ULTRAFILTRATION RECIRCULATION PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. Pump failure wills stop transfer out from UFP-VSL-00002A, except for the solid transfer step.
	UFP-PMP-00043-A	ULTRAFILTRATION RECIRCULATION PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. Pump failure wills stop transfer out from UFP-VSL-00002A, except for the solid transfer step.
	UFP-PMP-00044-A	ULTRAFILTRATION RECIRCULATION PUMP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. If failed cannot transfer out from UFP-VSL-00002A during solid transfer step and cleaning steps.
	UFP-PV-0416	UFP HXCHGR A MN DRN HDR OUT	43,800	88 / PIH crane usage 40	Valve controls loop pressure for permeate for UFP-VSL-0002A only. Stop flowing out from UFP-VSL-00002A during concentration steps. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-TE-0117/UFP-TT-0117	UFLTR FD VSL A	66,667	42	Instrument is located in hotcell will require crane and remove of jumper. The instrument failure should be assigned to UFP-VSL-00002A.
	UFP-VSL-00002-A	ULTRAFILTRATION FEED VESSEL	350,400		
	UFP-YV-0124	UFLTR FD PMP A SUCT	43,800	88 / PIH crane usage 40	Valve failure prevents circulation through train A filters. Cannot perform concentrating steps. Cannot perform cleaning steps. EXTERNAL EFFECTS on PIH-Crane.
	UFP-YV-0155 - Critical Valve	UFLTR A HDR TO PRMT VSL C	43,800	88 / PIH crane usage 40	Valve fail closed disables transfers from Train A to UFP-VSL-00062C only. EXTERNAL EFFECTS on PIH-Crane
	UFP-YV-0156 - Critical Valve	UFLTR A HDR TO PRMT VSL B	43,800	88 / PIH crane usage 40	Valve fail closed disables transfers from Train A to UFP-VSL-00062B only. EXTERNAL EFFECTS on PIH-Crane

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0157 - Critical Valve	UFLTR A HDR TO PRMT VSL A	43,800	88 / PIH crane usage 40	Valve fail closed disables transfers from Train A to UFP-VSL-62A only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-YV-0165	UF FD VSL A STM EJCTR DISCH	43,800	88 / PIH crane usage 40	Failure prevents transfer of cleaning solutions to PWD. Will impact the chemical cleaning step of the UFP cycle (UFP-VSL-00002A). Require the use of the PIH Crane.
	UFP-YV-0187	UF FD VSL A 2M HNO3 IN	333,333	24	Valve failure prevents nitric acid cleaning step (UFP-VSL-00002A)
	UFP-YV-0192 - Critical Valve	UF FD VSL A PUMP SUCT	43,800	88 / PIH crane usage 40	Cannot perform solid transfer if this valve fails.
	UFP-YV-0229	UF FD VSL B XFR TO HLP VSL A	43,800	88 / PIH crane usage 40	Failure prevents transfers from UFP-VSL-00002A to HLP-VSL-00027A. PIH Crane is required for repair.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0230	UF FD VSL B XFR TO HLP BLNDG VSL	43,800	88 / PIH crane usage 40	Failure prevents transfer from UFP-VSL-00002A to HLP-VSL-00028. PIH Crane is required for repair.
	UFP-YV-0313 - Critical Valve	UFLTR A XFR HDR DRN	43,800	88 / PIH crane usage 40	Valve failure prevents draining recirc line during chem cleaning. Cannot perform the cleaning step. EXTERNAL EFFECTS on PIH Crane.
	UFP-YV-0325 - Critical Valve	UFLTR A XFR HDR DRN	43,800	88 / PIH crane usage 40	Valve failure prevents draining recirculation line during chemical cleaning. Cannot perform chemical cleaning steps for Train A. EXTERNAL EFFECTS on PIH Crane.
	UFP-YV-0417	POWER FLUSH - HPAV	43,800	88 / PIH crane usage 40	HPAV 1 out of 1 is required, the UFP-VSL-00002A should fail.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0418	PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0418 and YV/ZSL/ZSH-0419) the UFP-VSL-00002A should fail. 1 out of 2 is required after HPAV.
	UFP-YV-0419	PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0418 and YV/ZSL/ZSH-0419) the UFP-VSL-00002A should fail. 1 out of 2 is required after HPAV.
	UFP-ZE-0416	UFP HXCHGR A MN DRN HDR OUT	100,000	88 / PIH crane usage 40	Instrument controls loop pressure for permeate for UFP-VSL-0002A only.
	UFP-ZSL-0124/UFP-ZSH-0124 B	UFLTR FD PMP A SUCT	499,320	56 / PIH crane usage 28	Position switch failure will impact pump UFP-PMP-00042A suction. Valve failure prevents circulation through train A filters.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0165/UFP-ZSH-0165	UF FD VSL A STM EJCTR DISCH	499,320	56 / PIH crane usage 28	Failure prevents transfer of cleaning solutions to PWD. Will impact the chemical cleaning step of the UFP cycle (UFP-VSL-2A). Require the use of the PIH Crane.
	UFP-ZSL-0187/UFP-ZSH-0187	UF FD VSL A 2M HNO3 IN	499,320	42	Valve failure prevents nitric acid cleaning step (UFP-VSL-2A).
	UFP-ZSL-0192/UFP-ZSH-0192	UF FD VSL A STM EJCTR SUCT	499,320	56 / PIH crane usage 28	Failure prevents solid transfer from UFP-VSL-00002 A.
	UFP-ZSL-0313/UFP-ZSH-0313	UFLTR A XFR HDR DRN	499,320	56 / PIH crane usage 28	Switch failure prevents draining recirc line during chem cleaning.
	UFP-ZSL-0325/UFP-ZSH-0325	UFLTR A XFR HDR DRN	499,320	56 / PIH crane usage 28	Switch failure prevents draining recirculation line during chemical cleaning.
	UFP-ZSL-0417/UFP-ZSH-0417	POWER FLUSH - HPAV	499,320	56 / PIH crane usage 28	HPAV 1 out of 1 is required the UFP-VSL-00002A should fail.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0418/UFP-ZSH-0418	PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0418 and YV/ZSL/ZSH-0419) the UFP-VSL-00002A should fail. 1 out of 2 is required after HPAV.
	UFP-ZSL-0419/UFP-ZSH-0419	PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0418 and YV/ZSL/ZSH-0419) the UFP-VSL-00002A should fail. 1 out of 2 is required after HPAV.
UFP-VSL-00002-B	UFP-ASD-00044-B	ULTRAFILTRATION RECIRCULATION PUMP	312,500	24	Pumps are located in the hotcell. Pump failure will impact the solid transfer step and the cleaning steps of the UFP cycles. Associate with transfer out from UFP-VSL-00002B.
	UFP-FILT-00001/2/3/4/5-B	ULTRAFILTER	87,600	353	All five filters on the same train are replaced together.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-LT-0219/UFP-DT-0220	UFLTR FD VSL B	28,855	42	Item required for safety, 2 SC mix/1 operate. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-LT-0327/UFP-DT-0328/UFP-YY-0327/UFP-YV-0327-A/B	UFLTR FD VSL B	28,855	42	Item required for safety, 2 SC mix/1 operate. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-LT-0329/UFP-DT-0330/UFP-YY-0329/UFP-YV-0329-A/B	UFLTR FD VSL B	28,855	42	Item required for safety, 2 SC mix/1 operate. Failure will also impact fluidic controllers time calibration for this vessel.
	UFP-PJM-00012_1101 Subsystem	UFLTR FD VSL B PJM CTRL	53,534	42	
	UFP-PJM-00013_1102 Subsystem	UFLTR FD VSL B PJM CTRL	53,534	42	
	UFP-PJM-00014_1103 Subsystem	UFLTR FD VSL B PJM CTRL	53,534	42	
	UFP-PJM-00015_1104 Subsystem	UFLTR FD VSL B PJM CTRL	53,534	42	
	UFP-PJM-00016_1105 Subsystem	UFLTR FD VSL B PJM CTRL	53,534	42	
	UFP-PJM-00017_1106 Subsystem	UFLTR FD VSL B PJM CTRL	53,534	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-PMP-00042-B	ULTRAFILTRATION RECIRCULATION PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. Pump failure wills stop transfer out from UFP-VSL-00002B, except for the solid transfer step.
	UFP-PMP-00043-B	ULTRAFILTRATION RECIRCULATION PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. Pump failure wills stop transfer out from UFP-VSL-00002B, except for the solid transfer step.
	UFP-PMP-00044-B	ULTRAFILTRATION RECIRCULATION PUMP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Pump is located in the hotcell. If failed cannot transfer out from UFP-VSL-0002B during solid transfer step and cleaning steps.
	UFP-PV-0380	UFP HXCHGR B MN DRN HDR OUT	43,800	88 / PIH crane usage 40	Valve controls loop pressure for permeate for UFP-VSL-0002B only. Stop flowing out from UFP-VSL-0002B during concentration steps. EXTERNAL EFFECT on PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-TE-0217/UFP-TT-0217	UFLTR FD VSL B	66,667	42	Instrument is located in hotcell will require crane and remove of jumper. The instrument failure should be assigned to UFP-VSL-00002B.
	UFP-VSL-00002-B	ULTRAFILTRATION FEED VESSEL	350,400		
	UFP-YV-0224 - Critical Valve	UFLTR FD PMP B SUCT	43,800	88 / PIH crane usage 40	Valve failure prevents circulation through train B filters. Cannot perform concentrating steps. Cannot perform cleaning steps. EXTERNAL EFFECTS on PIH-Crane.
	UFP-YV-0227	UF FD VSL B XFR TO HLP VSL B	43,800	88 / PIH crane usage 40	Failure prevents transfers from UFP-VSL-0002B to HLP-VSL-00027B. PIH Crane is required for repair.
	UFP-YV-0261	UF FD VSL B STM EJCTR DISCH	43,800	88 / PIH crane usage 40	Failure prevents transfer of cleaning solutions to PWD. Will impact the chemical cleaning step of the UFP cycle (UFP-VSL-0002B). Require the use of the PIH Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0287	UF FD VSL B 2M HNO3 IN	333,333	24	Valve failure prevents nitric acid cleaning step (UFP-VSL-2B).
	UFP-YV-0292 - Critical Valve	UF FD VSL B PUMP SUCT	43,800	88 / PIH crane usage 40	Cannot perform solid transfer if this valve fails.
	UFP-YV-0301 - Critical Valve	UFLTR B XFR HDR DRN	43,800	88 / PIH crane usage 40	Failure closed prevents draining pump suction during cleaning. Cannot perform the cleaning step. EXTERNAL EFFECTS on PIH Crane.
	UFP-YV-0326	UFLTR B XFR HDR DRN	43,800	88 / PIH crane usage 40	Valve failure prevents draining circulation loop during chemical cleaning. Cannot perform chemical cleaning steps for Train B. EXTERNAL AFFECTS on PIH Crane.
	UFP-YV-0381	POWER FLUSH - HPAV	43,800	88 / PIH crane usage 40	HPAV 1 out of 1 is required, the UFP-VSL-00002B should fail.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YV-0382	PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0382 and YV/ZSL/ZSH-0383) the UFP-VSL-00002B should fail.
	UFP-YV-0383	PURGE AIR SUPPLY - HPAV	43,800	88 / PIH crane usage 40	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0382 and YV/ZSL/ZSH-0383) the UFP-VSL-00002B should fail.
	UFP-ZE-0380	UFP HXCHGR B MN DRN HDR OUT	100,000	88 / PIH crane usage 40	Instrument controls loop pressure for permeate for UFP-VSL-0002B only.
	UFP-ZSL-0224/UFP-ZSH-0224 B	UFLTR FD PMP B SUCT	499,320	56 / PIH crane usage 28	Valve fail closed prevent circulation through filters
	UFP-ZSL-0227/UFP-ZSH-0227	UF FD VSL B XFR TO HLP VSL B	499,320	56 / PIH crane usage 28	Failure prevents transfers from UFP-VSL-0002B to HLP-VSL-00027B. PIH Crane is required for repair.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0229/UFP-ZSH-0229	UF FD VSL B XFR TO HLP VSL A	499,320	56 / PIH crane usage 28	Failure prevents transfers from UFP-VSL-00002A to HLP-VSL-00027A. PIH Crane is required for repair.
	UFP-ZSL-0230/UFP-ZSH-0230	UF FD VSL B XFR TO HLP BLNDG VSL	499,320	56 / PIH crane usage 28	Failure prevents transfer from UFP-VSL-00002A to HLP-VSL-00028. PIH Crane is required for repair.
	UFP-ZSL-0261/UFP-ZSH-0261	UF FD VSL B STM EJCTR DISCH	499,320	56 / PIH crane usage 28	Failure prevents transfer of cleaning solutions to PWD. Will impact the chemical cleaning step of the UFP cycle (UFP-VSL-00002B). Require the use of the PIH Crane.
	UFP-ZSL-0287/UFP-ZSH-0287	UF FD VSL B 2M HNO3 IN	499,320	42	Valve failure prevents nitric acid cleaning step (UFP-VSL-00002B).
	UFP-ZSL-0292/UFP-ZSH-0292	UF FD VSL A STM EJCTR SUCT	499,320	56 / PIH crane usage 28	Failure prevents solid transfer from UFP-VSL-00002B.
	UFP-ZSL-0301/UFP-ZSH-0301 B	UFLTR B XFR HDR DRN	499,320	56 / PIH crane usage 28	Failure closed prevents draining pump suction during cleaning.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0326/UFP-ZSH-0326 B	UFLTR B XFR HDR DRN	499,320	56 / PIH crane usage 28	Valve failure prevents draining circulation loop during chemical cleaning.
	UFP-ZSL-0381/UFP-ZSH-0381	POWER FLUSH - HPAV	499,320	56 / PIH crane usage 28	HPAV 1 out of 1 is required the UFP-VSL-00002B should fail.
	UFP-ZSL-0382/UFP-ZSH-0382	PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0382 and YV/ZSL/ZSH-0383) the UFP-VSL-00002B should fail. 1 out of 2 is required after HPAV.
	UFP-ZSL-0383/UFP-ZSH-0383	PURGE AIR SUPPLY - HPAV	499,320	56 / PIH crane usage 28	2 out of 2 of these instrument loops is required for HPAV (YV/ZSL/ZSH-0382 and YV/ZSL/ZSH-0383) the UFP-VSL-00002B should fail. 1 out of 2 is required after HPAV.
UFP-VSL-00062-A	UFP-LT-0167/UFP-DT-0164/UFP-YY-0167/UFP-YV-0167-A/B	UFLTR PRMT VSL A	28,855	42	This UFP failure should be assigned to UFP-VSL-00062A.
	UFP-PJM-00018_0601 Subsystem	UFLTR PRMT VSL A PJM CTRL	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-PJM-00019_0602 Subsystem	UFLTR PRMT VSL A PJM CTRL	57,798	42	
	UFP-PJM-00020_0603 Subsystem	UFLTR PRMT VSL A PJM CTRL	57,798	42	
	UFP-PJM-00021_0604 Subsystem	UFLTR PRMT VSL A PJM CTRL	57,798	42	
	UFP-PJM-00022_0605 Subsystem	UFLTR PRMT VSL A PJM CTRL	57,798	42	
	UFP-PJM-00052_0606 Subsystem	UFLTR PRMT VSL A PJM CTRL	57,798	42	
	UFP-VSL-00062-A	ULTRAFILTER PERMEATE COLLECTION VESSEL	350,400		
	UFP-YV-0257 - Critical Valve	UFLTR B HDR TO PRMT VSL C	43,800	88 / PIH crane usage 40	Valve failure disables transfers from UFP Train B to UFP-VSL-00062A. EXTERNAL AFFECTS on PIH-Crane.
	UFP-YV-0401 - Critical Valve	UF PRMT VSL A 19M NAOH IN	333,333	24	Valve fail closed disables transfers out of UFP-VSL-00062A only.
	UFP-YY-0401	UF PRMT VSL A 19M NAOH IN	499,320	12	Valve fail closed disables transfers to UFP-VSL-00062A only. EXTERNAL EFFECTS on PIH-Crane

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0157/UFP-ZSH-0157	UFLTR A HDR TO PRMT VSL A	499,320	56 / PIH crane usage 28	Valve fail closed disables transfers to UFP-VSL-00062A only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-ZSL-0257/UFP-ZSH-0257	UFLTR B HDR TO PRMT VSL A	499,320	56 / PIH crane usage 28	Valve fail closed disables transfers to UFP-VSL-00062A only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-ZSL-0401/UFP-ZSH-0401	UF PRMT VSL A 19M NAOH IN	499,320	42	Valve fail closed disables transfers to UFP-VSL-00062A only.
UFP-VSL-00062-B	UFP-LT-0262/UFP-DT-0259/UFP-YY-0262/UFP-YV-0262-A/B	UFLTR PRMT VSL B	28,855	42	This UFP failure should be assigned to UFP-VSL-00062B.
	UFP-PJM-00039_0607 Subsystem	UFLTR PRMT VSL B PJM CTRL	57,798	42	
	UFP-PJM-00040_0608 Subsystem	UFLTR PRMT VSL B PJM CTRL	57,798	42	
	UFP-PJM-00041_0609 Subsystem	UFLTR PRMT VSL B PJM CTRL	57,798	42	
	UFP-PJM-00042_0610 Subsystem	UFLTR PRMT VSL B PJM CTRL	57,798	42	
	UFP-PJM-00043_0611 Subsystem	UFLTR PRMT VSL B PJM CTRL	57,798	42	
	UFP-PJM-00051_0612 Subsystem	UFLTR PRMT VSL B PJM CTRL	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-VSL-00062-B	ULTRAFILTER PERMEATE COLLECTION VESSEL	350,400		
	UFP-YV-0256 - Critical Valve	UFLTR B HDR TO PRMT VSL B	43,800	88 / PIH crane usage 40	Valve failure disables transfers from UFP Train B to UFP-VSL-00062B. EXTERNAL AFFECTS on PIH-Crane.
	UFP-YV-0402 - Critical Valve	UF PRMT VSL B 19M NAOH IN	333,333	24	Valve fail closed disables transfers out of UFP-VSL-00062B only.
	UFP-YY-0402	UF PRMT VSL B 19M NAOH IN	499,320	12	Valve fail closed disables transfers to UFP-VSL-00062B only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-ZSL-0156/UFP-ZSH-0156	UFLTR A HDR TO PRMT VSL B	499,320	56 / PIH crane usage 28	Valve fail closed disables transfers to UFP-VSL-00062B only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-ZSL-0256/UFP-ZSH-0256	UFLTR B HDR TO PRMT VSL B	499,320	56 / PIH crane usage 28	Valve fail closed disables transfers to UFP-VSL-00062B only. EXTERNAL EFFECTS on PIH-Crane.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-ZSL-0402/UFP-ZSH-0402	UF PRMT VSL B 19M NAOH IN	499,320	42	Valve fail closed disables transfers to UFP-VSL-00062B only.
UFP-VSL-00062-C	UFP-LT-0162/UFP-DT-0159/UFP-YY-0162/UFP-YV-0162-A/B	UFLTR PRMT VSL C	28,855	42	This UFP failure should be assigned to UFP-VSL-00062C.
	UFP-PJM-00070_1005 Subsystem	UFLTR PRMT VSL C PJM CTRL	57,798	42	
	UFP-PJM-00073_1001 Subsystem	UFLTR PRMT VSL C PJM CTRL	57,798	42	
	UFP-PJM-00076_1002 Subsystem	UFLTR PRMT VSL C PJM CTRL	57,798	42	
	UFP-PJM-00077_1003 Subsystem	UFLTR PRMT VSL C PJM CTRL	57,798	42	
	UFP-PJM-00078_1004 Subsystem	UFLTR PRMT VSL C PJM CTRL	57,798	42	
	UFP-PJM-00107_1006 Subsystem	UFLTR PRMT VSL C PJM CTRL	57,798	42	
	UFP-VSL-00062-C	ULTRAFILTER PERMEATE COLLECTION VESSEL	350,400		
	UFP-YV-0255 - Critical Valve	UFLTR B HDR TO PRMT VSL A	43,800	88 / PIH crane usage 40	Valve failure disables transfers from UFP Train B to UFP-VSL-00062C. EXTERNAL AFFECTS on PIH-Crane
	UFP-YV-0403 - Critical Valve	UF PRMT VSL C 19M NAOH IN	333,333	24	Valve fail closed disables transfers out of UFP-VSL-00062C only.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	UFP-YY-0403	UF PRMT VSL C 19M NAOH IN	499,320	12	Valve fail closed disables transfers to UFP-VSL-00062C only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-ZSL-0155/UFP-ZSH-0155	UFLTR A HDR TO PRMT VSL C	499,320	56 / PIH crane usage 28	Valve fail closed disables transfers to UFP-VSL-62C only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-ZSL-0255/UFP-ZSH-0255	UFLTR B HDR TO PRMT VSL C	499,320	56 / PIH crane usage 28	Valve fail closed disables transfers to UFP-VSL-00062C only. EXTERNAL EFFECTS on PIH-Crane.
	UFP-ZSL-0403/UFP-ZSH-0403	UF PRMT VSL C 19M NAOH IN	499,320	42	Valve fail closed disables transfers to UFP-VSL-00062C only.

2.4 System HLP: HLW Lag Storage and Feed Blending Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HLP-PMP-00017-A	HLP-FT-0143	HLW SLDS XFR PMP A DISCH	66,667	42	
HLP-PMP-00017-B	HLP-FT-0146	HLW SLDS XFR PMP B DISCH	66,667	42	
	HLP-YV-0113	HLW FD RTN HDR TO DOE	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HLP-PMP-00019-A	HLP-YV-0163	HLW TRTD SLDS XFR TO DRN	43,800	88 / PIH crane usage 40	
	HLP-YV-0250	HLW TRTD SLDS MN HDR VLV	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0259	HLW BLND FD XFR PMP A DISCH	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
HLP-PMP-00019-B	HLP-YV-0260	HLW BLND FD XFR PMP B DISCH	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0261	HLW BLND FD XFR TO HLW VSL	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0263	HLW BLND FD XFR TO HLW VSL	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0287	HLP TO HLW XFR LN LK DRN VLV	43,800	88 / PIH crane usage 40	
	HLP-YV-0288	HLP TO HLW XFR LN LK DRN VLV	43,800	88 / PIH crane usage 40	
	HLP-YV-0289	HLP TO HLW XFR LN LK DRN VLV	43,800	88 / PIH crane usage 40	
	HLP-YV-0290	HLP TO HLW XFR LN LK DRN VLV	43,800	88 / PIH crane usage 40	
HLP-PMP-00021	HLP-YV-0256	HLW FD RTN TO DOE	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0271	HLW FD XFR TO FEP VSL A	43,800	88 / PIH crane usage 40	
	HLP-YV-0280	HLW FD XFR TO FEP VSL B	43,800	88 / PIH crane usage 40	
	HLP-YV-0295	HLW FD XFR TO DRN HDR	43,800	88 / PIH crane usage 40	
HLP-VSL-00022	HLP-LT-0214/DT-0215	LEVEL TRANSMITTER - BUBBLER	28,855	42	
	HLP-LT-0216/DT-0217	LEVEL TRANSMITTER - BUBBLER	28,855	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HLP-DT-0221/HLP-LT-0220 Assembly	HLW FD REC VSL	28,855	42	
	HLP-PJM-00056_0701 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00057_0702 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00084_0705 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00085_0706 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00086_0707 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00087_0708 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00088_0709 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00089_0710 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00090_0703 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00091_0704 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00092_0717 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-00093_0718 Subsystem	HLW FD REC VSL PJM CNTRL	53,534	42	
	HLP-PJM-TEMP-01	New PJM for HLP-VSL-00022 (18 total).	53,534	42	Operating philosophy is to be determined.
	HLP-PJM-TEMP-02	New PJM for HLP-VSL-00022 (18 total).	53,534	42	Operating philosophy is to be determined.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HLP-PJM-TEMP-03	New PJM for HLP-VSL-00022 (18 total).	53,534	42	Operating philosophy is to be determined.
	HLP-PJM-TEMP-04	New PJM for HLP-VSL-00022 (18 total).	53,534	42	Operating philosophy is to be determined.
	HLP-PJM-TEMP-05	New PJM for HLP-VSL-00022 (18 total).	53,534	42	Operating philosophy is to be determined.
	HLP-PJM-TEMP-06	New PJM for HLP-VSL-00022 (18 total).	53,534	42	Operating philosophy is to be determined.
	HLP-PMP-00021	HLW FEED RECEIPT TRANSFER PUMP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	HLP-TE-0218	HLW FD REC VSL	333,333	42	
	HLP-VSL-00022	HLW FEED RECEIPT VESSEL	350,400		
	HLP-YV-0223 - Critical Valve	HLW FD XFR PMP SUCT	43,800	88 / PIH crane usage 40	
	HLP-YV-0229 - Critical Valve	HLW FD XFR PMP DISCH	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0269 - Critical Valve	HLW FD XFR TO UFP VSL A	43,800	88 / PIH crane usage 40	
	HLP-YV-0270 - Critical Valve	HLW FD XFR TO UFP VSL B	43,800	88 / PIH crane usage 40	
	HLP-YV-0292 - Critical Valve	HLW FD XFR HDR MN VLV	43,800	88 / PIH crane usage 40	
	HLP-YV-0293 - Critical Valve	HLW FD XFR TO ASMLPR	43,800	88 / PIH crane usage 40	
HLP-VSL-00022/27A/B/28	HLP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES HLP-VSL-00022/27A/B/28	17,159	8	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HLP-PPJ-PNL	PROGRAMMABLE PROTECTION (PPJ) I/O MODULES HLP-VSL-00022/27A/B/28	2,027,064	8	
HLP-VSL-00027A	HLP-DT-0166/HLP-LT-0160 Assembly	HLW LAG STOR VSL A	28,855	42	
	HLP-PJM-00060_0501 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PJM-00061_0502 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PJM-00062_0503 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PJM-00063_0504 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PJM-00064_0505 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PJM-00065_0506 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PJM-00066_0507 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PJM-00067_0508 Subsystem	HLW LAG STOR VSL A PJM CTRL	53,534	42	
	HLP-PMP-00017-A	HLW SOLIDS TRANSFER PUMP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	HLP-VSL-00027-A	HLW LAG STORAGE VESSEL	350,400		
	HLP-YV-0107 - Critical Valve	HLW SLDS XFR PMP A SUCT	43,800	88 / PIH crane usage 40	
	HLP-YV-0118 - Critical Valve	HLW SLDS XFR PMP A DISCH	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HLP-YV-0148	MN HDR TO LAG STOR VSL A	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0152 - Critical Valve	HLW LAG STOR VSL A MN HDR	43,800	88 / PIH crane usage 40	
	HLP-YV-0161 - Critical Valve	HLW LAG STOR VSL A ASMPLR IN	43,800	88 / PIH crane usage 40	
HLP-VSL-00027B	HLP-DT-0167/HLP-LT-0164 Assembly	HLW LAG STOR VSL B	28,855	42	
	HLP-PJM-00068_0509 Subsystem	HLW LAG STOR VSL B PJM CTRL	53,534	42	
	HLP-PJM-00069_0510 Subsystem	HLW LAG STOR VSL B PJM CTRL	53,534	42	
	HLP-PJM-00070_0511 Subsystem	HLW LAG STOR VSL B PJM CTRL	53,534	42	
	HLP-PJM-00071_0512 Subsystem	HLW LAG STOR VSL B PJM CTRL	53,534	42	
	HLP-PJM-00072_0601 Subsystem	HLW LAG STOR VSL B PJM CNTRL	53,534	42	
	HLP-PJM-00073_0602 Subsystem	HLW LAG STOR VSL B PJM CNTRL	53,534	42	
	HLP-PJM-00074_0603 Subsystem	HLW LAG STOR VSL B PJM CNTRL	53,534	42	
	HLP-PJM-00075_0604 Subsystem	HLW LAG STOR VSL B PJM CNTRL	53,534	42	
	HLP-PMP-00017-B	HLW SOLIDS TRANSFER PUMP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	HLP-VSL-00027-B	HLW LAG STORAGE VESSEL	350,400		

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HLP-YV-0127 - Critical Valve	HLW SLDS XFR PMP B SUCT	43,800	88 / PIH crane usage 40	
	HLP-YV-0135 - Critical Valve	HLW SLDS XFR PMP B DISCH	43,800	88 / PIH crane usage 40	
	HLP-YV-0157 - Critical Valve	HLW LAG STOR VSL B MN HDR	43,800	88 / PIH crane usage 40	
	HLP-YV-0158	MN HDR TO LAG STOR VSL B	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	HLP-YV-0165 - Critical Valve	HLW LAG STOR VSL B ASMPLR IN	43,800	88 / PIH crane usage 40	
HLP-VSL-00028	HLP-DT-0299/HLP-LT-0296 Assembly	HLW FD BLNDG VSL	28,855	42	
	HLP-PJM-00076_0605 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	
	HLP-PJM-00077_0606 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	
	HLP-PJM-00078_0607 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	
	HLP-PJM-00079_0608 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	
	HLP-PJM-00080_0609 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	
	HLP-PJM-00081_0610 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	
	HLP-PJM-00082_0611 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	
	HLP-PJM-00083_0612 Subsystem	HLW FD BLNDG VSL PJM CNTRL	53,534	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HLP-PMP-00019-A	HLW MELTER FEED PUMP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	HLP-PMP-00019-B	HLW MELTER FEED PUMP	17,520	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	HLP-TE-0236	HLW FD BLDNG VSL	333,333	42	
	HLP-VSL-00028	HLW FEED BLEND VESSEL	350,400		
	HLP-YV-0242	HLW BLND FD XFR PMP A SUCT	43,800	88 / PIH crane usage 40	
	HLP-YV-0253 - Critical Valve	HLW FD BLND XFR PMP DISCH	43,800	88 / PIH crane usage 40	
	HLP-YV-0284 - Critical Valve	HLW BLND FD XFR HDR MN VLV	43,800	88 / PIH crane usage 40	
	HLP-YV-0285 - Critical Valve	HLW TRTD SLDS XFR TO BLND VSL	43,800	88 / PIH crane usage 40	
	HLP-YV-0297	HLW BLND FD XFR PMP B SUCT	43,800	88 / PIH crane usage 40	
	HLP-YV-0298 - Critical Valve	HLW BLND FD XFR TO ASMPLR	43,800	88 / PIH crane usage 40	
MCR20-PMP-TEMP01	MCR20-PMP-TEMP01	Mobile pumps used to fill and/or remove volume from HLP-VSL-00022, 27A, 27B and 28 during scheduled maintenance.	17,520	672	
MCR20-PMP-TEMP02	MCR20-PMP-TEMP02		17,520	672	
MCR20-PMP-TEMP03	MCR20-PMP-TEMP03		17,520	672	

2.5 System CXP: Cesium Removal Using Ion Exchange Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CXP-BULGE-00004	CXP-YV-0322	Valve - On/Off Plug (2 Way)	43,800	88 / PIH crane usage 40	
CXP-HX-00001-A	CXP-AE-0119	LAW FD PMP A IN	200,000	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-TE-0120	FD CLR A OUT TO IXCS	333,333	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
CXP-HX-00001-B	CXP-AE-0129	LAW FD PMP B IN	200,000	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-TE-0130	FD CLR B OUT TO IXCS	333,333	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
CXP-IXC-00001	CXP-FT-1427	N2 BTL SPLY IXC1	66,667	42	
	CXP-IXC-00001	CS ION EXCHANGE COLUMN	87,600	499 / PIH crane usage 279	
	CXP-RE-0351	CXP-BULGE-00004	200,000	42	
	CXP-YV-0201	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0201 E Jumper	ELECTRICAL JUMPER	1,678,000	68 / PIH crane usage 40	
	CXP-YV-0202	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-YV-0202 E Jumper	ELECTRICAL JUMPER	1,678,000	68 / PIH crane usage 40	
	CXP-YV-0207	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	CXP-YV-0207 E Jumper	ELECTRICAL JUMPER	156,000	68 / PIH crane usage 40	
	CXP-YV-0208	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0208 E Jumper	ELECTRICAL JUMPER	1,678,000	68 / PIH crane usage 40	
	CXP-YV-0209	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0209 E Jumper	ELECTRICAL JUMPER	156,000	68 / PIH crane usage 40	
	CXP-YV-0264	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0264 E Jumper	ELECTRICAL JUMPER	156,000	68 / PIH crane usage 40	
	CXP-YV-0340	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0340 E Jumper	ELECTRICAL JUMPER	336,500	68 / PIH crane usage 40	
CXP-IXC-00001/2	CXP-RE-0282	IXC1 TRTD LAW TO CXP	200,000	42	
CXP-IXC-00002	CXP-FT-1425	N2 BTL SPLY IXC 2	66,667	42	
	CXP-IXC-00002	CS ION EXCHANGE COLUMN	87,600	499 / PIH crane usage 279	
	CXP-YV-0205	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0205 E Jumper	ELECTRICAL JUMPER	169,600	68 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-YV-0210	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0210 E Jumper	ELECTRICAL JUMPER	141,500	68 / PIH crane usage 40	
	CXP-YV-0211	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0211 E Jumper	ELECTRICAL JUMPER	141,500	68 / PIH crane usage 40	
	CXP-YV-0216	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0216 E Jumper	ELECTRICAL JUMPER	202,400	68 / PIH crane usage 40	
	CXP-YV-0217	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0217 E Jumper	ELECTRICAL JUMPER	141,500	68 / PIH crane usage 40	
	CXP-YV-0218	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0218 E Jumper	ELECTRICAL JUMPER	141,500	68 / PIH crane usage 40	
	CXP-YV-0265	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	CXP-YV-0265 E Jumper	ELECTRICAL JUMPER	202,400	68 / PIH crane usage 40	
CXP-IXC-00003	CXP-FT-1423	N2 BTL SPLY IXC3	66,667	42	
	CXP-IXC-00003	CS ION EXCHANGE COLUMN	87,600	499 / PIH crane usage 279	
	CXP-YV-0214	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-YV-0214 E Jumper	ELECTRICAL JUMPER	202,400	68 / PIH crane usage 40	
	CXP-YV-0219	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0219 E Jumper	ELECTRICAL JUMPER	169,600	68 / PIH crane usage 40	
	CXP-YV-0220	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0220 E Jumper	ELECTRICAL JUMPER	169,600	68 / PIH crane usage 40	
	CXP-YV-0225	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0225 E Jumper	ELECTRICAL JUMPER	142,100	68 / PIH crane usage 40	
	CXP-YV-0226	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0226 E Jumper	ELECTRICAL JUMPER	142,100	68 / PIH crane usage 40	
	CXP-YV-0227	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0227 E Jumper	ELECTRICAL JUMPER	142,100	68 / PIH crane usage 40	
	CXP-YV-0333	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	CXP-YV-0333 E Jumper	ELECTRICAL JUMPER	1,616,000	68 / PIH crane usage 40	
CXP-IXC-00003/4	CXP-AE-0223	SPNT RSN OUT	200,000	42	
CXP-IXC-00004	CXP-FT-1421	N2 BTL SPLY IXC4	66,667	42	
	CXP-IXC-00004	CS ION EXCHANGE COLUMN	87,600	499 / PIH crane usage 279	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-YV-0301	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0301 E Jumper	ELECTRICAL JUMPER	144,800	68 / PIH crane usage 40	
	CXP-YV-0302	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0302 E Jumper	ELECTRICAL JUMPER	1,616,000	68 / PIH crane usage 40	
	CXP-YV-0303	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0311	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0311 E Jumper	ELECTRICAL JUMPER	228,800	68 / PIH crane usage 40	
	CXP-YV-0312	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	CXP-YV-0312 E Jumper	ELECTRICAL JUMPER	228,800	68 / PIH crane usage 40	
	CXP-YV-0313	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0313 E Jumper	ELECTRICAL JUMPER	144,800	68 / PIH crane usage 40	
	CXP-YV-0315	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0315 E Jumper	ELECTRICAL JUMPER	144,800	68 / PIH crane usage 40	
	CXP-YV-0321	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0325	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-YV-0325 E Jumper	ELECTRICAL JUMPER	1,616,000	68 / PIH crane usage 40	
CXP-PMP-00001-A	CXP-FT-0118	LAW FD PMP A OUT	66,667	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-YV-0135	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0339	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0339 E Jumper	ELECTRICAL JUMPER	336,500	68 / PIH crane usage 40	
CXP-PMP-00001-B	CXP-FT-0128	LAW FD PMP B OUT	66,667	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-YV-0136	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
CXP-VSL-00001	CXP-RE-0282 Surveillance		720	6	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-HX-00001-A	CS ION EXCHANGE FEED COOLER - 24 GPM	43,800	120	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-HX-00001-B	CS ION EXCHANGE FEED COOLER - 24 GPM	43,800	120	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-PMP-00001-A	CS ION EXCHANGE FEED PUMP - HORIZONTAL SEALLESS CENTRIFUGAL PUMP API 685 - 22 GPM 7.5 HP	33,288	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-PMP-00001-B	CS ION EXCHANGE FEED PUMP - HORIZONTAL SEALLESS CENTRIFUGAL PUMP API 685 - 22 GPM 7.5 HP	33,288	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-VSL-00001	CS ION EXCHANGE FEED VESSEL	350,400		
	CXP-YV-0115	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0115 E Jumper	ELECTRICAL JUMPER	259,200	68 / PIH crane usage 40	
	CXP-YV-0117	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0117 E Jumper	ELECTRICAL JUMPER	300,700	68 / PIH crane usage 40	
	CXP-YV-0125	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0127	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0131 Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CXP-YV-0131 E Jumper		299,100	68 / PIH crane usage 40	
	CXP-YV-0318	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CXP-VSL-00004	CXP-FT-0139	CSTC RNS COLL VSL 0.25M NAOH IN	66,667	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-FT-0140	CSTC RNS COLL VSL PROC COND IN	66,667	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-LT-0102	CS IX CSTC RNS COLL VSL	2,000,000	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-DT-0113/CXP-LT-0114 Assembly	CS IX LAW FD VSL	28,855	42	Disabled in WTP OR Model if the UFP back-end leaching scenario is selected.
	CXP-PJM-00001_0501 Subsystem	CS CSTC RNS COLL VSL PJM CTRL UNIT	57,798	42	
	CXP-VSL-00004	CS IX CAUSTIC RINSE COLLECTION VESSEL	350,400		
	CXP-YV-0121 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
CXP-VSL-00005	CXP-FT-0103	CS REAGT VSL DMW IN	66,667	42	
	CXP-FT-0107	CS REAGT 0.25M NAOH IN	66,667	42	
	CXP-FT-0137	CS REAGT VSL HNO3 IN	66,667	42	
	CXP-FT-0138	CS REAGT VSL 0.1M NAOH IN	66,667	42	
	CXP-LT-0108	CS REAGT VSL	2,000,000	42	
	CXP-VSL-00005	CS IX REAGENT VESSEL	350,400		
	CXP-YV-0110 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-YV-0111 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
CXP-VSL-00026A	CXP-DT-1002/CXP-LT-1003 Assembly	CS IX TRTD LAW COLL VSL 26A	28,855	42	
	CXP-PJM-00002_1102 Subsystem	CS IX TRTD LAW COLL VSL 26A PJM CNTRL	57,798	42	
	CXP-PJM-00003_1104 Subsystem	CS IX TRTD LAW COLL VSL 26A PJM CNTRL	57,798	42	
	CXP-PJM-00004_1106 Subsystem	CS IX TRTD LAW COLL VSL 26A PJM CNTRL	57,798	42	
	CXP-PJM-00005_1105 Subsystem	CS IX TRTD LAW COLL VSL 26A PJM CNTRL	57,798	42	
	CXP-PJM-00006_1103 Subsystem	CS IX TRTD LAW COLL VSL 26A PJM CNTRL	57,798	42	
	CXP-PJM-00007_1101 Subsystem	CS IX TRTD LAW COLL VSL 26A PJM CNTRL	57,798	42	
	CXP-AE-0298	IXC TRTD LAW TO CXP VSL 26 A/B/C	200,000	42	
	CXP-VSL-00026-A	CESIUM ION EXCHANGE TREATED LAW COLLECTION VESSEL	350,400		
	CXP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES FOR CXP-VSL-00004, CXP-VSL-00026A/B/C	17,159	8	
CXP-VSL-00026B	CXP-PMP-00002-A	TREATED LAW FEED PUMP - HORIZONTAL SEALLESS CENTRIFUGAL PUMP API 685 - 34 GPM	43,800	84 / Parallel pump stopped 72 hr	
	CXP-PMP-00002-B	TREATED LAW FEED PUMP - HORIZONTAL SEALLESS CENTRIFUGAL PUMP API 685 - 34 GPM	43,800	84 / Parallel pump stopped 72 hr	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-LT-1008/CXP-DT-1007 Assembly	TRTD LAW COLL VSL 26B	28,855	42	
	CXP-PJM-00008_1111 Subsystem	CS IX TRTD LAW COLL VSL 26B PJM CNTRL	57,798	42	
	CXP-PJM-00009_1108 Subsystem	CS IX TRTD LAW COLL VSL 26B PJM CNTRL	57,798	42	
	CXP-PJM-00010_1109 Subsystem	CS IX TRTD LAW COLL VSL 26B PJM CNTRL	57,798	42	
	CXP-PJM-00011_1110 Subsystem	CS IX TRTD LAW COLL VSL 26B PJM CNTRL	57,798	42	
	CXP-PJM-00012_1112 Subsystem	CS IX TRTD LAW COLL VSL 26B PJM CNTRL	57,798	42	
	CXP-PJM-00013_1107 Subsystem	CS IX TRTD LAW COLL VSL 26B PJM CNTRL	57,798	42	
	CXP-VSL-00026-B	CESIUM ION EXCHANGE TREATED LAW COLLECTION VESSEL	350,400		
CXP-VSL-00026C	CXP-DT-1012/CXP-LT-1013 Assembly	TRTD LAW COLL VSL 26C	28,855	42	
	CXP-PJM-00014_1202 Subsystem	CS IX TRTD LAW COLL VSL 26C PJM CNTRL	57,798	42	
	CXP-PJM-00015_1203 Subsystem	CS IX TRTD LAW COLL VSL 26C PJM CNTRL	57,798	42	
	CXP-PJM-00016_1204 Subsystem	CS IX TRTD LAW COLL VSL 26C PJM CNTRL	57,798	42	
	CXP-PJM-00017_1205 Subsystem	CS IX TRTD LAW COLL VSL 26C PJM CNTRL	57,798	42	
	CXP-PJM-00018_1206 Subsystem	CS IX TRTD LAW COLL VSL 26C PJM CNTRL	57,798	42	
	CXP-PJM-00019_1207 Subsystem	CS IX TRTD LAW COLL VSL 26C PJM CNTRL	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CXP-VSL-00026-C	CESIUM ION EXCHANGE TREATED LAW COLLECTION VESSEL	350,400		

2.6 System CNP: Cesium Nitric Acid Recovery Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CNP-BRKPT-00002	CNP-YV-0125	VALVE - ON/OFF BALL (2 WAY)	333,333	24	
CNP-DISTC-00001	CNP-PMP-00002	PROCESS CONDENSATE RETURN PUMP (50 HP - 3500 GPM)	10,512	108	
	CNP-YV-1004 - Critical Valve	VALVE - ON/OFF BALL (2 WAY)	43,800	12	Deactivated in OR model (MTBF=100,000,000)
CNP-EVAP-00001	CNP-EVAP-00001	CS EVAPORATOR SEPARATOR VESSEL	350,400		
	CNP-FV-0822 - Critical Valve	CONTROL VALVE - GLOBE	43,800	12	Deactivated in OR model (MTBF=100,000,000)
	CNP-FV-1006 - Critical Valve	CONTROL VALVE - GLOBE	43,800	12	Deactivated in OR model (MTBF=100,000,000)
	CNP-LT-0117/CNP-DT-0132	LEVEL MONITORING LOOP (PNEUMERCATOR)	7143	42	
	CNP-LT-0102/CNP-DT-0103		7143	42	
	CNP-LV-0203 - Critical Valve	CONTROL VALVE - GLOBE	43,800	12	Deactivated in OR model (MTBF=100,000,000)
	CNP-PDT-0114/CNP-PDT-0113	CS EVAP SEPR VSL	50,000	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	CNP-PMP-00001	PROCESS CONDENSATE RETURN PUMP - AXIAL FLOW	10,512	63 / 69 every third failure PIH crane usage 36 / 48 every third failure	
	CNP-PT-1116	PRESSURE CONTROL LOOP	50,000	42	
	CNP-TE-1111	CONDENSATE COLLECTION VESSEL	333,333	42	
	CNP-YV-0128	VALVE - ON/OFF GLOBE (2 WAY)	333,333	24	
	CNP-YV-0805 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0806 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0807 - Critical Valve	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
CNP-HX-00001	CNP-FE-0823/CNP-FT-0823	CS EVAP REBLR CNDS IN	66,667	42	
	CNP-FE-0822/CNP-FT-0822	CS EVAP REBLR STM IN	66,667	42	
	CNP-PT-0825	CS EVAP REBLR STM IN	50,000	42	
	CNP-RE-0816	CS EVAP REBLR GAMMA MNTR	200,000	42	
	CNP-RE-0829	CS EVAP SEPR VSL	200,000	42	
	CNP-TE-0824	CS EVAP REBLR STM IN	333,333	42	
CNP-HX-00002	CNP-LT-0203	CS EVAP PRMRY CONDENSER	2,000,000	42	
CNP-PMP-00002	CNP-FE-1006/CNP-FT-1006	PRCS COND REFLX	66,667	42	
CNP-VSL-00001	CNP-DISTC-00001	CS EVAPORATOR NITRIC ACID RECTIFIER	350,400		
	CNP-YV-0135	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0135 E Jumper	ELECTRICAL JUMPER	175,800	68 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CNP-VSL-00003	CNP-DT-0103/CNP-LT-0102 Assembly	HNO3 ELUATE CONTINGENCY STOR VSL	28,855	42	
	CNP-PJM-00013_0301 Subsystems	ELUATE CONTINGENCY STOR VSL PJM CTRL	57,798	42	
	CNP-PJM-00014_0302 Subsystems	ELUATE CONTINGENCY STOR VSL PJM CTRL	57,798	42	
	CNP-PJM-00015_0303 Subsystems	ELUATE CONTINGENCY STOR VSL PJM CTRL	57,798	42	
	CNP-PJM-00016_0304 Subsystems	ELUATE CONTINGENCY STOR VSL PJM CTRL	57,798	42	
	CNP-TE-0104	HNO3 ELUATE CONTINGENCY STOR VSL	333,333	42	
	CNP-YV-0136	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0136 E Jumper	ELECTRICAL JUMPER	168,200	68 / PIH crane usage 40	
	CNP-YV-0137	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0137 E Jumper	ELECTRICAL JUMPER	168,200	68 / PIH crane usage 40	
	CNP-YV-0138	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-YV-0138 E Jumper	ELECTRICAL JUMPER	168,200	68 / PIH crane usage 40	
CNP-VSL-00003/4	CNP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES FOR CNP-VSL-00003 AND CNP-VSL-00004	17,159	8	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CNP-VSL-00004	CNP-DT-0235/CNP-LT-0207 Assembly	CS EVAP RECVRD HNO3 VSL	28,855	42	
	CNP-VSL-00004	CS EVAPORATOR RECOVERED NITRIC ACID VESSEL	350,400		
	CNP-YV-0229	VALVE - ON/OFF GLOBE (2 WAY)	333,333	24	
	CNP-YV-0234	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	
	CNP-PJM-00019_0401 Subsystems	CS EVAP RCVRD HNO3 VSL PJM CTRL	57,798	42	
	CNP-PJM-00020_0402 Subsystems	CS EVAP RCVRD HNO3 VSL PJM CTRL	57,798	42	
	CNP-PJM-00021_0403 Subsystems	CS EVAP RCVRD HNO3 VSL PJM CTRL	57,798	42	
	CNP-PJM-00022_0404 Subsystems	CS EVAP RCVRD HNO3 VSL PJM CTRL	57,798	42	
CNP-VSL-0168	CNP-LT-1102	CNP VSL 00168 REBLR CNDS COLL VSL	2,000,000	42	
	CNP-PMP-00003-A	REBOILER CONDENSATE RECYCLE PUMP	43,800	48	
	CNP-PMP-00003-B	REBOILER CONDENSATE TRANSFER PUMP	43,800	48	
	CNP-VSL-0168	REBOILER CONDENSATE COLLECTION VESSEL	350,400		

2.7 System RDP: Spent Resin Collection and Dewatering Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
RDP-CASK-00001	RDP-ME-0210	SPNT RESIN DEWTRG CNTNR OUT	200,000	42	
RDP-PMP-00008-A	RDP-YV-0119	SPNT RESIN SLRY PMP A OUT	43,800	88 / PIH crane usage 40	
RDP-PMP-00008-B	RDP-RE-0146	SPENT RESIN SLURRY PMPS RECIRC	200,000	42	
	RDP-YV-0133	SPNT RESIN DISTR HDR IXC OUT	43,800	88 / PIH crane usage 40	
	RDP-YV-0147	SPNT RESIN DISTR HDR FEP OUT	43,800	88 / PIH crane usage 40	
	RDP-YV-0148	SPNT RESIN DISTR HDR FEP OUT	43,800	88 / PIH crane usage 40	
RDP-SKID-00001	RDP-BLWR-00001	SPENT RESIN DEWATERING BLOWER	30,000	60	
	RDP-CHU-00001	SPENT RESIN DEWATERING CHILLER	47,500	240	
RDP-VSL-00002A	RDP-LT-0103	SPNT RESIN SLRY VSL A	2,000,000	24	
	RDP-PJM-00001_0601 Subsystem	RDP-VSL-00002A CTRLR UNIT	57,798	42	
	RDP-PJM-00002_0602 Subsystem	RDP-VSL-00002A CTRLR UNIT	57,798	42	
	RDP-PJM-00003_0603 Subsystem	RDP-VSL-00002A CTRLR UNIT	57,798	42	
	RDP-PJM-00004_0604 Subsystem	RDP-VSL-00002A CTRLR UNIT	57,798	42	
	RDP-VSL-00002-A	SPENT RESIN SLURRY VESSEL	350,400		
	RDP-YV-0149	SPNT RESIN COLL VSL A RECIRC IN	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	RDP-YV-0241	SPNT RESIN RECYL TO SPNT RESIN SLRY VSL A	43,800	88 / PIH crane usage 40	
RDP-VSL-00002A/B/C	RDP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES RDP-VSL-00002A/B/C	17,159	8	
	RDP-PMP-00008-A	SPENT RESIN SLURRY PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	RDP-PMP-00008-B	SPENT RESIN SLURRY PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	RDP-YV-0101	CS SPNT SAMPLE RTN	43,800	88 / PIH crane usage 40	
	RDP-YV-0102	SPNT RESIN RECIRC	43,800	88 / PIH crane usage 40	
	RDP-YV-0115	SPNT RESIN COLL VSL A OUT	43,800	88 / PIH crane usage 40	
	RDP-YV-0117	SPNT RESIN SLRY PMP A IN	43,800	88 / PIH crane usage 40	
	RDP-YV-0124	SPNT RESIN SLRY PMP B IN	43,800	88 / PIH crane usage 40	
	RDP-YV-0126	SPNT RESIN SLRY PMP B OUT	43,800	88 / PIH crane usage 40	
	RDP-YV-0130 - Critical Valve	SPNT RESIN DISTR HDR SAMPLE OUT	43,800	88 / PIH crane usage 40	
	RDP-YV-0134- Critical Valve	SPNT RESIN DISTR HDR DEWTRG CNTNR	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	RDP-YV-0203 - Critical Valve	SPNT RESIN MSTRE SEPR VSL IN	43,800	72	
	RDP-YV-0204 - Critical Valve	SPNT RESIN MSTRE SEPR VSL OUT	43,800	72	
	RDP-YV-0235 - Critical Valve	SPNT RESIN XFMR IN DEWTRG CASK	43,800	72	
RDP-VSL-00002B	RDP-LT-0108	SPNT RESIN SLRY VSL B	2,000,000	42	
	RDP-PJM-00005_0605 Subsystem	RDP-VSL-00002B CTRLR UNIT	57,798	42	
	RDP-PJM-00006_0606 Subsystem	RDP-VSL-00002B CTRLR UNIT	57,798	42	
	RDP-PJM-00007_0607 Subsystem	RDP-VSL-00002B CTRLR UNIT	57,798	42	
	RDP-PJM-00008_0608 Subsystem	RDP-VSL-00002B CTRLR UNIT	57,798	42	
	RDP-VSL-00002-B	SPENT RESIN SLURRY VESSEL	350,400		
	RDP-YV-0116	SPNT RESIN COLL VSL B IN	43,800	88 / PIH crane usage 40	
	RDP-YV-0122	SPNT RESIN COLL VSL B OUT	43,800	88 / PIH crane usage 40	
	RDP-YV-0150	SPNT RESIN COLL VSL B RECIRC IN	43,800	88 / PIH crane usage 40	
	RDP-YV-0242	SPNT RESIN RECYL TO SPNT RESIN SLRY VSL B	43,800	88 / PIH crane usage 40	
RDP-VSL-00002C	RDP-LT-0113	SPNT RESIN SLRY VSL C	2,000,000	42	
	RDP-PJM-00009_0609 Subsystem	RDP-VSL-00002C CTRLR UNIT	57,798	42	
	RDP-PJM-00010_0610 Subsystem	RDP-VSL-00002C CTRLR UNIT	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	RDP-PJM-00011_0611 Subsystem	RDP-VSL-00002C CTRLR UNIT	57,798	42	
	RDP-PJM-00012_0612 Subsystem	RDP-VSL-00002C CTRLR UNIT	57,798	42	
	RDP-YV-0120	SPNT RESIN COLL VSL C IN	43,800	88 / PIH crane usage 40	
	RDP-YV-0129	SPNT RESIN COLL VSL C OUT	43,800	88 / PIH crane usage 40	
	RDP-YV-0152	SPNT RESIN COLL VSL C RECIRC IN	43,800	88 / PIH crane usage 40	
	RDP-YV-0243	SPNT RESIN RECYL TO SPNT RESIN SLRY VSL C	43,800	88 / PIH crane usage 40	
RDP-VSL-00004	RDP-LT-0206	SPENT RESIN DEWATERING MOISTURE SEPARATION VESSEL	2,000,000	42	
	RDP-PMP-00011	SPENT RESIN DEWATERING PUMP	43,800	108	
	RDP-SMPLR-00001	SPENT RESIN DEWATERING SAMPLE CYLINDER	40,000	60	
	RDP-VSL-00004	SPENT RESIN DEWATERING MOISTURE SEPARATION VESSEL	350,400		
	RDP-YV-0114	SPNT RESIN COLL VSL A IN	43,800	88 / PIH crane usage 40	

2.8 System TLP: Treated LAW Evaporation Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
TLP-COND-00001	TLP-RE-0215	EVAP PRMRY COND OUT	200,000	42	
TLP-PMP-00005-A	TLP-FT-0126	LAW SBS CNDS PMP DISCH	66,667	42	
TLP-RBLR-00001	TLP-FT-0301	EVAP REBLR DHTR LPS	66,667	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	TLP-FT-0350	EVAP REBLR DHTR STM COND	66,667	42	
	TLP-RE-0339	EVAP REBLR STM CNDS OUT	200,000	42	
	TLP-VSL-00047	REBOILER CONDENSATE COLLECTION VESSEL	350,400		
TLP-SEP-00001	TLP-COND-00001	TREATED LAW EVAPORATOR PRIMARY CONDENSER	254,040	192	
	TLP-COND-00002	TREATED LAW EVAPORATOR INTERCONDENSER	254,040	192	
	TLP-COND-00003	TREATED LAW EVAPORATOR AFTERCONDENSER	254,040	192	
	TLP-LT-0308	TRTD LAW EVAP SEPR VSL	2,000,000	42	
	TLP-LT-0353	TRTD LAW EVAP SEPR VSL	2,000,000	42	
	TLP-PMP-00001	TREATED LAW EVAPORATOR RECIRCULATION PUMP	43,800	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	
	TLP-PMP-00011-A	TREATED LAW EVAPORATOR CONCENTRATE PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TLP-PMP-00011-B	TREATED LAW EVAPORATOR CONCENTRATE PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TLP-PT-0313	TRTD LAW EVAP SEPR VSL	50,000	42	
	TLP-PV-0313 - Critical Valve	TRTD LAW EVAP SEPR VSL	43,800	12	
	TLP-RBLR-00001	TREATED LAW EVAPORATOR REBOILER	350,400		Deactivated in OR model (MTBF=10,000,000)

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	TLP-SEP-00001	TREATED LAW EVAPORATOR SEPARATOR VESSEL	350,400		
	TLP-YV-0223 - Critical Valve	RLD PRCS CNDS TK CNDS IN	43,800	12	
	TLP-YV-0320 - Critical Valve	EVAP SEPR LWR DMSTR SPRY	43,800	12	
	TLP-YV-0321 - Critical Valve	EVAP SEPR ANFM REAGT IN	43,800	12	
TLP-VSL-00002	TLP-LT-0217	TRTD LAW EVAP CNDS VSL	2,000,000	42	
	TLP-PMP-00002-A	TREATED LAW EVAPORATOR CONDENSATE PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TLP-PMP-00002-B	TREATED LAW EVAPORATOR CONDENSATE PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TLP-VSL-00002	TREATED LAW EVAPORATOR CONDENSATE VESSEL	350,400		
TLP-VSL-00009-A	TLP-DT-0109/TLP-LT-0108	LAW SBS CNDS REC VSL A	28,855	42	
	TLP-PJM-00001_0501 Subsystem	SBS CNDS REC VSL A PJM 1	57,798	42	
	TLP-PJM-00002_0502 Subsystem	SBS CNDS REC VSL A PJM	57,798	42	
	TLP-PJM-00003_0503 Subsystem	SBS CNDS REC VSL A PJM 3	57,798	42	
	TLP-PJM-00004_0504 Subsystem	SBS CNDS REC VSL A PJM 4	57,798	42	
	TLP-PJM-00005_0505 Subsystem	SBS CNDS REC VSL A PJM 5	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	TLP-PJM-00006_0506 Subsystem	SBS CNDS REC VSL A PJM 6	57,798	42	
	TLP-PJM-00007_0507 Subsystem	SBS CNDS REC VSL A PJM 7	57,798	42	
	TLP-PJM-00008_0508 Subsystem	SBD CNDS REC VSL A PJM 8	57,798	42	
	TLP-YV-0135	VALVE - ON/OFF PLUG (2 WAY)	43,800	88 / PIH crane usage 40	Disabled in WTP OR Model.
	TLP-YV-0143	REC VSL A 5M NAOH IN	333,333	24	
TLP-VSL-00009-A/B	TLP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES TLP-VSL-00009A or 9B	17,159	8	
	TLP-PMP-00005-A	LAW SBS CONDENSATE FEED PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TLP-PMP-00005-B	LAW SBS CONDENSATE FEED PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TLP-VSL-00009-A	LAW SBS CONDENSATE RECEIPT VESSEL	350,400		
	TLP-VSL-00009-B	LAW SBS CONDENSATE RECEIPT VESSEL	350,400		
	TLP-YV-0101 - Critical Valve	REC VSL A LAW SBS CNDS IN	43,800	12	
	TLP-YV-0102 - Critical Valve	REC VSL A LAW SBS CNDS IN	43,800	12	
TLP-VSL-00009-B	TLP-DT-0116/TLP-LT-0115	LAW SBS CNDS REC VSL B	28,855	42	
	TLP-PJM-00009_0601 Subsystem	SBS CNDS REC VSL B PJM 9	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	TLP-PJM-00010_0602 Subsystem	SBS CNDS REC VSL PJM 10	57,798	42	
	TLP-PJM-00011_0603 Subsystem	SBS CNDS REC VSL B PJM 11	57,798	42	
	TLP-PJM-00012_0604 Subsystem	SBS CNDS REC VSL B PJM 12	57,798	42	
	TLP-PJM-00013_0605 Subsystem	SBS CNDS REC VSL B PJM 13	57,798	42	
	TLP-PJM-00014_0606 Subsystem	SBS CNDS REC VSL B PJM 14	57,798	42	
	TLP-PJM-00015_0607 Subsystem	SBS CNDS REC VSL B PJM 15	57,798	42	
	TLP-PJM-00016_0608 Subsystem	SBS CNDS REC VSL B PJM 16	57,798	42	
	TLP-YV-0144	REC VSL B 5M NAOH IN	333,333	24	
TLP-VSL-00047	TLP-LT-0357	TRTD LAW EVAP SEPR VSL	2,000,000	42	
	TLP-PMP-00012-A	REBOILER CONDENSATE TRANSFER PUMP	43,800	48	
	TLP-PMP-00012-B	REBOILER CONDENSATE TRANSFER PUMP	43,800	48	
	TLP-PT-0257	TRTD LAW EVAP COND PMP DISCH	50,000	42	

2.9 System PWD: Plant Wash and Disposal

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
PWD-EJCTR-00064	PWD-YV-1019	P-0119 SMP EJCTR VLV	43,800	88 / PIH crane usage 40	
PWD-SUMP-00004	PWD-YV-3603	PWD-EJCTR-00057	333,333	36	
PWD-SUMP-00005	PWD-YV-3502	HPS TO PWD-EJCTR-00058	333,333	36	
	PWD-YV-3604	PWD-EJCTR-00055A	333,333	36	
PWD-SUMP-00006	PWD-YV-3605	PWD-EJCTR-00059	333,333	36	
PWD-SUMP-00028	PWD-YV-3607	PWD-EJCTR-00080	333,333	36	
PWD-SUMP-00029	PWD-YV-3608	PWD-EJCTR-00081	333,333	36	
PWD-SUMP-00032	PWD-YV-3606	PWD-EJCTR-00065	333,333	36	
PWD-SUMP-00033	PWD-YV-3602	PWD-EJCTR-00066	333,333	36	
PWD-SUMP-00035	PWD-YV-3610	PWD-EJCTR-00072	333,333	36	
PWD-SUMP-00037	PWD-YV-3601	PWD-EJCTR-00074	333,333	36	
PWD-VSL-00015	PWD-LT-0302	ACD EFL VSL	2,000,000	42	
	PWD-PJM-00001_2408 Subsystem	ACD EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00002_2409 Subsystem	ACD EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00003_2410 Subsystem	ACD EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00004_2411 Subsystem	ACD EFL VSL PJM CTRL	57798	42	
	PWD-PJM-00005_2412 Subsystem	ACD EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00006_2301 Subsystem	ACD EFL VSL PJM CTRL	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	PWD-PJM-00007_2302 Subsystem	ACD EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00008_2303 Subsystem	ACD EFL VSL PJM CTRL	57,798	42	
	PWD-VSL-00015	ACID/ALKALINE EFFLUENT VESSEL	350,400		
	PWD-YV-0314	19M NaOH IN	333,333	24	
	PWD-YV-0321	PRCS CNDS IN	43,800	88 / PIH crane usage 40	
PWD-VSL-00015/16 PWD-VSL-00033/43/44	PWD-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES FOR PWD-VSL-00015/16/33/43/44	17,159	8	
PWD-VSL-00016	PWD-LT-0309	ACD/ALK EFL VSL	2,000,000	42	
	PWD-PJM-00011_2401 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00012_2402 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00013_2403 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00014_2404 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00015_2405 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00016_2406 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00017_2407 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	
	PWD-PJM-00018_2501 Subsystem	ACD/ALK EFL VSL PJM CTRL	57,798	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	PWD-VSL-00016	ACIDIC/ALKALINE EFFLUENT VESSEL	350,400		
	PWD-YV-0317	19 M NaOH IN	333,333	24	
PWD-VSL-00033	PWD-LT-0208/DT-0207	ULT OVFL VSL	28,855	42	
	PWD-LT-0210/DT-0209	ULT OVFL VSL	28,855	42	
	PWD-LT-0213/PWD-DT-0212 Assembly		7143	42	
	PWD-DT-0212/PWD-LT-0213 Assembly	ULT OVFL VSL	28,855	42	
	PWD-PJM-00031_2101 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
	PWD-PJM-00032_2102 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
	PWD-PJM-00033_2103 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
	PWD-PJM-00034_2104 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
	PWD-PJM-00035_2105 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
	PWD-PJM-00036_2106 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
	PWD-PJM-00037_2107 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
	PWD-PJM-00038_2108 Subsystem	ULT OVFL VSL PJM CTRL	53,534	42	
PWD-VSL-00033/43/44	PWD-PPJ-PNL	PROGRAMMABLE PROTECTION (PPJ) I/O MODULES FOR PWD-VSL-00033/43/44	2,027,064	8	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
PWD-VSL-00043	PWD-DT-0214/PWD-LT-0215 Assembly	HLW EFL XFR VSL	28,855	42	
	PWD-LT-0239/DT-0238	LEVEL TRANSMITTER - BUBBLER	28,855	42	
	PWD-LT-0241/DT-0240	LEVEL TRANSMITTER - BUBBLER	28,855	42	
	PWD-PJM-00041_2001 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-PJM-00042_2002 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-PJM-00043_2003 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-PJM-00044_2004 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-PJM-00045_2005 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-PJM-00046_2006 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-PJM-00047_2007 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-PJM-00048_2008 Subsystem	HLW EFL XFR VSL PJM CTRL	53,534	42	
	PWD-VSL-00043	HLW EFFLUENT TRANSFER VESSEL	350,400		
PWD-VSL-00044	PWD-LT-0202/PWD-DT-0203 Assembly	PLNT WSH VSL	28,855	42	
	PWD-DT-0203/PWD-LT-0202 Assembly	PLNT WSH VSL	28,855	42	
	PWD-LT-0235/DT-0234	LEVEL TRANSMITTER - BUBBLER	28,855	42	
	PWD-LT-0237/DT-0236	LEVEL TRANSMITTER - BUBBLER	28,855	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	PWD-PJM-00021_1801 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-PJM-00022_1802 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-PJM-00023_1803 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-PJM-00024_1804 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-PJM-00025_1805 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-PJM-00026_1806 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-PJM-00027_1807 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-PJM-00028_1808 Subsystem	PLNT WSH VSL PJM CTRL	53,534	42	
	PWD-VSL-00044	PLANT WASH VESSEL	350,400		
	PWD-YV-0224	19 M NaOH IN	333,333	24	
	PWD-YV-0231	PLT WASH FR LAW-RLD-VSL-00003	43,800	88 / PIH crane usage 40	
	PWD-YV-0232	PLT WASH FR LAW-RLD-VSL-00003	43,800	88 / PIH crane usage 40	
	PWD-YV-3503	HPS TO PWD-VSL-00044 EJCTR	333,333	36	
PWD-VSL-00045	PWD-LT-4104	C2 AREAS FLR DRNS VSL	2,000,000	42	
	PWD-PMP-00023-A	TRANSFER PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	PWD-PMP-00023-B	TRANSFER PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	PWD-RE-4115	C2 AREAS FLR DRNS VSL	200,000	42	
PWD-VSL-00046	PWD-LT-4304	C3 AREAS FLR DRNS VSL	2,000,000	42	
	PWD-PMP-00024-A	TRANSFER PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	PWD-PMP-00024-B	TRANSFER PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
UFP-VSL-00002A	PWD-YV-1305	ACTUATED ON/OFF VALVE FF	333,333	36	
UFP-VSL-00002B	PWD-YV-1301	ACTUATED ON/OFF VALVE FF	333,333	36	
UFP-VSL-00062A	PWD-YV-1201	ACTUATED ON/OFF VALVE FF	333,333	36	
UFP-VSL-00062B	PWD-YV-1202	ACTUATED ON/OFF VALVE FF	333,333	36	
UFP-VSL-00062C	PWD-YV-1203	ACTUATED ON/OFF VALVE FF	333,333	36	

2.10 System PIH: PIH Crane

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
PIH-CRN-00004	PIH-CRN-00004	INCELL BRIDGE CRANE	730	24 / 204 every fourth failure	MTTR in the WTP OR Model uses a Triangle distribution (most likely value +/- 15 %)

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	PIH-CRN-00004 MAINT	CRANE INSPECTIONS			Daily inspections every 11.5 hours for 0.5 hours, every month for 11 hours and every quarter for 15 hours. The number of inspections per year (720) is equivalent to 502 hours.
	PIH-CRN-00004 Wrench	INCELL BRIDGE CRANE IMPACT WRENCHES @ 0", 7", 12", 24" EXTENSIONS	4380	12	
	PIH-MANIP-00005	POWER MANIPULATOR TELESCOPIC MAST	21,900	120	Deactivated in OR model (MTBF=10,000,000)
	PIH-RCVY-00004	REEL ASSEMBLY UNIT INCELL BRIDGE CRANE CABLE REELING SYSTEM	87,600	720	
PIH-DOOR-00004	PIH-Door-00004 Gear Box	SHIELDED ACCESS DOOR HOT CELL CRANE (VERTICAL)	43,800	60	
	PIH-Door-00004 Motor		87,600	12	

2.11 System CRP: Cesium Resin Addition Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CRP-VSL-00001	CRP-AGT-00001	CS RESIN ADDITION VESSEL AGITATOR (5 HP)	43,800	12	
	CRP-SCN-00002	CS RESIN ADDITION FOREIGN MATERIAL SCREEN	43,800	240	
	CRP-YC-0104	RESIN ADD VSL NAOH IN	333,333	24	

2.12 System PJV: Pulse Jet Ventilation

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hrs)	MTTR/MTTM (hrs)	Comments
PJV-DMST-00002A	PJV-LT-1011	PJV DMSTR A	2,000,000	42	
	PJV-PT-1003	EXH GASES FROM RFD/PJM	50,000	42	
PJV-DMST-00002B	PJV-LT-1017	PJV DMSTR B	2,000,000	42	
	PJV-PDT-1018	PJV DMSTR	50,000	42	
PJV-DMST-00002C	PJV-LT-1023	PJV DMSTR C	2,000,000	42	
	PJV-PDT-1012	PJV DMSTR	50,000	42	
	PJV-PDT-1024	PJV DMSTR	50,000	42	
PJV-FAN-00001-A	PJV-PDT-1302	PJV EXH FAN	50,000	42	
PJV-FAN-00001-B	PJV-PDT-1307	PJV EXH FAN	50,000	42	
PJV-FAN-00001-C	PJV-PDT-1312	PJV EXH FAN	50,000	42	
PJV-HEPA-00001-A	PJV-FE-1703	PRMRY EXH HEPA FLTR	66,667	42	
	PJV-PDT-1104	PJV PRI HEPA FLTR	50,000	42	
PJV-HEPA-00001-B	PJV-FE-1704	PRMRY EXH HEPA FLTR	66,667	42	
PJV-HEPA-00001-C	PJV-FE-1705	PRMRY EXH HEPA FLTR	66,667	42	
PJV-HEPA-00001-D	PJV-FE-1801	PRMRY EXH HEPA FLTR	66,667	42	
PJV-HEPA-00001-E	PJV-FE-1804	PRMRY EXH HEPA FLTR	66,667	42	
PJV-HEPA-00001-F	PJV-FE-1802	PRMRY EXH HEPA FLTR	66,667	42	
PJV-HEPA-00001-G	PJV-FE-1803	PRMRY EXH HEPA FLTR	66,667	42	
PJV-HEPA-00002-A	PJV-FE-1124	PJV SEC HEPA FLTR	66,667	42	
	PJV-PDT-1118	PJV SEC HEPA FLTR	50,000	42	
PJV-HEPA-00002-B	PJV-FE-1125	PJV SEC HEPA FLTR	66,667	42	
PJV-HEPA-00002-C	PJV-FE-1126	PJV SEC HEPA FLTR	66,667	42	
PJV-HEPA-00002-D	PJV-FE-1127	PJV SEC HEPA FLTR	66,667	42	
PJV-HEPA-00002-E	PJV-FE-1128	PJV SEC HEPA FLTR	66,667	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hrs)	MTTR/MTTM (hrs)	Comments
PJV-HEPA-00002-F	PJV-FE-1129	PJV SEC HEPA FLTR	66,667	42	
PJV-VSL-00002	PJV-LT-1033	HEME DRN COLL VSL	2,000,000	42	

2.13 System RLD: Radioactive Liquid Waste Disposal

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
RLD-PMP-00014A/B	RLD-PT-1428	PRCS CNDS DISTR HDR	50,000	42	
RLD-TK-00006-A	RLD-LT-1110	PRCS CNDS	2,000,000	42	
	RLD-TK-00006-A	PROCESS CONDENSATE TANK	350,400		
RLD-TK-00006A/B	RLD-FT-1225	PRCS CNDS DELIVERY	66,667	42	
	RLD-PT-0001	PRESSURE TRANSMITTER	50,000	42	
	RLD-PT-0002	PRESSURE TRANSMITTER	50,000	42	
	RLD-RE-1224	LERF/ETF ACCEPTANCE	200,000	42	
RLD-TK-00006-B	RLD-LT-1124	PRCS CNDS	2,000,000	42	
	RLD-TK-00006-B	PROCESS CONDENSATE TANK	350,400		
RLD-VSL-00017-A	RLD-LT-1302	ALK EFL VSL	2,000,000	42	
	RLD-VSL-00017-A	ALKALINE EFFLUENT VESSEL	350,400		
RLD-VSL-00017-A/B	RLD-RE-1424	LERF/ETF ACCEPTANCE	200,000	42	
	RLD-PMP-00005-A	ALKALINE EFFLUENT PUMP - CENTRIFUGAL PUMP ASME B73.1 400 GPM	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	RLD-PMP-00005-B	ALKALINE EFFLUENT PUMP - CENTRIFUGAL PUMP ASME B73.1 400 GPM	43,800	84 / Parallel pump - Actual stop time is 72 hr	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
RLD-VSL-00017-B	RLD-LT-1306	ALK EFL VSL	2,000,000	42	
	RLD-VSL-00017-B	ALKALINE EFFLUENT VESSEL	350,400		
LAW Melter Feed Tank and LAW Melter (LMP2)	RLD-AGT-00001		87,600	84	
	RLD-AGT-00002		333,333	36	
LAW Melter Feed Tank and LAW Melter (LMP1)	RLD-AGT-00001		87,600	84	Duplicated tag name
	RLD-AGT-00002		333,333	36	Duplicated tag name
RLD-VSL-00007/8	RLD-PCJ-PNL		17,159	8	
RLD-VSL-00007	RLD-LT-3152		2,000,000	42	
	RLD-PJM-00005	VSL PJM CTRL	57,798	42	
	RLD-PJM-00006	VSL PJM CTRL	57,798	42	
	RLD-PJM-00007	VSL PJM CTRL	57,798	42	
	RLD-PJM-00008	VSL PJM CTRL	57,798	42	
RLD-VSL-00008	RLD-LT-3153		2,000,000	42	
	RLD-PJM-00001	VSL PJM CTRL	57,798	42	
	RLD-PJM-00002	VSL PJM CTRL	57,798	42	
	RLD-PJM-00003	VSL PJM CTRL	57,798	42	
	RLD-PJM-00004	VSL PJM CTRL	57,798	42	

2.14 System TCP: Treated LAW Concentrate Storage Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
TCP-PMP-00001-A	TCP-RE-0035 Surveillance	TRTD LAW CONC XFR HDR	720	6	
	TCP-RE-0035	TRTD LAW CONC XFR HDR	200,000	42	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
TCP-VSL-00001	TCP-DT-0004/TCP-LT-0001 Assembly	TRTD LAW CONC STOR VSL	28,855	42	
	TCP-PCJ-PNL	PROCESS CONTROL (PCJ) I/O MODULES TCP-VSL-00001	17,159	8	
	TCP-PJM-00001_0201 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PJM-00002_0202 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PJM-00003_0203 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PJM-00004_0204 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PJM-00004_0205 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PJM-00006_0206 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PJM-00007_0207 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PJM-00008_0208 Subsystem	TRTD LAW CONC STOR PJM	57,798	42	
	TCP-PMP-00001-A	TREATED LAW CONCENTRATE TRANSFER PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TCP-PMP-00001-B	TREATED LAW CONCENTRATE TRANSFER PUMP	43,800	84 / Parallel pump - Actual stop time is 72 hr	
	TCP-VSL-00001	TREATED LAW CONCENTRATE STORAGE VESSEL	350,400		

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	TCP-YV-0036 - Critical Valve	TRTD LAW CONC XFR HDR	43,800	12	
	TCP-YV-0037 - Critical Valve	TRTD CONC LAW XFR HDR	43,800	12	

2.15 System RWH: Radioactive Solid Waste Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hrs)	MTTR/MTTM (hrs)	Comments
RWH-CRN-00012	RWH-CRN-00012	RWH SPENT FILTER DRUM HANDLING CRANE	87,600	80	Disabled in WTP OR Model.
	RWH-CRN-00012 MAINT	CRANE INSPECTIONS			Disabled in WTP OR Model. Daily inspections for 0.5 hours, every quarter for 24 hours and every year for 96 hours. The number of inspections per year (361) is equivalent to 346.5 hours.

2.16 System AFR: Anti-Foam Reagent

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
AFR-TK-00001	AFR-AGT-00001	ANTI-FOAM REAGENT MECHANICAL AGITATOR	200,000	24	
	AFR-FISL-0007	LOW FLOW SWITCH	238,095	24	
	AFR-FISL-0009	LOW FLOW SWITCH	238,095	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	AFR-FISL-0016	LOW FLOW SWITCH	238,095	24	
	AFR-FT-0021	HLP/UFP ANFM ADD HDR	333,333	24	
	AFR-LT-0002	ANFM REAGT VSL	40,000	24	
	AFR-PMP-00006	ANTI-FOAM REAGENT ELECTRIC METERING PUMP	33,333	24	
	AFR-PMP-00007	ANTI-FOAM REAGENT ELECTRIC METERING PUMP	33,333	24	
	AFR-PMP-00008	ANTI-FOAM REAGENT ELECTRIC METERING PUMP	33,333	24	
	AFR-PMP-00011	ANTI-FOAM REAGENT GEAR PUMP	33,333	24	
	AFR-YV-0001	ANFM REAGT VSL DMW MKUP	333,333	24	
	AFR-YV-0022	HLW LAG STOR VSL ANFM ADD	333,333	24	
	AFR-YV-0023	HLW FD BLND VSL ANFM ADD	333,333	24	
	AFR-YV-0024	UFD FD VSL ANFM ADD	333,333	24	
	AFR-YV-0025	UFP FD PREP VSL ANFM ADD	333,333	24	
	AFR-YV-0026	UFP FD PREP VSL B ANFM ADD	333,333	24	

2.17 System HPS: High Pressure Steam

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HPS-RK-00002	HPS-V-09760	CHECK VALVE	333,333	36	
	HPS-YV-1056	UFP UTIL SRVC RK 2 HPS	333,333	36	
HPS-RK-00003	HPS-V-09722	CHECK VALVE	333,333	36	
	HPS-YV-1060	PWD UTIL SRVC RK 3 HPS	333,333	36	
HPS-YV-1107	HPS-YV-1107	HPS DISTR IN HDR	333,333	36	

2.18 System NAR: Nitric Acid Reagent

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
NAR-PMP-0017A/B	NAR-FT-1008	UFP VSL 2M HNO3 ADD	333,333	24	
	NAR-FT-1013	FLOW TOTALIZER / INDICATOR/TRANSMITTER / POWER SUPPLY	333,333	24	
	NAR-YV-1023	2M HNO3 IN HDR	333,333	24	
	NAR-YV-1025	PNEUMATIC FLOW CONTROL VALVE	333,333	24	
NAR-VSL-00007	NAR-FT-1011	CNP 2M HNO3 ADD	333,333	24	

2.19 System PSW: Process Service Water

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
PSW-PMP-00004A/B	PSW-FS-1661	CS EVAP RECRC PMP SL H2O	238,095	36	
	PSW-FS-1836	LAW EVAP RECRC PMP SL H2O	238,095	36	
	PSW-FS-1933	WST FD XFR PMP SL H2O	238,095	36	
	PSW-V-02476	CHECK VALVE SPRING LOADED	333,333	36	
	PSW-V-11946	CHECK VALVE SPRING LOADED	333,333	36	
	PSW-V-11998	CHECK VALVE SPRING LOADED	333,333	36	
	PSW-YV-1658	CS EVAP RECRC PMP SL H2O	333,333	36	
	PSW-YV-1816	LAW EVAP RECRC PMP SL H2O	333,333	36	
	PSW-YV-1909	WST FD XFR PMP SL H2O	333,333	36	
PSW-TK-00002 (BOF)	PSW-PMP-00004-A	SEAL WATER BOOSTER PUMP	43,800	36	Pump is redundant; therefore, this event was not included in the model.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	PSW-PMP-00004-B	SEAL WATER BOOSTER PUMP	43,800	36	Pump is redundant; therefore, this event was not included in the model.

2.20 System PVP: Pretreatment Vessel Vent Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
PVP-CLR-00001	PVP-TE-0602	PVP VOC OXID UNIT	333,333	42	Disabled in WTP OR Model.
PVP-HEME-00001A	PVP-LT-0418	VSL VENT HEME	2,000,000	42	
PVP-HEME-00001A/B/C	PVP-HEME-00001-A	VESSEL VENT HEME	43,800	168	
	PVP-HEME-00001-B	VESSEL VENT HEME	43,800	168	
	PVP-HEME-00001-C	VESSEL VENT HEME	43,800	168	
PVP-HEME-00001B	PVP-LT-0425	VSL VENT HEME	2,000,000	42	
PVP-HEME-00001C	PVP-LT-0432	VSL VENT HEME	2,000,000	42	
PVP-OXID-00001	PVP-TE-0625	PVP VOC OXID UNIT	333,333	42	Disabled in WTP OR Model.
PVP-SCB-00002	PVP-LV-0409/PVP-DT-1704	CSTS SCRBR	7143	42	
	PVP-HX-00002	VESSEL VENT SCRUBBING LIQUID COOLER	131,400	106	Disabled in WTP OR Model.
	PVP-PMP-00001-A	VESSEL VENT SCRUBBER RECIRCULATION PUMP - VERTICAL SEALLESS CENTRIFUGAL PUMP API 685 150 GPM	33,288	74 / Parallel pump - Actual stop time is 38 hr	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	PVP-PMP-00001-B	VESSEL VENT SCRUBBER RECIRCULATION PUMP - VERTICAL SEALLESS CENTRIFUGAL PUMP API 685 150 GPM	33,288	74 / Parallel pump - Actual stop time is 38 hr	
	PVP-PMP-00002-A	VESSEL VENT SCRUBBER RECIRCULATION PUMP - VERTICAL SEALLESS CENTRIFUGAL PUMP API 685 150 GPM	33,288	74 / Parallel pump - Actual stop time is 38 hr	
	PVP-PMP-00002-B	VESSEL VENT SCRUBBER RECIRCULATION PUMP - VERTICAL SEALLESS CENTRIFUGAL PUMP API 685 150 GPM	33,333	74 / Parallel pump - Actual stop time is 38 hr	
	PVP-PT-0404	VSL VENT TO SCRBR	50,000	42	
	PVP-SCB-00002	VESSEL VENT CAUSTIC SCRUBBER - 260 GPM	350,400		
	PVP-SCB-00002 HC Actuator		43,800	72	
	PVP-TE-0405	CSTC SCRBR	333,333	42	Disabled in WTP OR Model.
	PVP-YC-1705		14,535	24	
	PVP-PSL-00001		350,400		
	PVP-PT-1706		50,000	42	
	PVP-PT-1707		50,000	42	

2.21 Special Equipment Option RAM Values

The following RAM data is used in the WTP OR Model as a result of the implementation of the Equipment Option for CXP Solids Control. Since the design for this CXP Solids Control option was in-progress at the time the WTP OR Model was built, the number and type of valves, pumps, flow meters, and RAM data were based on pre-design speculation. In addition, the following RAM data will only apply to the UFP back-end leaching option.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CXP-VSL-00001	MCR15-HX-1511	Heat Exchanger at the recirculation loop to enhance solubility. If HX-1511 fails, UFP-VSL-000062A/B/C have steam ejector capability to fulfill the heating function. Bypass line available so repairing or replacing HX-1511 will not impact the process.	43,800	120	Disabled in WTP OR Model.
CXP-VSL-00004N	MCR15-CXP-RE-0282	CXP-RE-0282 is a gamma detection instrument with surveillance function, and must be operational at all times.	720	6	If CXP-RE-0282 fails, stop feeding ion exchange columns, i.e., stop flowing out of CXP-VSL-00004N, which also means stop the recirculation loop.
	MCR15-DT-1525/MCR15-LT-1526	PJM controls	28,855	42	If failed, stop flow into and out of CXP-VSL-00004N. RAM data follows those used for CNP-VSL-00004, CXP-VSL-00004, and UFP-VSL-00062A/B/C.
	MCR15-FE-1508	Measure flow of the ion exchange columns. Assume a magnetic flow meter for RAM data.	61,320	24	Flow meter failure will stop the feed forward to ion exchange columns.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	MCR15-FILT-1509 MAINT	Guard Filter. Assumption - filter replacement unlikely with regular maintenance.	18	0.25	The maintenance activity consists of periodically flush the guard filter. Cannot transfer forward to the ion exchange columns during this maintenance activity.
	MCR15-PJM-1527	PJM controls to CXP-VSL-00004N.	57,798	42	For the MCR15-PJMs collectively, if X = 1, no action. If X > 1, fail CXP-VSL-00004N. Group logic is hard coded into the WTP OR Model.
	MCR15-PJM-1528	PJM controls to CXP-VSL-00004N.	57,798	42	
	MCR15-PJM-1529	PJM controls to CXP-VSL-00004N.	57,798	42	
	MCR15-PJM-1530	PJM controls to CXP-VSL-00004N.	57,798	42	
	MCR15-YV-1510	Down stream of the guard filter, and upstream of the ion exchange columns.	43,800	88 / PIH crane usage 40	Cannot feed forward to ion exchange columns if the valve fails.
CXP-VSL-00005	MCR15-FE-1522	This flow meter is used to support the ion exchange resin regeneration.	61,320	24	Associate failure with CXP-VSL-00005.
	MCR15-HX-1523	This element is for heating for the first resin regeneration step - fluid displacement (NaOH) - to prevent precipitation.	43,800	120	Stop flow into and out of CXP-VSL-00005. RAM data is assumed to be similar to the current CXP-HX-00001A/B.
	MCR15-HX-1524	This element is for cooling the HNO3, which is used for resin regeneration	43,800	120	Stop flow into and out of CXP-VSL-00005. RAM data is assumed to be similar to the current CXP-HX-00001A/B.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-VSL-00002-A	MCR15-YV-1512	For UFP Train A - transfer wash water to PWD-VSL-00016 during second and third washes.	43,800	88 / PIH crane usage 40	Need YV-1512 or YV-1513 to transfer permeate/wash water to PWD-VSL-00015 or 16, for UFP Train A operation. Since there is no isolation valve between YV-1512 and YV-1513, failure of either YV-1512 and YV-1513 will stop transfer wash water to both PWD-VSL-00015 and PWD-VSL-00016.
	MCR15-YV-1513	For UFP Train A - transfer wash water to PWD-VSL-00015 during second and third washes.	43,800	88 / PIH crane usage 40	
UFP-VSL-00002-B	MCR15-YV-1514	For UFP Train B - transfer wash water to PWD-VSL-00016 during second and third washes.	43,800	88 / PIH crane usage 40	Need YV-1514 or YV-1515 to transfer permeate/wash water to PWD-VSL-00015 or 16, for UFP Train B operation. Since there is no isolation valve between YV-1514 and YV-1515, failure of either YV-1514 and YV-1515 will stop transfer wash water to both PWD-VSL-00015 and PWD-VSL-00016.
	MCR15-YV-1515	For UFP Train B - transfer wash water to PWD-VSL-00016 during second and third washes.	43,800	88 / PIH crane usage 40	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
UFP-VSL-00062-A	MCR15-RFD-1519	RFD for UFP-62A. Assume the fluidic controller subsystem failure is the similar to that of an PJM.	57,798	42	Stop flow into and out of UFP 62A. Use RAM data of the single train non-ITS fluidic controller.
UFP-VSL-00062-A UFP-VSL-00062-B UFP-VSL-00062-C CXP-VSL-00004N	MCR15-FE-1504	Measure flow to UFP-62A. Assume a magnetic flow meter for RAM data.	61,320	24	Flow meter failure will stop the recirculation loop and stop feed forward to ion exchange columns.
	MCR15-FE-1505	Measure flow to UFP-62B. Assume a magnetic flow meter for RAM data.	61,320	24	Flow meter failure will stop the recirculation loop and stop feed forward to ion exchange columns.
	MCR15-FE-1506	Measure flow to UFP-62C. Assume a magnetic flow meter for RAM data.	61,320	24	Flow meter failure will stop the recirculation loop and stop feed forward to ion exchange columns.
	MCR15-FE-1507	Stop recycling back to UFP 62A/B/C. Assume a magnetic flow meter for RAM data	61,320	24	Flow meter failure will stop the recirculation loop and stop feed forward to ion exchange columns.
	MCR15-PMP-1517A	Pump to remove permeate out of CXP-VSL-00004N.	33,288	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	Require (YV-1516A, PMP-1517A, and YV-1518A), or (YV-1516B, PMP-1517B, and YV-1518B) to be

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	MCR15-PMP-1517B	Pump to remove permeate out of CXP-VSL-00004N.	33,288	63 / 69 every third failure / PIH crane usage 36 / 48 every third failure	operational. Otherwise cannot recycle to Supertank and cannot feed forward to the ion exchange columns.
	MCR15-YV-1501	Valve at the recirculation loop for flowing to UFP 62A.	43,800	88 / PIH crane usage 40	The failure of this valve requires the entire recirculation loop to stop; therefore, no feed forward to the ion exchange columns is possible. The repair needs to be completed in isolation since it is located at the common header.
	MCR15-YV-1502	Valve at the recirculation loop for flowing to UFP 62B.	43,800	88 / PIH crane usage 40	The failure of this valve requires the entire recirculation loop to stop; therefore, no feed forward to the ion exchange columns is possible. The repair needs to be completed in isolation since it is located at the common header.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	MCR15-YV-1503	Valve at the recirculation loop for flowing to UFP 62C.	61,320	24	The failure of this valve requires the entire recirculation loop to stop; therefore, no feed forward to the ion exchange columns is possible. The repair needs to be completed in isolation since it is located at the common header.
	MCR15-YV-1516A	Valve at suction side of PMP-1517A	43,800	88 / PIH crane usage 40	Require (YV-1516A, PMP-1517A, and YV-1518A), or (YV-1516B, PMP-1517B, and YV-1518B) to be operational. Otherwise cannot recycle to Supertank and cannot feed forward to the ion exchange columns.
	MCR15-YV-1516B	Valve at suction side of PMP-1517B	43,800	88 / PIH crane usage 40	
	MCR15-YV-1518A	Valve at discharge side of PMP-1517A	43,800	88 / PIH crane usage 40	
	MCR15-YV-1518B	Valve at discharge side of PMP-1517B	43,800	88 / PIH crane usage 40	
UFP-VSL-00062-B	MCR15-RFD-1520	RFD for UFP-62B. Assume the fluidic controller subsystem failure is the similar to that of an PJM. Use RAM data of the single train non-ITS fluidic controller.	57,798	42	Stop flow into and out of UFP-00062B.
UFP-VSL-00062-C	MCR15-RFD-1521	RFD for UFP-62C. Assume the fluidic controller subsystem failure is the similar to that of an PJM. Use RAM data of the single train non-ITS fluidic controller.	57,798	42	Stop flow into and out of UFP-00062C.

3 LAW RAM Data

3.1 System LCP: LAW Concentrate Receipt Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LCP-VSL-00001	LCP-AGT-00001	CONCENTRATE RECEIPT VESSEL 1 AGITATOR	43,800	288	
	LCP-FSH-0155	SEAL DMW TO LCP-PMP-000001A/000001B	87,600	12	
	LCP-IT-0134	CONC REC VSL AGTR 1	87,600	12	
	LCP-LS-0149	SEAL VENT LCP-PMP-00001A	87,600	24	
	LCP-LS-0151	SEAL VENT LCP-PMP-00001B	87,600	24	
	LCP-LT-0131	CONC REC VSL 1	87,600	24	
	LCP-LT-0139	CONC REC VSL 1	87,600	24	
	LCP-PT-0142	CONC REC VSL 1 HDR	87,600	24	
	LCP-PT-0154	PRESS COL EXP VSL 5 DMW IN	87,600	12	
	LCP-VSL-00001	CONCENTRATE RECEIPT VESSEL	350,400		
	LCP-VSL-00005	PUMP COLUMN EXPANSION VESSEL	87,600	24	
	LCP-VSL-00001 Autosampler	AUTOSAMPLER	43,800	288	
	LCP-VSL-00001 P Transfer	PNEUMATIC TRANSFER	43,800	24	
	LCP-VSL-00001 LT MAINT	LT MAINTENANCE	8760	12	
LCP-VSL-00002	LCP-AGT-00002	CONCENTRATE RECEIPT VESSEL 2 AGITATOR	43,800	288	
	LCP-FSH-0276	SEAL DMW TO LCP-PMP-000002A/000002B	87,600	12	
	LCP-IT-0234	CONC REC VSL 2 AGTR	87,600	12	
	LCP-LS-0270	SEAL VENT LCP-PMP-00002A	87,600	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LCP-LS-0272	SEAL VENT LCP-PMP-00002B	87,600	24	
	LCP-LT-0233	CONC REC VSL 2	87,600	24	
	LCP-LT-0252	CONC REC VSL 2	87,600	24	
	LCP-PT-0255	CONC REC VSL 3 HDR	87,600	24	
	LCP-PT-0275	PRESS COL EXP VSL 6 DMW IN	87,600	12	
	LCP-VSL-00002	CONCENTRATE RECEIPT VESSEL	350,400		
	LCP-VSL-00006	PUMP COLUMN EXPANSION VESSEL	87,600	24	
	LCP-VSL-00002 Autosampler	AUTOSAMPLER	43,800	288	
	LCP-VSL-00002 P Transfer	PNEUMATIC TRANSFER	43,800	24	
	LCP-VSL-00002 LT MAINT	LT MAINTENANCE	8760	12	

3.2 System LFP: LAW Melter Feed Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFP-VSL-00001	LFP-AGT-00001	MELTER 1 FEED PREPARATION VESSEL AGITATOR	43,800	288	
	LFP-IT-1126	MLTR 1 FD PREP VSL AGTR 1	87,600	12	
	LFP-LT-1124	MLTR 1 FD PREP VSL 1	87,600	24	
	LFP-LT-1140	MLTR 1 FD PREP VSL 1	87,600	24	
	LFP-VSL-00001 LT MAINT	LT MAINTENANCE	8760	12	
	LFP-VSL-00001	MELTER 1 FEED PREPARATION VESSEL	350,400		
LFP-VSL-00001/2	LFP-PT-1150	MLTR 1 FD VSL 1/2 PMP HDR	87,600	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFP-VSL-00002	LFP-AGT-00002	MELTER 1 FEED VESSEL AGITATOR	43,800	288	
	LFP-LT-1145	MLTR 1 FD VSL 2	87,600	12	
	LFP-LT-1146	MLTR 1 FD VSL 2	87,600	12	
	LFP-VSL-00002 LT MAINT	LT MAINTENANCE	8760	12	
	LFP-VSL-00002	MELTER 1 FEED VESSEL	350,400		
LFP-VSL-00003	LFP-AGT-00003	MELTER 2 FEED PREPARATION VESSEL AGITATOR	43,800	288	
	LFP-IT-2126	MLTR 2 FD PREP AGT 3	87,600	12	
	LFP-LT-2124	MLTR 2 FD PREP VSL 3	87,600	24	
	LFP-LT-2140	MLTR 2 FD VSL 3	87,600	24	
	LFP-VSL-00003 LT MAINT	LT MAINTENANCE	8760	12	
	LFP-VSL-00003	MELTER 2 FEED PREPARATION VESSEL	350,400		
LFP-VSL-00003/4	LFP-PT-2150	MLTR 2 FD PREP VSL 3/4 PMP HDR	87,600	24	
LFP-VSL-00004	LFP-AGT-00004	MELTER 2 FEED VESSEL AGITATOR	43,800	288	
	LFP-LT-2145	MLTR 2 FD VSL 4	87,600	12	
	LFP-LT-2146	MLTR 2 FD VSL 4	87,600	12	
	LFP-VSL-00004 LT MAINT	LT MAINTENANCE	8760	12	
	LFP-VSL-00004	MELTER 2 FEED VESSEL	350,400		

3.3 System LMP: LAW Melter Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LMP-ALFT-00001	LMP-FE-1046 / LMP-FT-1046	MLTR 1 EAST ALIFT INSTR AIR IN	66,667	48	Gas injection rate to the air lance is needed to control the glass flow rate. Failure results in idle 1/2 pour rate for Melter 1
	LMP-FV-1046	MLTR 1 EAST ALIFT INSTR AIR IN	333,333	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 1
	LMP-YV-1047	MLTR 1 EAST ALFT INSTR AIR IN	43,800	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 1
LMP-ALFT-00002	LMP-FE-1124 / LMP-FT-1124	MLTR 1 WEST ALIFT INSTR AIR IN	66,667	48	Gas injection rate to the air lance is needed to control the glass flow rate. Failure results in idle 1/2 pour rate for Melter 1

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-FV-1124	MLTR 1 WEST ALIFT INSTR AIR IN	333,333	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 1
	LMP-YV-1125	MLTR 1 WEST ALIFT INSTR AIR IN	43,800	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 1
LMP-ALFT-00003	LMP-FE-2046 / LMP-FT-2046	MLTR 2 EAST ALIFT INSTR AIR IN	66,667	48	Gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 2
	LMP-FV-2046	MLTR 2 EAST ALIFT INSTR AIR IN	333,333	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 2
	LMP-YV-2047	MLTR 2 EAST ALFT INSTR AIR IN	43,800	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 2

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LMP-ALFT-00004	LMP-FE-2124 / LMP-FT-2124	MLTR 2 WEST ALIFT INSTR AIR IN	66,667	48	Gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 2
	LMP-FV-2124	MLTR 2 WEST ALIFT INSTR AIR IN	333,333	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 2
	LMP-YV-2125	MLTR 2 WEST ALIFT INSTR AIR IN	43,800	48	Control of the gas injection rate to the air lance is needed to control the glass flow rate. Failure results in 1/2 pour rate for Melter 2
LMP-BBLR-00055	LMP-DT-1404	MLTR 1 ARGON LDET BBLR	333,333	48	Melter glass level. Idle Melter 1
	LMP-LT-1403	MLTR 1 LVL BBLR	40,000	48	Melter glass level. Idle Melter 1
	LMP-LT-1405	MLTR 1 LVL BBLR	40,000	48	Visual confirmation of the melter glass level. DWP item. Idle Melter 1
LMP-BBLR-00056	LMP-DT-2404	MLTR 2 ARGON LDET BBLR	333,333	48	Melter glass level. Idle Melter 2
	LMP-LT-2403	MLTR 2 LVL BBLR	40,000	48	Melter glass level. Idle Melter 2

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-LT-2405	MLTR 2 LVL BBLR	40,000	48	Visual confirmation of the melter glass level. DWP item. Idle Melter 2
LMP-MLTR-00001	LMP-BBLR-00001 to 18 MAINT	MELTER 1 BUBBLER # 1 to 18 - Maintenance	2,184	75	The replacement of bubblers 1 to 18 have been combined into one breakdown event. Nine bubblers will be replaced every 13 weeks.
	LMP-LE-1466 / LMP-LT-1466	MLTR 1 WEST SL HD CMR PRG	17,520	60	Failure resulted in 1/2 Melter 1 pouring capacity.
	LMP-LE-1511 / LMP-LT-1511	MLTR 1 EAST SL HD CMR PRG	17,520	60	Failure resulted in 1/2 Melter 1 pouring capacity.
	LMP-LE-1632	MLTR 1 Monitor Slurry Feed	40,000	96	Idle Melter 1
	LMP-MLTR-00001 MAINT	LAW MELTER 1 - Maintenance	43,800	4380	Idle Melter 1
	LMP-PCV-1282	MLTR 1 ELCTD CLG	769,231	48	Potentially lose cooling. Idle Melter 1
	LMP-PCV-1521	MLTR 1 IA SPLY	769,231	48	The Pressure Differential Indicator probe (WS1-A) could become blocked. Plenum calibration transmitted online (ITS) therefore must operate for production. Idle Melter 1

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-PDT-1410	MLTR 1 PLENUM/SHIELD ANNULUS	333,333	48	Melter 1 plenum pressure control point for offgas. DWP. Need one of two PDT-1410 and PDT-1411
	LMP-PDT-1411	MLTR 1 SCND SHLD/PLNM	333,333	48	Melter 1 plenum pressure control point for offgas. DWP. Need one of two PDT-1410 and PDT-1411
	LMP-PDT-1528	Pressure Differential Transmitter (ITS)	8760	14	For LMP-PDT-1528 and PDT-1529, require 1 of 2. If both PDT-1528 and PDT-1529 fail, idle Melter 1
	LMP-PDT-1529	Pressure Differential Transmitter (ITS)	8760	14	For LMP-PDT-1528 and PDT-1529, require 1 of 2. If both PDT-1528 and PDT-1529 fail, idle Melter 1
	LMP-TE-1074 / LMP-TT-1074	MLTR 1 EAST DISCH CHAMB	8760	7	There are 4 thermocouples per side (east/west) for a total of 8. If 3 fail on either side, stop melter production until replaced. All thermocouples are replaced at the same time.
	LMP-TE-1075 / LMP-TT-1075	MLTR 1 EAST DISCH CHAMB	8760	7	
	LMP-TE-1076 / LMP-TT-1076	MLTR 1 EAST DISCH CHAMB	8760	7	
	LMP-TE-1077 / LMP-TT-1077	MLTR 1 EAST DISCH CHAMB	8760	7	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-TE-1152	MLTR 1 WEST DISCH CHAMB	8760	7	There are 4 thermocouples per side (east/west) for a total of 8. If 3 fail on either side, stop melter 1 production until replaced. All thermocouples are replaced at the same time.
	LMP-TE-1153	MLTR 1 WEST DISCH CHAMB	8760	7	
	LMP-TE-1154	MLTR 1 WEST DISCH CHAMB	8760	7	
	LMP-TE-1155	MLTR 1 WEST DISCH CHAMB	8760	7	
	LMP-TE-1200	Refractory Thermocouples	8760	48 (but use Melter Life)	The thermocouples are only used during melter startup. One-year life is plenty and failure of the TE after the melter started would have no impact to production. Item is not included in WTP OR Model.
	LMP-TE-1201	Refractory Thermocouples	8760	48 (but use Melter Life)	
	LMP-TE-1202	Refractory Thermocouples	8760	48 (but use Melter Life)	
	LMP-TE-1203	Refractory Thermocouples	8760	48 (but use Melter Life)	
	LMP-TE-1263 A/B/C through LMP-TE-1280 A/B/C	Melter 1 glass/plenum thermal couples. Change out with bubblers. There are 18 TC assemblies per melter.	Life of the Bubbler	Life of the Bubbler	LMP-TE-1267 C, LMP-TE-1272 C and LMP-TE-1280 C are considered DWP items. Items are not included in WTP OR Model.
	LMP-TE-1286/1287	Melter 1 Electrode Extension Thermalcouples	8760	Melter Life	The electrode extensions (TE) are just for indication and loss of measurements.
	LMP-TE-1293/1294	Melter 1 Electrode Extension Thermalcouples	8760	Melter Life	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-TE-1300/1301	Melter 1 Electrode Extension Thermalcouples	8760	Melter Life	They do not have any effect on melter operation. Items are not included in WTP OR Model.
	LMP-TE-1307/1308	Melter 1 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-1314/1315	Melter 1 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-1321/1322	Melter 1 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-1288	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	The life for these thermocouples is five years. They will be replaced during melter change-out. Items are not included in WTP OR Model.
	LMP-TE-1295	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
	LMP-TE-1302	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
	LMP-TE-1309	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
	LMP-TE-1316	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
	LMP-TE-1323	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
LMP-MLTR-00002	LMP-BBLR-00019 to 36 MAINT	MELTER 2 BUBBLER # 1 to 18 - Maintenance	2184	75	The replacement of bubblers 1 to 18 have been combined into one breakdown event. Nine bubblers will be replaced every 13 weeks.
	LMP-LE-2466 / LMP-LT-2466	MLTR 2 WEST SL HD CMR PRG	17,520	60	Failure resulted in 1/2 Melter 2 pouring capacity.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-LE-2511 / LMP-LT-2511	MLTR 2 EAST SL HD CMR PRG	17,520	60	Failure resulted in 1/2 Melter 2 pouring capacity.
	LMP-LE-2632	MLTR 2 Monitor Slurry Feed	40,000	96	Idle Melter 2
	LMP-MLTR-00002 MAINT	LAW MELTER 2 - Maintenance	43,800	4380	Idle Melter 2
	LMP-PCV-2282	MLTR 2 ELCTD CLG	769,231	48	Potentially lose cooling. Idle Melter 2
	LMP-PCV-2521	MLTR 2 IA SPLY	769,231	48	The Pressure Differential Indicator probe (WS1-A) could become blocked. Plenum calibration transmitted online (ITS) therefore must operate for production. Idle Melter 2
	LMP-PDT-2410	MLTR 2 PLNM/SHLD ANNULUS	333,333	48	Melter 2 plenum pressure control point for offgas. DWP. Need one of two PDT-2410 and PDT-2411
	LMP-PDT-2411	MLTR 2 SCND SHLD/PLNM	333,333	48	Melter 2 plenum pressure control point for offgas. DWP. Need one of two PDT-2410 and PDT-2411

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-PDT-2528	MLTR 2 PLMN/ANNULUS	8760	14	For LMP-PDT-2528 and PDT-2529, require 1 of 2. If both PDT-2528 and PDT-2529 fail, idle Melter 2
	LMP-PDT-2529	MLTR 2 PLMN/ANNULUS	8760	14	For LMP-PDT-2528 and PDT-2529, require 1 of 2. If both PDT-2528 and PDT-2529 fail, idle Melter 2
	LMP-TE-2074 / LMP-TT-2074	MLTR 2 EAST DISCH CHAMB	8760	7	There are 4 thermocouples per side (east/west) for a total of 8. If 3 fail on either side, stop melter production until replaced.
	LMP-TE-2075 / LMP-TT-2075	MLTR 2 EAST DISCH CHAMB	8760	7	
	LMP-TE-2076 / LMP-TT-2076	MLTR 2 EAST DISCH CHAMB	8760	7	
	LMP-TE-2077 / LMP-TT-2077	MLTR 2 EAST DISCH CHAMB	8760	7	
	LMP-TE-2152	MLTR 2 WEST DISCH CHAMB	8760	7	There are 4 thermocouples per side (east/west) for a total of 8. If 3 fail on either side, stop melter production until replaced.
	LMP-TE-2153	MLTR 2 WEST DISCH CHAMB	8760	7	
	LMP-TE-2154	MLTR 2 WEST DISCH CHAMB	8760	7	
	LMP-TE-2155	MLTR 2 WEST DISCH CHAMB	8760	7	
	LMP-TE-2200	Refractory Thermocouples	8760	48 (use Melter Life)	The thermocouples are only used during melter startup. One-year life is plenty and failure of the TE after the melter startup
	LMP-TE-2201	Refractory Thermocouples	8760	48 (use Melter Life)	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-TE-2202	Refractory Thermocouples	8760	48 (use Melter Life)	would have no impact to production. Items are not included in WTP OR Model.
	LMP-TE-2203	Refractory Thermocouples	8760	48 (use Melter Life)	
	LMP-TE-2263 A/B/C through LMP-TE-2280 A/B/C	Melter 2 glass/plenum thermal couples. Change out with bubblers. There are 18 TC assemblies per melter.	Life of the Bubbler	Life of the Bubbler	LMP-TE-2267 C, LMP-TE-2272 C and LMP-TE-2280 C are considered DWP items. Items are not included in WTP OR Model.
	LMP-TE-2286/2287	Melter 2 Electrode Extension Thermalcouples	8760	Melter Life	The electrode extensions (TE) are just for indication and loss of measurements. They do not have any effect on melter operation. Items are not included in WTP OR Model.
	LMP-TE-2293/2294	Melter 2 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-2300/2301	Melter 2 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-2307/2308	Melter 2 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-2314/2315	Melter 2 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-2321/2322	Melter 2 Electrode Extension Thermalcouples	8760	Melter Life	
	LMP-TE-2288	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	The life for these thermocouples is five years. They will be replaced during melter change-out. Items are
	LMP-TE-2295	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
	LMP-TE-2302	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-TE-2309	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	not included in WTP OR Model.
	LMP-TE-2316	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
	LMP-TE-2323	Electrode Extension Cooling Air Exhaust Thermocouples	Life of the Melter	Melter Life	
LMP-TK-00001	LMP-TE-1637 / LMP-TT-1637	TEMPERATURE ELEMENT (DUAL RTD)	333,333	96	ITS items. All melter surfaces that could significantly heat the shielding annulus and the outer shielding are water-cooled to a specified temperature to minimize heat loading on the C5 ventilation system. If failed, idle Melter 1.
	LMP-TE-1638 / LMP-TT-1638	TEMPERATURE ELEMENT (DUAL RTD)	333,333	96	
	LMP-TE-1639	TEMPERATURE ELEMENT (DUAL RTD)	1,000,000	96	DWP items. All melter surfaces that could significantly heat the shielding annulus and outer shielding are water-cooled to a specified temperature to minimize heat loading on the C5 ventilation system. If failed, idle Melter 1.
	LMP-TE-1640	TEMPERATURE ELEMENT (DUAL RTD)	1,000,000	96	
LMP-TK-00002	LMP-TE-2637 / LMP-TT-2637	TEMPERATURE ELEMENT (DUAL RTD)	333,333	96	ITS items. All melter surfaces that could

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-TE-2638 / LMP-TT-2638	TEMPERATURE ELEMENT (DUAL RTD)	333,333	96	significantly heat the shielding annulus and the outer shielding are water-cooled to a specified temperature to minimize heat loading on the C5 ventilation system. If failed, idle Melter 2.
	LMP-TE-2639	TEMPERATURE TRANSMITTER- 8 PT VIRTUAL	1,000,000	96	DWP items. All melter surfaces that could significantly heat the shielding annulus and the outer shielding are water-cooled to a specified temperature to minimize heat loading on the C5 ventilation system. If failed, idle Melter 2.
	LMP-TE-2640	TEMPERATURE TRANSMITTER- 8 PT VIRTUAL	1,000,000	96	
MVE-PSUP-20001	LMP-ET-1055	MLTR 1 EAST DISCH HTR 1 PWR SPLY - GROUP A	333,333	48	Group A Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work.
	LMP-ET-1060	MLTR 1 EAST DISCH HTR 2 PWR SPLY - GROUP A	333,333	48	
	LMP-ET-1065	MLTR 1 EAST DISCH HTR 3 PWR SPLY - GROUP A	333,333	48	
	LMP-ET-1070	MLTR 1 EAST DISCH HTR 4 PWR SPLY - GROUP A	333,333	48	
	LMP-ET-1083	MLTR 1 EAST DISCH HTR 5 PWR SPLY - GROUP A	333,333	48	
	LMP-ET-1088	MLTR 1 EAST DISCH HTR 6 PWR SPLY - GROUP A	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-ET-1093	MLTR 1 EAST DISCH HTR 7 PWR SPLY - GROUP A	333,333	48	At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-ET-1098	MLTR 1 EAST DISCH HTR 8 PWR SPLY - GROUP A	333,333	48	
	LMP-ET-1103	MLTR 1 EAST DISCH HTR 9 PWR SPLY - GROUP A	333,333	48	
	LMP-ET-1108	MLTR 1 EAST DISCH HTR 10 DR - GROUP A	333,333	48	
	LMP-ET-1113	MLTR 1 EAST DISCH HTR 11 DR - GROUP A	333,333	48	
	LMP-ET-1118	MLTR 1 EAST DISCH HTR 12 DR - GROUP A	333,333	48	
	LMP-ET-1133	MLTR 1 WEST DISCH HTR 1 DR - GROUP B	333,333	48	Group B Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work.
	LMP-ET-1138	MLTR 1 WEST DISCH HTR 2 DR - GROUP B	333,333	48	
	LMP-ET-1143	MLTR 1 WEST DISCH HTR 3 DR - GROUP B	333,333	48	
	LMP-ET-1148	MLTR 1 WEST DISCH HTR 4 DR - GROUP B	333,333	48	
	LMP-ET-1161	MLTR 1 WEST DISCH HTR 5 DR - GROUP B	333,333	48	
	LMP-ET-1166	MLTR 1 WEST DISCH HTR 6 DR - GROUP B	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-ET-1171	MLTR 1 WEST DISCH HTR 7 PWR SPLY - GROUP B	333,333	48	At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-ET-1176	MLTR 1 WEST DISCH HTR 8 PWR SPLY - GROUP B	333,333	48	
	LMP-ET-1181	MLTR 1 WEST DISCH HTR 9 PWR SPLY - GROUP B	333,333	48	
	LMP-ET-1186	MLTR 1 WEST DISCH HTR 10 DR - GROUP B	333,333	48	
	LMP-ET-1191	MLTR 1 WEST DISCH HTR 11 DR - GROUP B	333,333	48	
	LMP-ET-1196	MLTR 1 WEST DISCH HTR 12 DR - GROUP B	333,333	48	
	LMP-IT-1056	MLTR 1 EAST DISCH HTR 1 PWR SPLY - GROUP A2	333,333	48	Group A2 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter
	LMP-IT-1061	MLTR 1 EAST DISCH HTR 2 PWR SPLY - GROUP A2	333,333	48	
	LMP-IT-1066	MLTR 1 EAST DISCH HTR 3 PWR SPLY - GROUP A2	333,333	48	
	LMP-IT-1071	MLTR 1 EAST DISCH HTR 4 PWR SPLY - GROUP A2	333,333	48	
	LMP-IT-1084	MLTR 1 EAST DISCH HTR 5 PWR SPLY - GROUP A2	333,333	48	
	LMP-IT-1089	MLTR 1 EAST DISCH HTR 6 PWR SPLY - GROUP A2	333,333	48	
	LMP-IT-1094	MLTR 1 EAST DISCH HTR 7 PWR SPLY - GROUP A2	333,333	48	
	LMP-IT-1099	MLTR 1 EAST DISCH HTR 8 PWR SPLY - GROUP A2	333,333	48	
	LMP-IT-1104	MLTR 1 EAST DISCH HTR 9 PWR SPLY - GROUP A2	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-IT-1109	MLTR 1 EAST DISCH HTR 10 DR - GROUP A2	333,333	48	controls half of the pour rate.
	LMP-IT-1114	MLTR 1 EAST DISCH HTR 11 DR - GROUP A2	333,333	48	
	LMP-IT-1119	MLTR 1 EAST DISCH HTR 12 DR - GROUP A2	333,333	48	
	LMP-IT-1134	MLTR 1 WEST DISCH HTR 1 DR - GROUP B2	333,333	48	Group B2 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-IT-1139	MLTR 1 WEST DISCH HTR 2 DR - GROUP B2	333,333	48	
	LMP-IT-1144	MLTR 1 WEST DISCH HTR 3 DR - GROUP B2	333,333	48	
	LMP-IT-1149	MLTR 1 WEST DISCH HTR 4 DR - GROUP B2	333,333	48	
	LMP-IT-1162	MLTR 1 WEST DISCH HTR 5 DR - GROUP B2	333,333	48	
	LMP-IT-1167	MLTR 1 WEST DISCH HTR 6 DR - GROUP B2	333,333	48	
	LMP-IT-1172	MLTR 1 WEST DISCH HTR 7 PWR SPLY - GROUP B2	333,333	48	
	LMP-IT-1177	MLTR 1 WEST DISCH HTR 8 PWR SPLY - GROUP B2	333,333	48	
	LMP-IT-1182	MLTR 1 WEST DISCH HTR 9 PWR SPLY - GROUP B2	333,333	48	
	LMP-IT-1187	MLTR 1 WEST DISCH HTR 10 DR - GROUP B2	333,333	48	
	LMP-IT-1192	MLTR 1 WEST DISCH HTR 11 DR - GROUP B2	333,333	48	
	LMP-IT-1197	MLTR 1 WEST DISCH HTR 12 DR - GROUP B2	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-US-1057	MLTR 1 EAST DISCH HTR 1 PWR SPLY - GROUP A3	333,333	48	Group A3 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-US-1062	MLTR 1 EAST DISCH HTR 2 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1067	MLTR 1 EAST DISCH HTR 3 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1072	MLTR 1 EAST DISCH HTR 4 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1085	MLTR 1 EAST DISCH HTR 5 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1090	MLTR 1 EAST DISCH HTR 6 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1095	MLTR 1 EAST DISCH HTR 7 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1100	MLTR 1 EAST DISCH HTR 8 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1105	MLTR 1 EAST DISCH HTR 9 PWR SPLY - GROUP A3	333,333	48	
	LMP-US-1110	MLTR 1 EAST DISCH HTR 10 DR - GROUP A3	333,333	48	
	LMP-US-1115	MLTR 1 EAST DISCH HTR 11 DR - GROUP A3	333,333	48	
	LMP-US-1120	MLTR 1 EAST DISCH HTR 12 DR - GROUP A3	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-US-1135	MLTR 1 WEST DISCH HTR 1 DR - GROUP B3	333,333	48	Group B3 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-US-1140	MLTR 1 WEST DISCH HTR 2 DR - GROUP B3	333,333	48	
	LMP-US-1145	MLTR 1 WEST DISCH HTR 3 DR - GROUP B3	333,333	48	
	LMP-US-1150	MLTR 1 WEST DISCH HTR 4 DR - GROUP B3	333,333	48	
	LMP-US-1163	MLTR 1 WEST DISCH HTR 5 DR - GROUP B3	333,333	48	
	LMP-US-1168	MLTR 1 WEST DISCH HTR 6 DR - GROUP B3	333,333	48	
	LMP-US-1173	MLTR 1 WEST DISCH HTR 7 PWR SPLY - GROUP B3	333,333	48	
	LMP-US-1178	MLTR 1 WEST DISCH HTR 8 PWR SPLY - GROUP B3	333,333	48	
	LMP-US-1183	MLTR 1 WEST DISCH HTR 9 PWR SPLY - GROUP B3	333,333	48	
	LMP-US-1188	MLTR 1 WEST DISCH HTR 10 DR - GROUP B3	333,333	48	
	LMP-US-1193	MLTR 1 WEST DISCH HTR 11 DR - GROUP B3	333,333	48	
	LMP-US-1198	MLTR 1 WEST DISCH HTR 12 DR - GROUP B3	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
MVE-PSUP-20002	LMP-ET-2055	MLTR 2 EAST DISCH HTR 1 DR - GROUP C	333,333	48	Group C Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-ET-2060	MLTR 2 EAST DISCH HTR 2 DR - GROUP C	333,333	48	
	LMP-ET-2065	MLTR 2 EAST DISCH HTR 3 DR - GROUP C	333,333	48	
	LMP-ET-2070	MLTR 2 EAST DISCH HTR 4 PWR SPLY - GROUP C	333,333	48	
	LMP-ET-2083	MLTR 2 EAST DISCH HTR 5 PWR SPLY - GROUP C	333,333	48	
	LMP-ET-2088	MLTR 2 EAST DISCH HTR 6 PWR SPLY - GROUP C	333,333	48	
	LMP-ET-2093	MLTR 2 EAST DISCH HTR 7 PWR SPLY - GROUP C	333,333	48	
	LMP-ET-2098	MLTR 2 EAST DISCH HTR 8 PWR SPLY - GROUP C	333,333	48	
	LMP-ET-2103	MLTR 2 EAST DISCH HTR 9 PWR SPLY - GROUP C	333,333	48	
	LMP-ET-2108	MLTR 2 EAST DISCH HTR 10 DR - GROUP C	333,333	48	
	LMP-ET-2113	MLTR 2 EAST DISCH HTR 11 DR - GROUP C	333,333	48	
	LMP-ET-2118	MLTR 2 EAST DISCH HTR 12 DR - GROUP C	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-ET-2133	MLTR 2 WEST DISCH HTR 1 PWR SPLY - GROUP D	333,333	48	Group D Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-ET-2138	MLTR 2 WEST DISCH HTR 2 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2143	MLTR 2 WEST DISCH HTR 3 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2148	MLTR 2 WEST DISCH HTR 4 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2161	MLTR 2 WEST DISCH HTR 5 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2166	MLTR 2 WEST DISCH HTR 6 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2171	MLTR 2 WEST DISCH HTR 7 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2176	MLTR 2 WEST DISCH HTR 8 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2181	MLTR 2 WEST DISCH HTR 9 PWR SPLY - GROUP D	333,333	48	
	LMP-ET-2186	MLTR 2 WEST DISCH HTR 10 DR - GROUP D	333,333	48	
	LMP-ET-2191	MLTR 2 WEST DISCH HTR 11 DR - GROUP D	333,333	48	
	LMP-ET-2196	MLTR 2 WEST DISCH HTR 12 DR - GROUP D	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-IT-2056	MLTR 2 EAST DISCH HTR 1 DR - GROUP C2	333,333	48	Group C2 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-IT-2061	MLTR 2 EAST DISCH HTR 2 DR - GROUP C2	333,333	48	
	LMP-IT-2066	MLTR 2 EAST DISCH HTR 3 PWR SPLY - GROUP C2	333,333	48	
	LMP-IT-2071	MLTR 2 EAST DISCH HTR 4 PWR SPLY - GROUP C2	333,333	48	
	LMP-IT-2084	MLTR 2 EAST DISCH HTR 5 PWR SPLY - GROUP C2	333,333	48	
	LMP-IT-2089	MLTR 2 EAST DISCH HTR 6 PWR SPLY - GROUP C2	333,333	48	
	LMP-IT-2094	MLTR 2 EAST DISCH HTR 7 PWR SPLY - GROUP C2	333,333	48	
	LMP-IT-2099	MLTR 2 EAST DISCH HTR 8 PWR SPLY - GROUP C2	333,333	48	
	LMP-IT-2104	MLTR 2 EAST DISCH HTR 9 PWR SPLY - GROUP C2	333,333	48	
	LMP-IT-2109	MLTR 2 EAST DISCH HTR 10 DR - GROUP C2	333,333	48	
	LMP-IT-2114	MLTR 2 EAST DISCH HTR 11 DR - GROUP C2	333,333	48	
	LMP-IT-2119	MLTR 2 EAST DISCH HTR 12 DR - GROUP C2	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-IT-2134	MLTR 2 WEST DISCH HTR 1 DR - GROUP D2	333,333	48	Group D2 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-IT-2139	MLTR 2 WEST DISCH HTR 2 DR - GROUP D2	333,333	48	
	LMP-IT-2144	MLTR 2 WEST DISCH HTR 3 PWR SPLY - GROUP D2	333,333	48	
	LMP-IT-2149	MLTR 2 WEST DISCH HTR 4 PWR SPLY - GROUP D2	333,333	48	
	LMP-IT-2162	MLTR 2 WEST DISCH HTR 5 PWR SPLY - GROUP D2	333,333	48	
	LMP-IT-2167	MLTR 2 WEST DISCH HTR 6 PWR SPLY - GROUP D2	333,333	48	
	LMP-IT-2172	MLTR 2 WEST DISCH HTR 7 PWR SPLY - GROUP D2	333,333	48	
	LMP-IT-2177	MLTR 2 WEST DISCH HTR 8 PWR SPLY - GROUP D2	333,333	48	
	LMP-IT-2182	MLTR 2 WEST DISCH HTR 9 PWR SPLY - GROUP D2	333,333	48	
	LMP-IT-2187	MLTR 2 WEST DISCH HTR 10 DR - GROUP D2	333,333	48	
	LMP-IT-2192	MLTR 2 WEST DISCH HTR 11 DR - GROUP D2	333,333	48	
	LMP-IT-2197	MLTR 2 WEST DISCH HTR 12 DR - GROUP D2	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-US-2057	MLTR 2 EAST DISCH HTR 1 DR - GROUP C3	333,333	48	Group C3 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-US-2062	MLTR 2 EAST DISCH HTR 2 DR - GROUP C3	333,333	48	
	LMP-US-2067	MLTR 2 EAST DISCH HTR 3 PWR SPLY - GROUP C3	333,333	48	
	LMP-US-2072	MLTR 2 EAST DISCH HTR 4 PWR SPLY - GROUP C3	333,333	48	
	LMP-US-2085	MLTR 2 EAST DISCH HTR 5 PWR SPLY - GROUP C3	333,333	48	
	LMP-US-2090	MLTR 2 EAST DISCH HTR 6 PWR SPLY - GROUP C3	333,333	48	
	LMP-US-2095	MLTR 2 EAST DISCH HTR 7 PWR SPLY - GROUP C3	333,333	48	
	LMP-US-2100	MLTR 2 EAST DISCH HTR 8 PWR SPLY - GROUP C3	333,333	48	
	LMP-US-2105	MLTR 2 EAST DISCH HTR 9 PWR SPLY - GROUP C3	333,333	48	
	LMP-US-2110	MLTR 2 EAST DISCH HTR 10 DR - GROUP C3	333,333	48	
	LMP-US-2115	MLTR 2 EAST DISCH HTR 11 DR - GROUP C3	333,333	48	
	LMP-US-2120	MLTR 2 EAST DISCH HTR 12 DR - GROUP C3	333,333	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LMP-US-2134	MLTR 2 WEST DISCH HTR 1 PWR SPLY - GROUP D3	333,333	48	Group D3 Two sections per melter: East and West. Each section has 12 heaters. Each heater includes 3 components: one LMP-ET, one LMP-IT and one LMP-US. All 3 components need to be working properly for the heater to work. At least 2 of the 12 heaters on a side of a melter need to work properly; otherwise, the pour rate of the melter is cut in half. Each side of a melter controls half of the pour rate.
	LMP-US-2139	MLTR 2 WEST DISCH HTR 2 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2144	MLTR 2 WEST DISCH HTR 3 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2149	MLTR 2 WEST DISCH HTR 4 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2163	MLTR 2 WEST DISCH HTR 5 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2168	MLTR 2 WEST DISCH HTR 6 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2173	MLTR 2 WEST DISCH HTR 7 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2178	MLTR 2 WEST DISCH HTR 8 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2183	MLTR 2 WEST DISCH HTR 9 PWR SPLY - GROUP D3	333,333	48	
	LMP-US-2188	MLTR 2 WEST DISCH HTR 10 DR - GROUP D3	333,333	48	
	LMP-US-2193	MLTR 2 WEST DISCH HTR 11 DR - GROUP D3	333,333	48	
	LMP-US-2198	MLTR 2 WEST DISCH HTR 12 DR - GROUP D3	333,333	48	

3.4 System LOP: LAW Primary Offgas Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LMP-MLTR-00001	LOP-FE-1113 / LOP-FT-1113	Measures film cooler air injection	66,667	12	
	LOP-FE-1140 / LOP-FT-1140	Measures film cooler air injection. Controls offgas flow from WESP	66,667	12	
	LOP-FE-1218 / LOP-FT-1218	Measures plant blowdown air flow to film cooer	66,667	12	
	LOP-FE-1220 / LOP-FT-1220	Measures wash water flow to film cooler	66,667	12	
	LOP-FI-1104	Monitor film cooler purge air	1,000,000	12	
	LOP-FI-1128	Monitor film cooler purge air	1,000,000	12	
	LOP-FV-1113	Valve controls film cooler injection air	333,333	12	
	LOP-FV-1140	ITS (Air Permit) valve controls offgas into LVP-HTR-1A/B	333,333	12	
	LOP-FY-1140B	ITS controls offgas to HTR-1A/B.	2,000,000	12	
	LOP-HTR-00001	Heat the air to the conductors clean and dry	130,378	48	
	LOP-LE-1018 / LOP-LT-1018	High-high interlock for LOP SCB 1	66,667	12	
	LOP-PV-1105	Valve controls air injection to film cooler	769,231	12	
	LOP-TE-1152 / LOP-TT-1152	Interlock with film cooler	66,667	12	
	LOP-TE-1153 / LOP-TT-1153	Interlock with film cooler	66,667	12	
	LOP-YV-1008	Valve has an air permit function ITS designation	43,800	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LOP-YV-1056	Valve controls non-ITS chilled water supply. If failed, process may continue for perhaps couple hours before idling the melter	43,800	24	
	LOP-YV-1061	ITS valve controls flush water supply to WESP	43,800	24	
	LOP-YV-1098	ITS valve controls film cooler purge air supply	43,800	24	
	LOP-YV-1109	ITS valve controls the supply of demin water to the film coolers	43,800	24	
	LOP-YV-1117	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-1122	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-1123	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-1127	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-1129	Valve controls the plant air supply to the film coolers	43,800	24	
	LOP-YV-1148	Valve controls flush water supply	43,800	24	
	LOP-YV-1219	Valve controls demin (flush) water supply	43,800	24	
	LOP-YV-1225	Valve controls plant service air to the film coolers	43,800	24	
	LVE-PSUP-20201	Performs air permit function. Can inspect the power supply during planned melter changeout	61,320	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LMP-MLTR-00002	LOP-FE-2113 / LOP-FT-2113	Measures film cooler air injection	66,667	12	
	LOP-FE-2140 / LOP-FT-2140	Measures film cooler air injection. Controls offgas flow from WESP	66,667	12	
	LOP-FE-2218 / LOP-FT-2218	Film cooler service air. Measure film cooler air flow	66,667	12	
	LOP-FE-2220 / LOP-FT-2220	Film cooler water wash. Measure film cooler water intake	66,667	12	
	LOP-FI-2104	Monitor film cooler purge air	1,000,000	12	
	LOP-FI-2128	Monitor film cooler purge air	1,000,000	12	
	LOP-FV-2113	Valve controls injection air flow to film cooler	333,333	12	
	LOP-FV-2140	ITS (Air Permit) valve controls offgas into LVP-HTR-1A/B	333,333	12	
	LOP-FY-2140B	ITS controls offgas to HTR-1A/B.	2,000,000	12	
	LOP-HTR-00002	Heat the air to the conductors clean and dry	130,378	48	
	LOP-LE-2018 / LOP-LT-2018	High-high interlock for LOP SCB 2	66,667	12	
	LOP-PV-2105	Valve controls air injection to film cooler	769,231	12	
	LOP-TE-2152 / LOP-TT-2152	Interlock with film cooler	66,667	12	
	LOP-TE-2153 / LOP-TT-2153	Interlock with film cooler	66,667	12	
	LOP-YV-2008	Valve has an air permit function ITS designation	43,800	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LOP-YV-2056	Valve controls non-ITS chilled water supply. If failed, process may continue for perhaps couple hours before idling the melter	43,800	24	
	LOP-YV-2061	ITS valve controls flush water supply to WESP	43,800	24	
	LOP-YV-2098	ITS valve controls film cooler purge air supply	43,800	24	
	LOP-YV-2109	ITS valve controls the supply of demin water to the film coolers.	43,800	24	
	LOP-YV-2117	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-2122	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-2123	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-2127	Valve controls the film cooler purge air	43,800	24	
	LOP-YV-2129	Valve controls the plant service air supply to the film coolers	43,800	24	
	LOP-YV-2148	Valve controls flush water supply	43,800	24	
	LOP-YV-2219	Valve controls the film coolers flush water supply	43,800	24	
	LOP-YV-2225	Valve controls the plant service air supply to the film coolers.	43,800	24	
	LVE-PSUP-20202	Performs air permit function. Can inspect the power supply during planned melter changeout	61,320	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LOP-SCB-00001	LOP-LT-1011	Radar level for SBS LOP SCB 1. Air permit item.	40,000	16	
	LOP-LT-1063	Radar level for SBS LOP SCB 1. ITS component.	40,000	16	
	LOP-SCB-00001		350,400		
LOP-SCB-00002	LOP-LT-2011	Radar level for SBS LOP SCB 2. Air permit item.	40,000	16	
	LOP-LT-2063	Radar level for SBS LOP SCB 2. ITS component.	40,000	16	
	LOP-SCB-00002		350,400		
LOP-WESP-00001	LOP-LT-1059	ITS radar level for WESP	40,000	16	
	LOP-WESP-00001		350,400		
LOP-WESP-00002	LOP-LT-2059	ITS radar level for WESP	40,000	16	
	LOP-WESP-00002		350,400		

3.5 System LVP: LAW Secondary Offgas/Vessel Vent Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LMP-MLTR-00001 LMP-MLTR-00002	LVP-AE-0027 / LVP-AT-0027	Non-ITS NOx Analyzer at ADBR inlet	26,280	12	
	LVP-AE-0051 / LVP-AT-0051	Non-ITS pH Analyzer providing set point for SHR flow control.	26,280	12	
	LVP-AE-0423 / LVP-AT-0423	Non-ITS Hg Analyzer at ADBR	26,280	12	
	LVP-AE-0439	Non-ITS Analyzer, but required for air permit.	200,000	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVP-AE-0514 / LVP-AT-0514	Non-ITS NOx Analyzer at SCR inlet	26,280	12	
	LVP-AE-0521 / LVP-AT-0521	Non-ITS VOC Analyzer at offgas outlet	26,280	12	
	LVP-AE-0522 / LVP-AT-0522	Non-ITS NOx Analyzer at offgas outlet	26,280	12	
	LVP-AE-0523 / LVP-AT-0523	Non-ITS NH3 Analyzer at offgas outlet	26,280	12	
	LVP-ASD-00001A	Adjustable speed drive for fan performance	100,000	48	
	LVP-ASD-00001B	Adjustable speed drive for fan performance	100,000	48	
	LVP-ASD-00001C	Adjustable speed drive for fan performance	100,000	48	
	LVP-AV-0514	Controls NOx concentration	333,333	24	
	LVP-AV-0523	Controls NH3 concentration	333,333	24	
	LVP-EXHR-00001-A		350,400		
	LVP-EXHR-00001-A_Motor		87,600	48	
	LVP-EXHR-00001-B		350,400		
	LVP-EXHR-00001-B_Motor		87,600	48	
	LVP-EXHR-00001-C		350,400		
	LVP-EXHR-00001-C_Motor		87,600	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVP-FE-0113 / LVP-FT-0113	Air permit function flow element measuring outlet flow of the primary HEPA filter.	66,667	12	If one or more components from Train 1 and one or more components from Train 2 are down, then idle both LAW melters; otherwise, no impact. Components are repaired as soon as they go down. Train 1 components: PDT-0011, PDI-0131, FE/FT-0114, PDI-0132, PDT-0012, FE/FT-0115 Train 2 components: PDI-0129, PDT 0007, FE/FT-0113, PDI-0130, PDT-0008.
	LVP-FE-0114 / LVP-FT-0114	Air permit function flow element measuring outlet flow of the primary HEPA filter.	66,667	12	
	LVP-FE-0115 / LVP-FT-0115	Air permit function flow element measuring outlet flow of the primary HEPA filter.	66,667	12	
	LVP-FI-0202	Non-ITS flow instrument monitors SCB quench	1,000,000	12	
	LVP-FT-0221	ITS flow instrument monitors the inflow to the SCB	333,333	16	
	LVP-FT-0529	Non-ITS flow instrument monitoring ammonia	333,333	12	
	LVP-FT-0539	Non-ITS flow instrument with air permit function	333,333	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVP-HTR-00001-A		350,400		
	LVP-HTR-00001-B		350,400		
	LVP-HTR-00002	The heater is primarily used for startup, or for operations with low NOx concentration	43,800	48	
	LVP-HTR-00002 MAINT		4380	12	
	LVP-HX-00001		350,400		
	LVP-JY-0510 / LVP-JZ-0510	ITS element controls VOC catalyst inlet temperature by adjusting power to LVP-JZ-0510	66,667	12	
	LVP-LT-0055	Non-ITS instruments measures the level of the caustic collection tank	40,000	36	
	LVP-LT-0409	Change from LS to LT	40,000	36	
	LVP-LT-0414	Change from LS to LT	40,000	36	
	LVP-LT-0417	Change from LS to LT	40,000	36	
	LVP-LT-0422	Change from LS to LT	40,000	36	
	LVP-MXR-00001	Ammonia mixing chamber	87,600	36	
	LVP-PCV-0527	Monitors NH3 supply pressure	769,231	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVP-PDI-0129		100,000	12	If one or more components from Train 1 and one or more components from Train 2 are down, then idle both LAW melters; otherwise, no impact. Components are repaired as soon as they go down. Train 1 components: PDT-0011, PDI-0131, FE/FT-0114, PDI-0132, PDT-0012, FE/FT-0115 Train 2 components: PDI-0129, PDT 0007, FE/FT-0113, PDI-0130, PDT-0008.
	LVP-PDI-0130		100,000	12	
	LVP-PDI-0131		100,000	12	
	LVP-PDI-0132		100,000	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVP-PDT-0007		333,333	12	If one or more components from Train 1 and one or more components from Train 2 are down, then idle both LAW melters; otherwise, no impact. Components are repaired as soon as they go down. Train 1 components: PDT-0011, PDI-0131, FE/FT-0114, PDI-0132, PDT-0012, FE/FT-0115 Train 2 components: PDI-0129, PDT 0007, FE/FT-0113, PDI-0130, PDT-0008.
	LVP-PDT-0008		333,333	12	
	LVP-PDT-0011		333,333	12	
	LVP-PDT-0012		333,333	12	
	LVP-PDT-0401	ITS pressure differential across the Hg ADBR	87,600	40	
	LVP-PDT-0402	ITS pressure differential across the Hg ADBR	87,600	40	
	LVP-PT-0071		333,333	12	
	LVP-PT-0216	ITS instrument monitoring process water to SCB	333,333	36	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVP-PT-0218	ITS instrument monitoring process service air to SCB	333,333	36	
	LVP-PT-0220	ITS instrument monitoring SCB quench spray	333,333	36	
	LVP-SCB-00001		350,400		
	LVP-SCB-00001_Packing		262,800	730	
	LVP-SCO-00001		350,400		Change during LVP-SCR-00001 MAINT, therefore, item not included in WTP OR Model.
	LVP-SCR-00001		350,400		Change during LVP-SCR-00001 MAINT, therefore, item not included in WTP OR Model.
	LVP-SCR-00001 MAINT	Bed change for LVP-ADBR-00001-A, LVP-ADBR-00001-B, LVP-SCO-00001 and LVP-SCR-00001 will occur at the same time.	17,520	60	Only one breakdown event will be used to model all 4 components in the WTP OR Model.
	LVP-TE-0001 / LVP-TT-0001	ITS instrument with air permit functions.	66,667	40	
	LVP-TE-0101 / LVP-TT-0101	Non-ITS instrument	66,667	16	
	LVP-TE-0104 / LVP-TT-0104	Non-ITS instrument	66,667	16	
	LVP-TE-0136 / LVP-TT-0136	ITS instrument	66,667	16	
	LVP-TE-0137 / LVP-TT-0137	ITS instrument	66,667	16	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVP-TE-0509 / LVP-TT-0509	ITS instrument	66,667	16	
	LVP-TE-0511 / LVP-TT-0511		66,667	16	
	LVP-TE-0554 / LVP-TT-0554		66,667	16	
	LVP-TK-00001		350,400		
	LVP-YV-0097	ITS control valve	43,800	48	
	LVP-YV-0201	ITS control valve controls SCB process water	43,800	48	
	LVP-YV-0215	Non-ITS control valve	43,800	24	
	LVP-YV-0217	ITS control valve controls SCB process service air	43,800	24	
	LVP-YV-0219	ITS control valve	43,800	48	
	LVP-YV-0223		43,800	48	
	LVP-YV-0403	The ITS control valve	43,800	48	
	LVP-YV-0423 A		43,800	48	
	LVP-YV-0423 B		43,800	48	
	LVP-YV-0423 C		43,800	48	
	LVP-YV-0427	ITS valve allows distribution of fire water	43,800	48	
	LVP-YV-0501	ITS control valve	43,800	48	
	LVP-YV-0528	ITS control valve	43,800	48	
	LVP-YV-0538	ITS control valve	43,800	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LVP-ADBR-00001-A	LVP-ADBR-00001-A	OFF GAS MERCURY ABSORBER	350,400		Change during LVP-SCR-00001 MAINT, therefore, item not included in WTP OR Model.
LVP-ADBR-00001-B	LVP-ADBR-00001-B	OFF GAS MERCURY ABSORBER	350,400		Change during LVP-SCR-00001 MAINT, therefore, item not included in WTP OR Model.

3.6 System C5V: C5 Ventilation

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
C5V-FAN-00009	C5V-FAN-00009	C02 DECONTAMINATION EXHAUST FAN	262,800		Deactivated in OR model (MTBF=10,000,000)
	C5V-FT-2124	C02 DECON FAN N LINE (FAN 9) AIRFLOW	87,600	12	
	C5V-PDT-2125	C02 DECON NORTH LINE dP (FAN9)	87,600	12	
	C5V-YD-2126	FAN 9 AIR OUT	87,600	12	
C5V-FAN-00010	C5V-FAN-00010	C02 DECONTAMINATION EXHAUST FAN	262,800		Deactivated in OR model (MTBF=10,000,000)
	C5V-FT-2128	C02 DECON FAN S LINE (FAN 10) AIRFLOW	87,600	12	
	C5V-PDT-2129	C02 DECON NORTH LINE dP (FAN10)	87,600	12	
	C5V-YD-2130	FAN 10 AIR OUT	87,600	12	

3.7 System SDJ: Stack Discharge Monitoring

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LVP-SCB-00001	SDJ-AE-2110 / SDJ-AT-2110 CO	STACK DISCH VSL VENT NON RAD	26,280	36	
	SDJ-AE-2110 / SDJ- AT-2110 NOx	STACK DISCH VSL VENT NON RAD	26,280	36	
	SDJ-AE-2110 / SDJ-AT-2110 VOC	STACK DISCH VSL VENT NON RAD	26,280	36	
	SDJ-FE-2113 / SDJ-FT-2113	STACK DISCH VSL VENT EXH FANS	66,667	36	
	SDJ-RE-2112 / SDJ-RT-2112	STACK DISCH VSL VENT EXH FANS RAD	26,280	36	
	SDJ-RX-2121	SAMPLER RECORDER	92,593	36	

3.8 System LRH: LAW Container Receipt Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LRH-CNVR-00001	LRH-CNVR-00001	CONTAINER RECEIPT CONVEYOR SOUTH LINE	87,600	24	
LRH-CNVR-00007	LRH-CNVR-00007	CONTAINER RECEIPT CONVEYOR NORTH LINE	87,600	24	
LRH-HST-00001	LRH-HST-00001	CONTAINER IMPORT HOIST SOUTH LINE	87,600	36	
LRH-HST-00002	LRH-HST-00002	CONTAINER IMPORT HOIST NORTH LINE	87,600	36	

3.9 System LPH: LAW Container Pour Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LPH-CRN-00002	LPH-CRN-00002	BUFFER STORE CRANE	35,040	72	
	LPH-CRN-00002 MAINT Q	Quarterly Maintenance	2190	36	
	LPH-CRN-00002 MAINT S	Semi-annual Maintenance	4380	36	
	LPH-CRN-00002 MAINT A	Annual Maintenance	8760	72	
	PTJ-XT-2026	BSCRN MTD CMR 1	17,520	12	
	PTJ-XT-2027	BSCRN MTD CMR 2	17,520	12	
LPH-HST-00001	LPH-HST-00001	POUR CAVE MONORAIL HOIST	43,800	48	
	LPH-HST-00001 MAINT Q	Quarterly Maintenance	2190	36	
	LPH-HST-00001 MAINT S	Semi-annual Maintenance	4380	36	
	LPH-HST-00001 MAINT A	Annual Maintenance	8760	72	
LPH-HST-00001/2	PTJ-XT-2020	PRCAV L-B015A L-B013C XFR GENL VWG CMR	17,520	12	
LPH-HST-00002	LPH-HST-00002	POUR CAVE MONORAIL HOIST	43,800	48	
	LPH-HST-00002 MAINT Q	Quarterly Maintenance	2190	36	
	LPH-HST-00002 MAINT S	Semi-annual Maintenance	4380	36	
	LPH-HST-00002 MAINT A	Annual Maintenance	8760	72	
LPH-HST-00003	LPH-HST-00003	POUR CAVE MONORAIL HOIST	43,800	48	
	LPH-HST-00003 MAINT Q	Quarterly Maintenance	2190	36	
	LPH-HST-00003 MAINT S	Semi-annual Maintenance	4380	36	
	LPH-HST-00003 MAINT A	Annual Maintenance	8760	72	
LPH-HST-00003/4	PTJ-XT-2022	PRCAV L-B013B L-B011C XFR GENL VWG CMR	17,520	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LPH-HST-00004	LPH-HST-00004	POUR CAVE MONORAIL HOIST	43,800	48	
	LPH-HST-00004 MAINT Q	Quarterly Maintenance	2190	36	
	LPH-HST-00004 MAINT S	Semi-annual Maintenance	4380	36	
	LPH-HST-00004 MAINT A	Annual Maintenance	8760	72	
LPH-TRLY-00001	LPH-TRLY-00001	CONTAINER TRANSPORT BOGIE SOUTH LINE	43,800	84	
	LPH-TRLY-00001 MAINT A	Annual Maintenance	8760	84	
LPH-TRLY-00002	LPH-TRLY-00002	CONTAINER TRANSPORT BOGIE NORTH LINE	43,800	84	
	LPH-TRLY-00002 MAINT A	Annual Maintenance	8760	84	

3.10 System LFH: LAW Container Finishing Handling System

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFH-CRN-00003	LFH-CRN-00003	CRANE - JIB LIDDING SOUTH FINISH LINE	17,520	120	
LFH-CRN-00004	LFH-CRN-00004	CRANE - JIB SEALING SOUTH FINISH LINE	17,520	120	
LFH-CRN-00006	LFH-CRN-00006	CRANE - JIB LIDDING NORTH FINISH LINE	17,520	120	
LFH-CRN-00007	LFH-CRN-00007	CRANE - JIB LIDDING NORTH FINISH LINE	17,520	120	
LFH-HST-00001	LFH-DOOR-00011	DOOR -TRAP, LINE TRANSFER, SOUTH FINISH LINE	13,140	36	
LFH-HST-00001	LFH-DOOR-00014	DOOR -TRAP, LINE TRANSFER, NORTH FINISH LINE	13,140	36	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFH-HST-00001	LFH-HST-00001	HOIST - MONORAIL LINE TRANSFER FOR BOTH FINISHING LINES	87,600	72	
LFH-HST-00001	LFH-TOOL-00014	GRAPPLE - LINE TRANSFER, FINISHING LINE	87,600	48	
LFH-HST-00005	LFH-HST-00005	HOIST - DUAL RAIL DECON SOUTH FINISH LINE	43,800	96	
	LFH-HST-00005 MAINT	Maintenance	2160	84	
LFH-HST-00006	LFH-DOOR-00016	DOOR, SWABBING/EXPORT CONTAINMENT, NORTH FINISH LINE	43,800	120	
LFH-HST-00006	LFH-DOOR-00020	DOOR - DECON/SWAB CONTAINMENT, SOUTH FINISH LINE	43,800	120	
LFH-HST-00006	LFH-HST-00006	HOIST - DUAL RAIL SWABBING SOUTH FINISH LINE	43,800	96	
	LFH-HST-00006 MAINT	Maintenance	2160	84	
LFH-HST-00006	LFH-TOOL-00016	GRAPPLE - SWABBING, NORTH FINISHING LINE	87,600	48	
LFH-HST-00008	LFH-HST-00008	HOIST - MONORAIL LIDDING NORTH FINISH LINE	43,800	96	
	LFH-HST-00008 MAINT	Maintenance for LFH-HST-00008, LFH-CRN-00004 and LFH-CRN-00006	2160	84	
LFH-HST-00009	LFH-HST-00009	HOIST - MONORAIL LIDDING SOUTH FINISH LINE	43,800	96	
	LFH-HST-00009 MAINT	Maintenance for LFH-HST-00009, LFH-CRN-00003 and LFH-CRN-00007	2160	84	
LFH-HST-00010	LFH-HST-00010	HOIST - DUAL RAIL DECON NORTH FINISH LINE	43,800	96	
	LFH-HST-00010 MAINT	Maintenance	2160	84	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFH-HST-00011	LFH-DOOR-00012	DOOR, SWABBING/EXPORT CONTAINMENT, SOUTH FINISH LINE	43,800	120	
LFH-HST-00011	LFH-DOOR-00022	DOOR - DECON/SWABBING CONTAINMENT, NORTH FINISH LINE	43,800	120	
LFH-HST-00011	LFH-HST-00011	HOIST - DUAL RAIL SWABBING NORTH FINISH LINE	43,800	96	
	LFH-HST-00011 MAINT	Maintenance	2160	84	
LFH-HST-00011	LFH-TOOL-00015	GRAPPLE - SWABBING, SOUTH FINISHING LINE	87,600	48	
LFH-LID-00025	LFH-LID-00023	MAGAZINE - LID, NORTH FINISH LINE	43,800	96	
LFH-LID-00025	LFH-LID-00025	PRESS - LID, NORTH FINISH LINE	26,280	96	
LFH-LID-00025	LFH-LID-00035	MAGAZINE - LID B, NORTH FINISH LINE	43,800	96	
LFH-LID-00026	LFH-LID-00024	MAGAZINE - LID, SOUTH FINISH LINE	43,800	96	
LFH-LID-00026	LFH-LID-00026	PRESS - LID, SOUTH FINISH LINE	26,280	96	
LFH-LID-00026	LFH-LID-00036	MAGAZINE - LID B, SOUTH FINISH LINE	43,800	96	
LFH-MANIP-00001	LFH-MANIP-00001	MANIPULATOR - UPPER POWER DECON NORTH FINISH LINE	43,800	120	
LFH-MANIP-00002	LFH-MANIP-00002	MANIPULATOR - POWER SWABBING NORTH FINISH LINE	43,800	120	
LFH-MANIP-00008	LFH-MANIP-00008	MANIPULATOR - UPPER POWER DECON SOUTH FINISH LINE	43,800	120	
LFH-MANIP-00009	LFH-MANIP-00009	MANIPULATOR - POWER SWABBING SOUTH FINISH LINE	43,800	120	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFH-MANIP-00011	LFH-MANIP-00011	MANIPULATOR - LOWER POWER DECON NORTH FINISH LINE	43,800	120	
LFH-MANIP-00012	LFH-MANIP-00012	MANIPULATOR - LOWER POWER DECON SOUTH FINISH LINE	43,800	120	
LFH-MHAN-00002	LFH-MHAN-00002	HOPPER, INERT FILL, NORTH FINISH LINE	43,800	120	
LFH-MHAN-00004	LFH-MHAN-00004	HOPPER, INERT FILL, SOUTH FINISH LINE	43,800	120	
LFH-RS-2001	LFH-RS-2001	GAMMA GATE SOUTH EXPT FLT HI	43,800	36	
LFH-RS-4201	LFH-RS-4201	GAMMA GATE SOUTH EXPORT FILTER - HI	43,800	36	
LFH-SMPLR-00003	LFH-MANIP-00023	MSM - SOUTH SAMPLING STATION [WEST]	43,800	48	
	LFH-MANIP-00024	MSM - SOUTH SAMPLING STATION [EAST]	43,800	48	
	LFH-SMPLR-00003	TRAY - SHARD SAMPLING SOUTH FINISH LINE	43,800	24	
	LFH-ZT-2355	NORTH LN SHDT LVL XDCR	32,000	120	
LFH-SMPLR-00005	LFH-MANIP-00021	MSM - NORTH SAMPLING STATION [WEST]	43,800	48	
	LFH-MANIP-00022	MSM - NORTH SAMPLING STATION [EAST]	43,800	48	
	LFH-SMPLR-00005	TRAY - SHARD SAMPLING NORTH FINISH LINE	43,800	24	
	LFH-ZT-0255	SOUTH LN SHDT LVL XDCR	32,000	120	
LFH-SMPLR-00006	LFH-SMPLR-00006	PORT - SWAB POSTING NORTH FINISH LINE	43,800	24	
LFH-SMPLR-00007	LFH-SMPLR-00007	PORT - SWAB POSTING SOUTH FINISH LINE	43,800	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFH-TRLY-00001	LFH-TRLY-00001	BOGIE - SWABBING NORTH FINISH LINE	43,800	132	
	LFH-TRLY-00001 MAINT	Maintenance for LFH-TRLY-00001, LFH-MANIP-00002, and LFH-SMPLR-00006	2160	84	
LFH-TRLY-00005	LFH-TRLY-00005	BOGIE - DECONTAMINATION NORTH FINISH LINE	43,800	132	
	LFH-TRLY-00005 MAINT	Maintenance for LFH-TRLY-00005, LFH-TTBL-00001, LFH-MANIP-00008 and LFH-MANIP-00011	2160	84	
LFH-TRLY-00005	LFH-TTBL-00001	TURNTABLE - DECON NORTH FINISH LINE	43,800	96	
LFH-TRLY-00006	LFH-DOOR-00015	DOOR - SHIELDED, LIDDING/DECON, NORTH FINISH LINE	43,800	120	
LFH-TRLY-00006	LFH-TRLY-00006	BOGIE - LIDDING SOUTH FINISH LINE	43,800	132	
	LFH-TRLY-00006 MAINT	Maintenance for LFH-TRLY-00006, LFH-MHAN-00004, LFH-SMPLR-00003, LFH-LID-00024, LFH-LID-00026, and LFH-LID-00036	2160	84	
LFH-TRLY-00007	LFH-DOOR-00019	DOOR - SHIELDED, LIDDING/DECON, SOUTH FINISH LINE	43,800	120	
LFH-TRLY-00007	LFH-TRLY-00007	BOGIE - LIDDING NORTH FINISH LINE	43,800	132	
	LFH-TRLY-00007 MAINT	Maintenance for LFH-TRLY-00007, LFH-MHAN-00002, LFH-SMPLR-00005, LFH-LID-00023, LFH-LID-00025, and LFH-LID-00035	2160	84	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LFH-TRLY-00008	LFH-TRLY-00008	BOGIE - DECONTAMINATION SOUTH FINISH LINE	43,800	132	
	LFH-TRLY-00008 MAINT	Maintenance for LFH-TRLY-00008, LFH-TTBL-00002, LFH-MANIP-00009 and LFH-MANIP-00012	2160	84	
LFH-TRLY-00008	LFH-TTBL-00002	TURNTABLE - DECON SOUTH FINISH LINE	43,800	96	
LFH-TRLY-00015	LFH-TRLY-00015	BOGIE - SWABBING SOUTH FINISH LINE	43,800	132	
	LFH-TRLY-00015 MAINT	Maintenance for LFH-TRLY-00015, LFH-MANIP-00001, and LFH-SMPLR-00007	2160	84	
LFH-WELD-00001	LFH-WELD-00001		43,800	48	
LFH-WELD-00002	LFH-WELD-00002		43,800	48	

3.11 System LEH: LAW Container Export Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LEH-CRN-00003	LEH-CRN-00003	CRANE, EXPORT HIGH BAY W/ RECOVERY 10 TON	3300	12	
	LEH-CRN-00003 MAINT A	Annual Maintenance	8760	12	
	LEH-TOOL-00002	GRAPPLE - CONTAINER, EXPORT	87,600	12	
	PTJ-XT-2161	LEH CRN CMR	17,520	8	
	PTJ-XT-2162	LEH CRN CMR	17,520	8	
	PTJ-XT-2163	LEH CRN CMR	17,520	8	

3.12 System LSH: LAW Melter Equipment Support Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
LSH-CRN-00001	LSH-CRN-00001	DRIVE THROUGH TRUCK BAY BRIDGE CRANE	87,600	36	
	LSH-CRN-00001 MAINT Q	Quarterly Maintenance	2190	36	
	LSH-CRN-00001 MAINT S	Semi-annual Maintenance	4380	36	
	LSH-CRN-00001 MAINT A	Annual Maintenance	8760	72	

3.13 System CDG: Carbon Dioxide Gas

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
CDG-VSL-00001	CDG-LT-0104	CNTNR DECON CO2 STOR VSL	87,600	12	
	CDG-VSL-00001	CONTAINER DECONTAMINATION CO2 STORAGE VESSEL	350,400		

3.14 System SHR: Sodium Hydroxide Reagent

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
SHR-VSL-00001	SHR-FT-1007	Cs EVAP SEPR 5M NAOH ADD	333,333	24	
	SHR-FT-1008	ACD/ALK EFL 19M NAOH ADD	333,333	24	
	SHR-FT-1017	SBS CONDS REC VSLS 5M NAOH ADD	333,333	24	
	SHR-FT-1018	CSTC SCRBR 5M NAOH ADD	333,333	24	
	SHR-FT-1023	PWD/UFP 19M NAOH ADD	333,333	24	
	SHR-FT-1024	FD PREP VSLS 19M NAOH ADD	333,333	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
SHR-TK-00003	SHR-TK-00003	CAUSTIC COLD CHEMICAL MIX TANK	350,400		

4 HLW Vitrification

4.1 System HFP: HLW Melter Feed Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HFP-VSL-00001	HFP-AGT-00001	MELTER 1 FEED PREP VESSEL AGITATOR	26,280	72	
	HFP-PMP-00005-A	HFP-VSL-00001 FEED PREP VESSEL TRANSFER/SAMPLE PUMP	43,800	156	
	HFP-PMP-00005-B	HFP-VSL-00001 FEED PREP VESSEL TRANSFER/SAMPLE PUMP	43,800	156	
	HFP-VSL-00001	MELTER 1 FEED PREPARATION VESSEL	350,400		
HFP-VSL-00002	HFP-AGT-00002	MELTER 1 FEED VESSEL AGITATOR	26,280	72	
	HFP-PMP-00001	MELTER 1 FEED AIR DISPLACEMENT SLURRY (ADS) PUMP	43,800	156	
	HFP-PMP-00002	MELTER 1 FEED AIR DISPLACEMENT SLURRY (ADS) PUMP	43,800	156	
	HFP-VSL-00002	MELTER 1 FEED VESSEL	350,400		

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HFP-VSL-00005	HFP-AGT-00004	MELTER 2 FEED PREP VESSEL AGITATOR	26,280	72	
	HFP-PMP-00018-A	HFP-VSL-00005 FEED PREP VESSEL TRANSFER/SAMPLE PUMP	43,800	156	
	HFP-PMP-00018-B	HFP-VSL-00005 FEED PREP VESSEL TRANSFER/SAMPLE PUMP	43,800	156	
	HFP-VSL-00005	MELTER 2 FEED PREPARATION VESSEL	350,400		
HFP-VSL-00006	HFP-AGT-00005	MELTER 2 FEED VESSEL AGITATOR	26,280	72	
	HFP-PMP-00014	MELTER 2 FEED AIR DISPLACEMENT SLURRY (ADS) PUMP	43,800	156	
	HFP-PMP-00015	MELTER 2 FEED AIR DISPLACEMENT SLURRY (ADS) PUMP	43,800	156	
	HFP-VSL-00006	MELTER 2 FEED VESSEL	350,400		

4.2 System HMP: HLW Melter Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HMP-MLTR-00001	HMP-BBLR-00001 to 5 MAINT	Melter 1 Agitation Bubblers 1 to 5, modeled as one breakdown event (maintenance).	730	15/ 2 bubblers 19.5/ 3 bubblers	
	HMP-BBLR-00006	MELTER 1 LEVEL DETECTOR	6570	6	
	HMP-DT-0132	MELTER 1 LEVEL BUBBLER	6570	12	
	HMP-MLTR-00001 MAINT	HLW MELTER 1	43,800	4380	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HMP-SPOOL-00007 to 10 MAINT	Melter 1 Thermo well 7 to 10, modeled as one breakdown event.	6570	36	Nine hours per SPOOL.
	HMP-TVT-00006	GAMMA DETECTOR EAST CHAMBER	8760	4	
	HMP-TVT-00007	GAMMA DETECTOR WEST CHAMBER	8760	4	
	HMP-YD-0222		87,600	28	
	HMP-YV-0260		43,800	24	
	HMP-YV-0261		43,800	24	
HMP-MLTR-00002	HMP-BBLR-00008 to 12 MAINT	Melter 2 Agitation Bubblers 8 to 12, modeled as one breakdown event. (maintenance).	730	15/ 2 bubblers 19.5/ 3 bubblers	
	HMP-BBLR-00013	MELTER 2 LEVEL DETECTOR	6570	6	
	HMP-DT-2132	MELTER 2 LEVEL BUBBLER	6570	12	
	HMP-MLTR-00002 MAINT	HLW MELTER 2	43,800	4380	
	HMP-SPOOL-00017 to 20 MAINT	Melter 2 Thermo well 17 to 20, modeled as one breakdown event.	6570	36	Nine hours per SPOOL.
	HMP-TVT-00013	GAMMA DETECTOR EAST CHAMBER	8760	4	
	HMP-TVT-00014	GAMMA DETECTOR WEST CHAMBER	8760	4	
	HMP-YD-2222		87,600	28	
	HMP-YV-2260		43,800	24	
	HMP-YV-2261		43,800	24	

4.3 System HOP: HLW Melter Offgas Treatment Process

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HMP-MLTR-00001	HOP-ABS-00002	Silver Mordenite Column.	78,840	72	
	HOP-ADBR-00001A	Active Carbon Absorber.	8760	120	ADBR-00001A or ADBR-00001B is required to keep melter working.
	HOP-ADBR-00001B	Active Carbon Absorber.	8760	120	
	HOP-AE-0332/HOP-AT-0332	INLET NOx.	26,280	48	
	HOP-AE-0367	SDJ - Air Permit Function. STACK HF/F2.	200,000	48	
	HOP-AE-0368	SDJ - Air Permit Function. STACK HCL/CL2.	200,000	48	
	HOP-AE-0513/HOP-AT-0513	NH3 OUTLET CONC.	26,280	48	
	HOP-AE-0515/HOP-AT-0515	SCO NOx CONC.	26,280	48	
	HOP-DT-0122/HOP-LT-0123	DWP. HOP-VSL-00903 MLTR 1 SBS CNDS VSL BBLR / Level.	28,855	24	
	HOP-FCLR-00001	Replace with Melter 1 changeout. No additional impact to process.	100,000,000	0	Disabled in WTP OR Model.
	HOP-FCLR-00003	Replace with Melter 1 changeout. No additional impact to process. Disabled.	100,000,000	0	Disabled in WTP OR Model.
	HOP-FE-0333	No impact or not modeled at this time	100,000,000	48	Disabled in WTP OR Model.
	HOP-FE-3113/HOP-FT-3113	SDJ - Air Permit Function.	66,667	48	
	HOP-FI-0307A	Air Permit Function.	1,000,000	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-FT-0333	NH3 HDR. Controls ammonia flow to the NOx selective catalytic reducer (HOP-SCR-0001).	17,520	48	
	HOP-FT-0510	ISA INLET FLOW - Coriolis.	333,333	24	
	HOP-FT-0517	AMMONIA INLET FLOW. Coriolis.	333,333	48	
	HOP-FT-0518	ISA INLET FLOW. ITS.	333,333	24	
	HOP-FV-0333	No impact or not modeled at this time.	100,000,000	48	Disabled in WTP OR Model.
	HOP-FV-0505	AMMONIA INLET FLOW CONTROL.	333,333	48	
	HOP-FV-0512	SCR INLET AMMONIA FLOW CONTROL.	333,333	48	
	HOP-HTR-00001	Catalyst Skid Electric Heater.	130,378	72	
	HOP-HTR-00003		43,800	12	
	HOP-HX-00001	Catalyst Skid Preheater.	131,400	336	
	HOP-HX-00002	Silver Mordenite Preheater.	131,400	336	
	HOP-IT-0268	Air Permit Function. WESP Power Supply - Primary.	333,333	24	
	HOP-IT-0279	Air Permit Function. WESP Power Supply - Secondary.	333,333	24	
	HOP-JY-0351A	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00008A.	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-0351B	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00008A.	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-0356A	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00008B.	100,000,000	48	Disabled in WTP OR Model.
	HOP-JY-0356B	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00008B.	100,000,000	48	Disabled in WTP OR Model.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-JY-0361A	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00008C.	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-0361B	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00008C.	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-0520	ITS ISOLATING CONTACTOR. ITS.	66,667	24	
	HOP-LE-0104	No impact or not modeled at this time.	100,000,000	12	Disabled in WTP OR Model.
	HOP-LE-0110/HOP-LT-0110	DWP. HOP-VSL-00903 MLTR 1 SBS CONDENSATE Level.	66,667	24	
	HOP-LT-0130	NOC and DWP. Melter 1 SBS ITS ultrasonic radar.	450,000	24	
	HOP-LT-0208	DWP. Melter 1 WESP level transmitter, which determines WESP drain pluggage.	40,000	24	
	HOP-PDT-0309	ITS FAN DIFF. 1/2 PDT 309 and PDT 310.	333,333	24	
	HOP-PDT-0310		333,333	24	
	HOP-PDT-0314	ITS FAN DIFF. 1/2 PDT 314 and PDT 315.	333,333	24	
	HOP-PDT-0315		333,333	24	
	HOP-PDT-0319	ITS FAN DIFF. 1/2 PDT 319 and PDT 320.	333,333	24	
	HOP-PDT-0320		333,333	24	
	HOP-PDT-0348	ITS DIFF. 1/2 PDT 348 and PDT 349.	333,333	24	
	HOP-PDT-0349		333,333	24	
	HOP-PDT-0353	ITS DIFF. 1/2 PDT 353 and PDT 354.	333,333	24	
	HOP-PDT-0354		333,333	24	
	HOP-PDT-0358	ITS DIFF. 1/2 PDT 358 and PDT 359.	333,333	24	
	HOP-PDT-0359		333,333	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-PJM-00001	For PJM 1/2/3/7. Collectively, if X = 1, no action. If X > 1, fail HOP VSL 903. A component remains broken until at least two components are down. When this happens, the vessel is considered to be down.	100,000,000	42	Disabled in WTP OR Model.
	HOP-PJM-00002		100,000,000	42	Disabled in WTP OR Model.
	HOP-PJM-00003		100,000,000	42	Disabled in WTP OR Model.
	HOP-PJM-00007		100,000,000	42	Disabled in WTP OR Model.
	HOP-PT-0711	ITS - Demister Isolation.	333,333	24	
	HOP-PT-0713	ITS - Demister Isolation.	333,333	24	
	HOP-PT-0849	SCO ISA ISOLATION. ITS.	333,333	24	
	HOP-RE-3111/HOP-RT-3111	SDJ - Air Permit Function.	26,280	48	
	HOP-RX-3144	SDJ - Air Permit Function.	92,593	48	
	HOP-SCB-00001	No impact or not modeled at this time.	100,000,000	0	Disabled in WTP OR Model.
	HOP-TE-0299/HOP-JZ-0239	Heater control; Purge process air. Prevent overheating of HTR-00003.	66,667	24	
	HOP-TE-0302	Air Permit Function. HOP FAN 1ABC entrance.	1,000,000	24	
	HOP-TE-0331		43,800	12	
	HOP-TE-0331/HOP-TT-0331/HOP-TC-0331	CAT SKID HEATER OUT. Temperature Indication provides a control function to the cooling water system.	43,800	24	
	HOP-TE-0336/HOP-TT-0336	NOx SCR OUT. ITS.	66,667	24	
	HOP-TE-0340/HOP-TT-0340/HOP-TI-0340	Air permit function. SILVER MORDENITE INLET.	66,667	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-TE-0399	HEAT EXCHANGER INLET Temperature. ITS items.	1,000,000	24	
	HOP-TE-0514/HOP-TT-0514	SCO PREHEATER HOUSING TEMP. ITS.	66,667	24	
	HOP-TT-0331		43,800	12	
	HOP-TV-0105B		43,800	12	
	HOP-WESP-00001	WESP unit. Life of plant item.	350,400		
	HOP-YV-0121	MLTR 1 SBS EJCTR PRCS AIR. 1/2 of YV 121 and YV 128.	43,800	24	
	HOP-YV-0128		43,800	24	
	HOP-YV-0133	MLTR 1 SBS EJCTR DEMIN. 1/2 of YV 133 and YV 134.	43,800	24	
	HOP-YV-0134		43,800	24	
	HOP-YV-0146	MLTR 1 SBS SIPHON BREAK. 1/2 YV 146 and YV 147.	43,800	24	
	HOP-YV-0147		43,800	24	
	HOP-YV-0504	AMMONIA INLET ISOLATION. ITS.	43,800	48	
	HOP-YV-0710	ITS - Demister Isolation.	43,800	24	
	HOP-YV-0712	ITS - Demister Isolation.	43,800	24	
	HOP-YV-0848	SCO ISA ISOLATION. ITS.	43,800	24	
	LVE-PSUP-30004	Air Permit Function. WESP Power Supply, which is expected to last seven years. Can be inspected or change during melter changeout.	61,320	168	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-AE-0804/HOP-AT-0804	All 12 instruments (HOP-AE/AT-0843, HOP-AE/AT-0804, HOP-YV-0809, HOP-AE/AT-0807, HOP-YV-0813, HOP-YV-0817, HOP-YV-0811, HOP-YV-0398, HOP-YV-0815, HOP-YV-0818, HOP-AE/AT-0826, and HOP-AE/AT-0808) must work, or idle HLW Melter 1.	26,280	48	
	HOP-AE-0807/HOP-AT-0807		26,280	48	
	HOP-AE-0808/HOP-AT-0808		26,280	48	
	HOP-AE-0826/HOP-AT-0826		26,280	48	
	HOP-AE-0843/HOP-AT-0843		26,280	48	
	HOP-YV-0398		43,800	48	
	HOP-YV-0809		43,800	48	
	HOP-YV-0811		43,800	48	
	HOP-YV-0813		43,800	48	
	HOP-YV-0815		43,800	48	
	HOP-YV-0817		43,800	48	
	HOP-YV-0818		43,800	48	
	HOP-FAN-00008A	Stack Extraction Fan.	87,600	48	Two out of three (FAN/ASD/YV) sets are needed to keep Melter 1 operational; otherwise Melter 1 will be disabled. Set A includes HOP-FAN-00008A, HOP-FAN-00008A ASD and HOP-YV-0350; Set B includes HOP-FAN-00008B, HOP-FAN-00008B ASD
	HOP-FAN-00008A ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00008B	Stack Extraction Fan.	87,600	48	
	HOP-FAN-00008B ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00008C	Stack Extraction Fan.	87,600	48	
	HOP-FAN-00008C ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-YV-0350	ITS DISCHARGE CONTROL. Outlet of FAN 00008A.	43,800	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-YV-0355	ITS DISCHARGE CONTROL. Outlet of FAN 00008B.	43,800	48	and HOP-YV-0355; and Set C includes HOP-FAN-00008C, HOP-FAN-00008C ASD and HOP-YV-0360.
	HOP-YV-0360	ITS DISCHARGE CONTROL. Outlet of FAN 00008C.	43,800	48	
	HOP-FAN-00001A	Stack Extraction Fan.	87,600	48	Two out of three (FAN/ASD) sets are needed to keep Melter 1 operational; otherwise Melter 1 will be disabled. Set A includes HOP-FAN-00001A and HOP-FAN-00001A ASD; Set B includes HOP-FAN-00001B and HOP-FAN-00001B ASD; and Set C includes HOP-FAN-00001C and HOP-FAN-00001C ASD.
	HOP-FAN-00001A ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00001B	Stack Extraction Fan.	87,600	48	
	HOP-FAN-00001B ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00001C	Stack Extraction Fan.	87,600	48	
	HOP-FAN-00001C ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-HEME-00001A	If one of two trains, Train A or Train B, is not completely available, then idle HLW Melter 1. (Train A: HOP-TE/TT-0250, HOP-LT-0216, HOP-PDT-0215, and HOP-HEME-00001A.; Train B: HOP-TE/TT-0255, HOP-LT-0229, HOP-PDT-0228, and HOP-HEME-00001B).	43,800	72	
	HOP-HEME-00001B		43,800	72	
	HOP-LT-0216		40,000	24	
	HOP-LT-0229		40,000	24	
	HOP-PDT-0215		333,333	24	
	HOP-PDT-0228		333,333	24	
	HOP-TE-0250/HOP-TT-0250		43,800	24	
	HOP-TE-0255/HOP-TT-0255		43,800	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-HEPA-00001A	If one of two trains, Train A or Train B, is not completely available, then idle HLW Melter 1. Train A is considered available if the following components are working: HOP-HTR-00002A, HOP-HEPA-00001A/2A, HOP-TE-0283/218/284/285,220, (HOP-PDT-0223 or HOP-PDT 0222), and (HOP-PDI-0210 or HOP-PDI-0211). Train B is considered available if the following components are working: HOP-HTR-00001B, HOP-HEPA-00001B/2B, HOP-TE-0286/231/287/288/233, (HOP-PDT-0236 or HOP-PDT-0235), and (HOP-PDI-0212 or HOP-PDI-0213). In addition, HOP-HTR-00001B and HOP-HTR-00002A contain 45 heating elements each. Both heaters require a total of 34 out of 45 heating elements to be operational to be functional. The time between failures for each heating element is 43,800 hours.	43,800	72	
	HOP-HEPA-00001B		43,800	72	
	HOP-HEPA-00002A		43,800	72	
	HOP-HEPA-00002B		43,800	72	
	HOP-HTR-00001B		130,378	72	
	HOP-HTR-00002A		130,378	72	
	HOP-PDI-0210		100,000	24	
	HOP-PDI-0211		100,000	24	
	HOP-PDI-0212		100,000	24	
	HOP-PDI-0213		100,000	24	
	HOP-PDT-0222		333,333	24	
	HOP-PDT-0223		333,333	24	
	HOP-PDT-0235		333,333	24	
	HOP-PDT-0236		333,333	24	
	HOP-TE-0218		1,000,000	24	
	HOP-TE-0220		1,000,000	24	
	HOP-TE-0231		1,000,000	24	
	HOP-TE-0233		1,000,000	24	
	HOP-TE-0283		1,000,000	24	
	HOP-TE-0284		1,000,000	24	
	HOP-TE-0285		1,000,000	24	
	HOP-TE-0286		1,000,000	24	
	HOP-TE-0287		1,000,000	24	
	HOP-TE-0288		1,000,000	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-SCO-00001	Thermal Catalytic Oxidizer. Failure of the Catalytic Thermal Oxidizer will allow the escape of untreated exhaust gases through the stack.	8760	72	The original 26280 / 336 RAM data for HOP-SCR-00001 and HOP-SCO-00001 is not reasonable. It's too short for equipment RAM, and too long for bed change. Therefore, it was assumed that the equipment has a life of five years and is changed out during melter maintenance. Bed Replacement - HOP-SCR-00001 and HOP-SCO-00001 will be replaced at the same time (only one MTTR instead of two separate MTTRs will be used).
	HOP-SCR-00001	NOx Selective Catalytic Reducer. Failure of the Catalytic NOx Scrubber will allow the escape of untreated exhaust gases through the stack.	100,000,000	72	
HMP-MLTR-00002	HOP-ABS-00003	Silver Mordenite Column.	78,840	72	
	HOP-ADBR-00002A	Active Carbon Adsorber.	8760	120	ADBR-00002A or ADBR-00002B is required to keep melter working.
	HOP-ADBR-00002B	Active Carbon Adsorber.	8760	120	
	HOP-AE-2332/HOP-AT-2332	INLET NOx.	26,280	48	
	HOP-AE-2367	SDJ - Air Permit Function. STACK HF/F2.	200,000	48	
	HOP-AE-2368	SDJ - Air Permit Function. STACK HCL/CL2.	200,000	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-AE-2513/HOP-AT-2513	NH3 OUTLET CONC.	26,280	48	
	HOP-AE-2515/HOP-AT-2515	SCO NOx CONC.	26,280	48	
	HOP-DT-2122/HOP-LT-2123	DWP. HOP-VSL-00904 MLTR 2 SBS CNDS VSL BBLR / Level.	28,855	24	
	HOP-FCLR-00002	Replace with Melter 2 changeout. No additional impact to process.	100,000,000	0	Disabled in WTP OR Model.
	HOP-FCLR-00004	Replace with Melter 2 changeout. No additional impact to process. Disabled.	100,000,000	0	Disabled in WTP OR Model.
	HOP-FE-2333	No impact or not modeled at this time.	100,000,000	48	Disabled in WTP OR Model.
	HOP-FE-3129/HOP-FT-3139	SDJ - Air Permit Function.	66,667	48	
	HOP-FI-2307A	Air Permit Function.	1,000,000	24	
	HOP-FT-2333	NH3 HDR. Controls ammonia flow to the NOx selective catalytic reducer (HOP-SCR-0002).	17,520	48	
	HOP-FT-2510	ISA INLET FLOW - Coriolis.	333,333	24	
	HOP-FT-2517	AMMONIA INLET FLOW. Coriolis.	333,333	48	
	HOP-FT-2518	ISA INLET FLOW. ITS.	333,333	24	
	HOP-FV-2333	No impact or not modeled at this time.	100,000,000	48	Disabled in WTP OR Model.
	HOP-FV-2505	AMMONIA INLET FLOW CONTROL.	333,333	48	
	HOP-FV-2512	SCR INLET AMMONIA FLOW CONTROL.	333,333	48	
	HOP-HTR-00006		43,800	12	
	HOP-HTR-00007	Catalyst Skid Electric Heater.	130,378	72	
	HOP-HX-00003	Catalyst Skid Preheater.	131,400	336	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-HX-00004	Silver Mordenite Preheater.	131,400	336	
	HOP-IT-2268	Air Permit Function. WESP Power Supply - Primary.	333,333	24	
	HOP-IT-2279	Air Permit Function. WESP Power Supply - Secondary.	333,333	24	
	HOP-JY-2351A	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00010A.	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-2351B	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00010A.	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-2356A	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00010B.	100,000,000	48	Disabled in WTP OR Model.
	HOP-JY-2356B	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00010B.	100,000,000	48	Disabled in WTP OR Model.
	HOP-JY-2361A	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00010C.	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-2361B	ITS DISCHARGE CONTROL. Tie to ASD-FAN-00010C	100,000,000	24	Disabled in WTP OR Model.
	HOP-JY-2520	ITS ISOLATING CONTACTOR. ITS.	66,667	24	
	HOP-LE-2104	No impact or not modeled at this time.	100,000,000	12	Disabled in WTP OR Model.
	HOP-LE-2110/HOP-LT-2110	DWP. HOP-VSL-00904 MLTR 2 SBS CONDENSATE Level.	66,667	24	
	HOP-LT-2130	NOC and DWP. Melter 2 SBS ITS ultrasonic radar.	450,000	24	
	HOP-LT-2208	DWP. Melter 2 WESP level transmitter, which determines WESP drain pluggage.	40,000	24	
	HOP-PDT-2309	ITS FAN DIFF. 1/2 PDT 2309 and PDT 2310.	333,333	24	
	HOP-PDT-2310		333,333	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-PDT-2314	ITS FAN DIFF. 1/2 PDT 2314 and PDT 2315.	333,333	24	
	HOP-PDT-2315		333,333	24	
	HOP-PDT-2319	ITS FAN DIFF. 1/2 PDT 2319 and PDT 2320.	333,333	24	
	HOP-PDT-2320		333,333	24	
	HOP-PDT-2348	ITS DIFF. 1/2 PDT 2348 and PDT 2349.	333,333	24	
	HOP-PDT-2349		333,333	24	
	HOP-PDT-2353	ITS DIFF. 1/2 PDT 2353 and PDT 2354.	333,333	24	
	HOP-PDT-2354		333,333	24	
	HOP-PDT-2358	ITS DIFF. 1/2 PDT 2358 and PDT 2359.	333,333	24	
	HOP-PDT-2359		333,333	24	
	HOP-PJM-00008	For PJM 8/9/10/11. Collectively, if X = 1, no action. If X > 1, fail HOP VSL 904. A component remains broken until at least two components are down. When this happens, the vessel is considered to be down.	100,000,000	42	Disabled in WTP OR Model.
	HOP-PJM-00009		100,000,000	42	Disabled in WTP OR Model.
	HOP-PJM-00010		100,000,000	42	Disabled in WTP OR Model.
	HOP-PJM-00011		100,000,000	42	Disabled in WTP OR Model.
	HOP-PT-2711	ITS - Demister Isolation.	333,333	24	
	HOP-PT-2713	ITS - Demister Isolation.	333,333	24	
	HOP-RE-3138/HOP-RT-3138	SDJ - Air Permit Function.	26,280	48	
	HOP-RX-3145	SDJ - Air Permit Function.	92,593	48	
	HOP-SCB-00002	No impact or not modeled at this time.	100,000,000	0	Disabled in WTP OR Model.
	HOP-TE-2299/HOP-JZ-2239	Heater control; Purge process air. Prevent overheating of HTR-00006.	66,667	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-TE-2302	Air Permit Function. HOP FAN 9ABC entrance.	1,000,000	24	
	HOP-TE-2331		43,800	12	
	HOP-TE-2331/HOP-TT-2331/HOP-TC-2331	CAT SKID HEATER OUT. Temperature Indication provides a control function to the cooling water system.	43,800	24	
	HOP-TE2336/HOP-TT-2336	NOx SCR OUT. ITS.	66,667	24	
	HOP-TE-2340/HOP-TT-2340/HOP-TI-2340	Air permit function. SILVER MORDENITE INLET.	66,667	24	
	HOP-TE-2399	HEAT EXCHANGER INLET Temperature. ITS items.	1,000,000	24	
	HOP-TE-2514/HOP-TT-2514	SCO PREHEATER HOUSING TEMP. ITS.	66,667	24	
	HOP-TT-2331		43,800	12	
	HOP-TV-2105B		43,800	12	
	HOP-WESP-00002	WESP unit. Life of plant item.	350,400		
	HOP-YV-2121	MLTR 1 SBS EJCTR PRCS AIR. 1/2 of YV 2121 and YV 2128.	43,800	24	
	HOP-YV-2128		43,800	24	
	HOP-YV-2133	MLTR 2 SBS EJCTR DEMIN. 1/2 of YV 2133 and YV 2134.	43,800	24	
	HOP-YV-2134		43,800	24	
	HOP-YV-2146	MLTR 2 SBS SIPHON BREAK. 1/2 YV 2146 and YV 2147.	43,800	24	
	HOP-YV-2147		43,800	24	
	HOP-YV-2504	AMMONIA INLET ISOLATION. ITS.	43,800	48	
	HOP-YV-2710	ITS - Demister Isolation.	43,800	24	
	HOP-YV-2712	ITS - Demister Isolation.	43,800	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	LVE-PSUP-30007	Air Permit Function. WESP Power Supply, which is expected to last seven years. Can be inspected or change during melter changeout.	61,320	168	
	HOP-AE-2804/HOP-AT-2804	All 12 instruments (HOP-AE/AT-2843, HOP-AE/AT-2804, HOP-YV-2809, HOP-AE/AT-2807, HOP-YV-2813, HOP-YV-2817, HOP-YV-2811, HOP-YV-2398, HOP-YV-2815, HOP-YV-2818, HOP-AE/AT-2826, and HOP-AE/AT-2808) must work, or idle HLW Melter 2.	26,280	48	
	HOP-AE-2807/HOP-AT-2807		26,280	48	
	HOP-AE-2808/HOP-AT-2808		26,280	48	
	HOP-AE-2826/HOP-AT-2826		26,280	48	
	HOP-AE-2843/HOP-AT-2843		26,280	48	
	HOP-YV-2398		43,800	48	
	HOP-YV-2809		43,800	48	
	HOP-YV-2811		43,800	48	
	HOP-YV-2813		43,800	48	
	HOP-YV-2815		43,800	48	
	HOP-YV-2817		43,800	48	
	HOP-YV-2818		43,800	48	
	HOP-FAN-00010A	Stack Extraction Fan.	87,600	48	Two out of three (FAN/ASD/YV) sets are needed to keep Melter 2 operational; otherwise Melter 2 will be disabled. Set A includes HOP-FAN-00010A,
	HOP-FAN-00010A ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00010B	Stack Extraction Fan.	87,600	48	
	HOP-FAN-00010B ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00010C	Stack Extraction Fan.	87,600	48	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-FAN-00010C ASD	Booster extraction fan variable speed drive.	100,000	48	HOP-FAN-00010A ASD and HOP-YV-2350; Set B includes HOP-FAN-00010B, HOP-FAN-00010B ASD and HOP-YV-2355; and Set C includes HOP-FAN-00010C, HOP-FAN-00010C ASD and HOP-YV-2360.
	HOP-YV-2350	ITS DISCHARGE CONTROL. Outlet of FAN 00010A.	43,800	48	
	HOP-YV-2355	ITS DISCHARGE CONTROL. Outlet of FAN 00010B.	43,800	48	
	HOP-YV-2360	ITS DISCHARGE CONTROL. Outlet of FAN 00010C.	43,800	48	
	HOP-FAN-00009A	Stack Extraction Fan.	87,600	48	Two out of three (FAN/ASD) sets are needed to keep Melter 2 operational; otherwise Melter 2 will be disabled. Set A includes HOP-FAN-00009A and HOP-FAN-00009A ASD; Set B includes HOP-FAN-00009B and HOP-FAN-00009B ASD; and Set C includes HOP-FAN-00009C and HOP-FAN-00009C ASD.
	HOP-FAN-00009A ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00009B	Stack Extraction Fan.	87,600	48	
	HOP-FAN-00009B ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-FAN-00009C	Stack Extraction Fan.	87,600	48	
	HOP-FAN-00009C ASD	Booster extraction fan variable speed drive.	100,000	48	
	HOP-HEME-00002A	If one of two trains, Train A or Train B, is not completely available, then idle HLW Melter 2. (Train A: HOP-TE/TT-2250, HOP-LT-2216, HOP-PDT-2215, and HOP-HEME-00002A.; Train B: HOP-TE/TT-2255, HOP-LT-2229,	43,800	72	
	HOP-HEME-00002B		43,800	72	
	HOP-LT-2216		40,000	24	
	HOP-LT-2229		40,000	24	
	HOP-PDT-2215		333,333	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-PDT-2228	HOP-PDT-2228, and HOP-HEME-00002B).	333,333	24	
	HOP-TE-2250/HOP-TT-2250		43,800	24	
	HOP-TE-2255/HOP-TT-2255		43,800	24	
	HOP-HEPA-00007A	If one of two trains, Train A or Train B, is not completely available, then idle HLW Melter 2. Train A is considered available if the following components are working: HOP-HTR-00005A, HOP-HEPA-00007A/8A, HOP-TE-2283/2218/2284/2285,2220, (HOP-PDT-2223 or HOP-PDT 2222), and (HOP-PDI-2210 or HOP-PDI-2211). Train B is considered available if the following components are working: HOP-HTR-00005B, HOP-HEPA-00007B/8B, HOP-TE-2286/2231/2287/2288/2233, (HOP-PDT-2236 or HOP-PDT-2235), and (HOP-PDI-2212 or HOP-PDI-2213). In addition, HOP-HTR-00005A and HOP-HTR-00005B contain 45 heating elements each. Both heaters require a total of 34 out of 45 heating elements to be functional. The time between failures for each heating element is 43,800 hours.	43,800	72	
	HOP-HEPA-00007B		43,800	72	
	HOP-HEPA-00008A		43,800	72	
	HOP-HEPA-00008B		43,800	72	
	HOP-HTR-00005A		130,378	72	
	HOP-HTR-00005B		130,378	72	
	HOP-PDI-2210		100,000	24	
	HOP-PDI-2211		100,000	24	
	HOP-PDI-2212		100,000	24	
	HOP-PDI-2213		100,000	24	
	HOP-PDT-2222		333,333	24	
	HOP-PDT-2223		333,333	24	
	HOP-PDT-2235		333,333	24	
	HOP-PDT-2236		333,333	24	
	HOP-TE-2218		1,000,000	24	
	HOP-TE-2220		1,000,000	24	
	HOP-TE-2231		1,000,000	24	
	HOP-TE-2233		1,000,000	24	
	HOP-TE-2283		1,000,000	24	
	HOP-TE-2284		1,000,000	24	
	HOP-TE-2285		1,000,000	24	
	HOP-TE-2286		1,000,000	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HOP-TE-2287		1,000,000	24	
	HOP-TE-2288		1,000,000	24	
	HOP-SCO-00004	Thermal Catalytic Oxidizer. Failure of the Catalytic Thermal Oxidizer will allow the escape of untreated exhaust gases through the stack.	8760	72	The original 26280 / 336 RAM data for HOP-SCR-00002 and HOP-SCO-00004 is not reasonable. It's too short for equipment RAM, and too long for bed change. Therefore, it was assumed that the equipment has a life of five years and is changed out during melter maintenance. Bed Replacement - HOP-SCR-00002 and HOP-SCO-00004 will be replaced at the same time (only one MTTR instead of two separate MTTRs will be used).
	HOP-SCR-00002	NOx Selective Catalytic Reducer. Failure of the Catalytic NOx Scrubber will allow the escape of untreated exhaust gases through the stack.	100,000,000	72	
HOP-VSL-00903 HOP-VSL-00904	HOP-PCJ-PNL	Use **50 %** uniform distribution to fail HOP VSL 903/904.	17,159	8	

4.4 System HDH: HLW Canister Decontamination Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HDH-CRN-00005	HDH-CRN-00005	6 TON OVERHEAD CRANE	87,600	96	
	HDH-CRN-00005 MAINT A	MAINTENANCE (Annually)	8760	96	
	HDH-CRN-00005 MAINT D	MAINTENANCE (Daily)	24	1	
	HDH-CRN-00005 MAINT Q	MAINTENANCE (Quarterly)	2190	24	
	HDH-DRIV-00002	DECONTAMINATION CAVE IMPORT HATCH THROUGH WALL DRIVE	87,600	24	
	HDH-DRIV-00003		87,600	24	
	HDH-HTCH-00003	HATCH, CANISTER HANDLING CAVE EXPORT (FRACTIONAL HORSEPOWER ELECTRIC MOTORS USED AS LIMIT SWITCHES ARE SHOWN INDIVIDUALLY)	87,600	192	
	HDH-HTCH-00004	HATCH, DECON CAVE IMPORT	87,600	192	
HDH-TRLY-00003	HDH-MHAN-00017	BOGIE POWER TRACK SYSTEM WATER	43,800	96	
	HDH-PMP-00001	BOGIE DECON CANISTER PUMP	43,800	96	
	HDH-RAIL-00004	CANISTER RINSE TUNNEL BOGIE SEISMIC RAILS	175,200	168	
	HDH-TRLY-00003	CANISTER RINSE BOGIE	43,800	48	
	HDH-TRLY-00003 MAINT A	MAINTENANCE (Annually)	8760	36	
	HDH-YV-0131	RINSE VSL WASH CTRL	43,800	24	
	HDH-YV-0133	RINSE VSL SL CTRL VLV	43,800	24	
	HDH-YV-0136	H2 PEROXIDE ADD CNTRL	43,800	24	
	HDH-YV-0159	RINSE VSL UPPER WASH CTRL	43,800	24	
	HDH-YV-0160	RINSE VSL BOT WASH CTRL	43,800	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HDH-YV-0182	RINSE VSL DRN VLV	43,800	24	
	HDH-ZS-2803	RINSE BGE POSN	17,520	48	
	HDH-ZS-2804	RINSE BGE POSN RAMP DOWN	17,520	48	
HDH-TRLY-00004	HDH-HTCH-00002	DECON CAVE EXPORT HATCH (FRACTIONAL HORSEPOWER ELECTRIC MOTORS USED AS LIMIT SWITCHES ARE SHOWN INDIVIDUALLY)	87,600	192	
	HDH-TRLY-00004	STORAGE TRANSFER TUNNEL BOGIE	43,800	48	
	HDH-TRLY-00004 MAINT A	MAINTENANCE (Annually)	8760	12	
	HDH-ZS-3003	STOR XFR BGE POSN	17,520	48	
	HDH-ZS-3004	STOR XFR BGE POSN	17,520	48	
HDH-TTBL-00001	HDH-DRIV-00004	THRU WALL DRIVE CANISTER SWABBING TURNTABLE (ASSUME FRACTIONAL HORSEPOWER ELECTRIC MOTOR)	9524	72	
	HDH-DRIV-00007	MANIPULATOR ELEVATOR THRU WALL DRIVE	17,520	24	
	HDH-MANIP-00001	DECONTAMINATION CAVE SWABBING TELEROBOTIC MANIPULATOR	6935	16	
	HDH-MANIP-00004	DECONTAMINATION CAVE SWABBING MASTER SLAVE MANIPULATOR (MSM)	6935	6	
	HDH-MHAN-00001	GLOVE BOX & SWAB POSTING BOX (INTEGRAL UNIT)	1460	12	
	HDH-TTBL-00001	CANISTER SWABBING TURNTABLE H33107	4441	72	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HDH-TWDVC-00002	DECONTAMINATION CAVE POSTING PORT	1460	12	
	HDH-ZS-4305	PMANIP ELEV ULTRSD	87,600	12	
	HDH-ZS-4306	PMANIP ELEV ULTLWRD	87,600	72	
	HDH-ZS-4307	HDH ROBOT ARM MANIPULATOR PROXIMITY SWITCHES	100,000,000	72	Disabled in WTP OR Model.
	HDH-ZS-4308	HDH ROBOT ARM MANIPULATOR PROXIMITY SWITCHES	100,000,000	72	Disabled in WTP OR Model.
HDH-VSL-00002	HDH-DRIV-00001	DECONTAMINATION CAVE DECON VESSEL LID SOUTH THROUGH WALL DRIVE	87,600	24	
	HDH-HX-0001	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	131,400	120	
	HDH-LT-0118	CSTR DECON VSL LVL	87,600	6	
	HDH-PMP-0026	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	43,800	24	
	HDH-PT-0129	DECON VSL	87,600	12	
	HDH-ST-00002	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	87,600	24	
	HDH-ST-00004	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	87,600	24	
	HDH-TE-0119	DECON VSL TEMP	87,600	6	
	HDH-TE-0146	CANISTER DECON VSL TEMP	87,600	6	
	HDH-TT-0119	DECON VSL TEMP	87,600	6	
	HDH-TT-0146	CANISTER DECON VSL TEMP	87,600	6	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HDH-TV-0119B	HDH HOT WATER SKID - Line 1.	43,800	24	
	HDH-VSL-00002	CANISTER DECON VESSEL	350,000		
	HDH-YV-0110	DECON VSL, DIW, IN	43,800	24	
	HDH-YV-0111	HNO3 ADD TK, HNO3, XFR	43,800	24	
	HDH-YV-0116	HNO3 ADD TK, HNO3, XFR	43,800	24	
	HDH-YV-0132	VALVE - ON/OFF BALL (2-WAY)	100,000,000	24	Disabled in WTP OR Model (Original MTBF = 43,800).
	HDH-YV-0177	DECON VSL SPARGE VLV	43,800	24	
	HDH-YV-0178	DECON VSL CERIUM HNO3 ADD VLV	43,800	24	
	HDH-YV-0192	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	43,800	24	
	HDH-YV-0401	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	43,800	24	
	HDH-YV-0416	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	43,800	24	
	HDH-YV-0417	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	43,800	24	
	HDH-YV-0418	HDH Hot Water Skid - Line 1. Impact modeled as a breakdown of HDH-VSL-00002	43,800	24	
HDH-VSL-00003	HDH-LT-0125	WST NEUT VSL LVL	87,600	6	
	HDH-TE-0126	WST NEUT VSL TEMP	87,600	6	
	HDH-TT-0126	WST NEUT VSL TEMP	87,600	6	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HDH-VSL-00003	CANISTER DECON VESSEL	350,000		
	HDH-YV-0179	NEUT VSL NAOH ADD VLV	43,800	24	
HDH-VSL-00004	HDH-DRIV-00008	DECONTAMINATION CAVE DECON VESSEL LID NORTH THROUGH WALL DRIVE	87,600	24	
	HDH-HX-0002	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	131,400	120	
	HDH-LT-0218	DECON VSL LVL	87,600	6	
	HDH-PMP-0027	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	43,800	24	
	HDH-PT-0229	DECON VSL PRESS	87,600	12	
	HDH-ST-00003	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	87,600	24	
	HDH-ST-00005	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	87,600	24	
	HDH-TE-0219	DECON VSL TEMP	87,600	6	
	HDH-TE-0246	DECON VSL TEMP	87,600	6	
	HDH-TT-0219	DECON VSL TEMP	87,600	6	
	HDH-TT-0246	DECON VSL TEMP	87,600	6	
	HDH-TV-0219B	HDH HOT WATER SKID - Line 2.	43,800	24	
	HDH-VSL-00004	CANISTER DECON VESSEL	350,000		
	HDH-YV-0210		100,000,000	24	Disabled in WTP OR Model
	HDH-YV-0212	DECON VSL CE4+ ADD CNTL	43,800	24	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HDH-YV-0216		100,000,000	24	Disabled in WTP OR Model
	HDH-YV-0232	VALVE - ON/OFF BALL (2-WAY)	100,000,000	24	Disabled in WTP OR Model (Original MTBF = 43,800).
	HDH-YV-0277	DECON VSL PA CNTL	43,800	24	
	HDH-YV-0278		43,800	24	
	HDH-YV-0292	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	43,800	24	
	HDH-YV-0501	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	43,800	24	
	HDH-YV-0516	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	43,800	24	
	HDH-YV-0517	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	43,800	24	
	HDH-YV-0518	HDH Hot Water Skid - Line 2. Impact modeled as a breakdown of HDH-VSL-00004	43,800	24	

4.5 System HEH: HLW Canister Export Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HEH-CRN-00001	HEH-CRN-00001	TRUCK BAY CASK HANDLING CRANE (60 TON)	87,600	48	
	HEH-CRN-00001 MAINT D		24	1	
	HEH-CRN-00001 MAINT Q		2190	24	
	HEH-CRN-00001 MAINT A		8760	96	
HEH-CRN-00003	HEH-CRN-00003	EXPORT CAVE CRANE (6 TON)	87,600	96	
	HEH-CRN-00003 MAINT D		24	1	
	HEH-CRN-00003 MAINT Q		2190	24	
	HEH-CRN-00003 MAINT A		8760	96	
	HEH-HTCH-00003	EXPORT CAVE EXPORT HATCH	87,600	192	
HEH-HTCH-00004	HEH-HTCH-00004	EXPORT CAVE IMPORT HATCH	87,600	192	
HEH-MHAN-00002	HEH-MHAN-00002	CANISTER EXPORT CAVE CANISTER STORAGE RACK	350,400		
HEH-TRLY-00005	HEH-MANIP-00001	CANISTER EXPORT CAVE MASTER SLAVE MANIPULATOR	6570	6	
	HEH-TRLY-00005	CASK HANDLING TUNNEL BOGIE	350,400		Deactivated in OR model (MTBF=100,000,000)

4.6 System HPH: HLW Canister Pour Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HPH-TRLY-00001	HPH-DRIV-00001	BOGIE DRIVE TUNNEL 1-EAST	26,298	108	
	HPH-TRLY-00001	BOGIE CHAIN TUNNEL 1-EAST	26,298	108	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HPH-TRLY-00004	HPH-DRIV-00002	BOGIE DRIVE TUNNEL 1-WEST	26,298	108	
	HPH-TRLY-00004	BOGIE CHAIN TUNNEL 1-WEST	26,298	108	
HPH-TRLY-00010	HPH-DRIV-00005	BOGIE DRIVE TUNNEL 2-EAST	26,298	108	
	HPH-TRLY-00010	BOGIE CHAIN TUNNEL 2-EAST	26,298	108	
HPH-TRLY-00011	HPH-DRIV-00006	BOGIE DRIVE TUNNEL 2-WEST	26,298	108	
	HPH-TRLY-00011	BOGIE CHAIN TUNNEL 2-WEST	26,298	108	
HPH-WELD-00005	HPH-WELD-00004	HPH CANISTER WELDER - EAST.	8760	12	
	HPH-WELD-00005		4380	48	
	HPH-WELD-00014	HPH CANISTER WELDER - EAST.	4380	48	
	Weld Torch East MAINT	HPH CANISTER WELDER - EAST.		1	The MTBM is based on the number of canisters rather than time (once every 10 canisters).
HPH-WELD-00009	HPH-WELD-00009		4380	48	
	HPH-WELD-00010	HPH CANISTER WELDER - WEST.	8760	12	
	HPH-WELD-00015	HPH CANISTER WELDER - WEST.	4380	48	
	Weld Torch West MAINT	HPH CANISTER WELDER - WEST.		1	The MTBM is based on the number of canisters rather than time (once every 10 canisters).

4.7 System HRH: HLW Canister Receipt Handling

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
HRH-CRN-00002	HRH-CRN-00002 MAINT D	Maintenance (daily)	24	1	
	HRH-CRN-00002 MAINT Q	Maintenance (quarterly)	2190	24	
	HRH-CRN-00002 MAINT A	Maintenance (annually)	8760	96	
HRH-HST-00001	HRH-HST-00001 MAINT D	Maintenance (daily)	24	1	
	HRH-HST-00001 MAINT Q	Maintenance (quarterly)	2190	24	
	HRH-HST-00001 MAINT A	Maintenance (annually)	8760	96	
	HRH-MHAN-00002	SYSTEM HRH CANISTER RACK	350,400		
	HRH-TOOL-00002	MECHANICAL SEQUENCE GRAPPLE	12,000	12	
HRH-TRLY-00002	HRH-TRLY-00002	CANISTER IMPORT BOGIE	350,400		
	HRH-TRLY-00002 MAINT D	Maintenance (daily)	24	1	
	HRH-TRLY-00002 MAINT Q	Maintenance (quarterly)	2190	24	
	HRH-TRLY-00002 MAINT A	Maintenance (annually)	8760	96	
	HRH-TRLY-00002_Motor	ELECTRICAL DRIVE MOTOR	43,800	48	
	HRH-TRLY-00002_Motor MAINT	Maintenance	8760	12	
HRH-TTBL-00001	HRH-TTBL-00001	CANISTER ROTATION/INSPECTION TABLE	350,400		
	HRH-TTBL-00001_Pump	CANISTER INSPECTION-ROTATION TABLE HYDRAULIC PUMP	33,333	12	

4.8 System NAR: Nitric Acid Reagent

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
NAR-TK-00001	NAR-TK-00001	NITRIC ACID DILUTION AND DISTRIBUTION TANK	350,400		
	NAR-PMP-00016-A	NITRIC ACID PUMP	43,800	48	

4.9 System SHR: Sodium Hydroxide Reagent

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
SHR-TK-00002	SHR-PMP-00013-A	SODIUM HYDROXIDE PUMP, 25 GPM	43,800	48	
	SHR-TK-00002	SODIUM HYDROXIDE STORAGE AND DISTRIBUTION TANK	350,400		

5 Abnormal Events RAM Data

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
Process Variability	Process Variability	Uses a uniform distribution to fail only one system at a time: FRP, FEP, UFP, CXP, TLP, TCP, CNP, CRP, RDP, HLP, PWD, RLD.	973	36	
Internal Fire	Internal Fire - PT	PT	236,520	1008	
	Internal Fire - LAW	LAW	236,520	1008	
	Internal Fire - HLW	HLW	236,520	1008	
	Internal Fire - BOF	BOF	236,520	1008	
Loss of Off-site	LOSP - Short 1 - PT	PT	8760	12	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
Power (Short Duration)	LOSP - Short 1 - LAW	LAW	8760	12	
	LOSP - Short 1 - HLW	HLW	8760	12	
	LOSP - Short 1 - BOF	BOF	8760	12	
	LOSP - Short 1 - LAB	LAB	8760	12	
	LOSP - Short 2 - PT	PT	87,600	12	
	LOSP - Short 2 - LAW	LAW	87,600	12	
	LOSP - Short 2 - HLW	HLW	87,600	12	
	LOSP - Short 2 - BOF	BOF	87,600	12	
	LOSP - Short 2 - LAB	LAB	87,600	12	
Loss of Off-site Power (Extended Duration)	LOSP - Long - PT	PT	289,080	168	
	LOSP - Long - LAW	LAW	289,080	168	
	LOSP - Long - HLW	HLW	289,080	168	
	LOSP - Long - BOF	BOF	289,080	168	
	LOSP - Long - LAB	LAB	289,080	168	
Range Fire	Range Fire - PT	PT	43,800	48	
	Range Fire - HLW	HLW	43,800	48	

6 Autosampling System (ASX) RAM Data

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-12-ISO-1	ASX-12-ISO-1 BD	ASX SAMPLER 12 - ISOLOK 1 (LAW)	9004	2.62	
ASX-12-ISO-2	ASX-12-ISO-2 BD	ASX SAMPLER 12 - ISOLOK 2 (LAW)			Disabled in WTP OR Model

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-12-ISO-3	ASX-12-ISO-3 BD	ASX SAMPLER 12 - ISOLOK 3 (LAW)	9004	2.62	
ASX-12-ISO-4	ASX-12-ISO-4 BD	ASX SAMPLER 12 - ISOLOK 4 (LAW)	9004	2.62	
ASX-12-ISO-5	ASX-12-ISO-5 BD	ASX SAMPLER 12 - ISOLOK 5 (LAW)			Disabled in WTP OR Model
ASX-12-ISO-6	ASX-12-ISO-6 BD	ASX SAMPLER 12 - ISOLOK 6 (LAW)	9004	2.62	
ASX-13-ISO-1	ASX-13-ISO-1 BD	ASX SAMPLER 13 - ISOLOK 1 (LAW)	9004	2.62	
ASX-13-ISO-2	ASX-13-ISO-2 BD	ASX SAMPLER 13 - ISOLOK 2 (LAW)			Disabled in WTP OR Model
ASX-13-ISO-3	ASX-13-ISO-3 BD	ASX SAMPLER 13 - ISOLOK 3 (LAW)	9004	2.62	
ASX-13-ISO-4	ASX-13-ISO-4 BD	ASX SAMPLER 13 - ISOLOK 4 (LAW)	9004	2.62	
ASX-13-ISO-5	ASX-13-ISO-5 BD	ASX SAMPLER 13 - ISOLOK 5 (LAW)			Disabled in WTP OR Model
ASX-13-ISO-6	ASX-13-ISO-6 BD	ASX SAMPLER 13 - ISOLOK 6 (LAW)			Disabled in WTP OR Model
ASX-28-ISO-1	ASX-28-ISO-1 BD	ASX SAMPLER 28 - ISOLOK 1 (HLW)	9004	2.62	
ASX-28-ISO-2	ASX-28-ISO-2 BD	ASX SAMPLER 28 - ISOLOK 2 (HLW)	9004	2.62	
ASX-28-ISO-3	ASX-28-ISO-3 BD	ASX SAMPLER 28 - ISOLOK 3 (HLW)	9004	2.62	
ASX-28-ISO-4	ASX-28-ISO-4 BD	ASX SAMPLER 28 - ISOLOK 4 (HLW)	9004	2.62	
ASX-28-ISO-5	ASX-28-ISO-5 BD	ASX SAMPLER 28 - ISOLOK 5 (HLW)			Disabled in WTP OR Model

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-28-ISO-6	ASX-28-ISO-6 BD	ASX SAMPLER 28 - ISOLOK 6 (HLW)			Disabled in WTP OR Model
ASX-29-ISO-1	ASX-29-ISO-1 BD	ASX SAMPLER 29 - ISOLOK 1 (HLW)	9004	2.62	
ASX-29-ISO-2	ASX-29-ISO-2 BD	ASX SAMPLER 29 - ISOLOK 2 (HLW)	9004	2.62	
ASX-29-ISO-3	ASX-29-ISO-3 BD	ASX SAMPLER 29 - ISOLOK 3 (HLW)	9004	2.62	
ASX-29-ISO-4	ASX-29-ISO-4 BD	ASX SAMPLER 29 - ISOLOK 4 (HLW)			Disabled in WTP OR Model
ASX-29-ISO-5	ASX-29-ISO-5 BD	ASX SAMPLER 29 - ISOLOK 5 (HLW)			Disabled in WTP OR Model
ASX-29-ISO-6	ASX-29-ISO-6 BD	ASX SAMPLER 29 - ISOLOK 6 (HLW)			Disabled in WTP OR Model
ASX-42-ISO-1	ASX-42-ISO-1 BD	ASX SAMPLER 42 - ISOLOK 1 (HLW)	9004	2.62	
ASX-42-ISO-2	ASX-42-ISO-2 BD	ASX SAMPLER 42 - ISOLOK 2 (HLW)	9004	2.62	
ASX-42-ISO-3	ASX-42-ISO-3 BD	ASX SAMPLER 42 - ISOLOK 3 (HLW)	9004	2.62	
ASX-42-ISO-4	ASX-42-ISO-4 BD	ASX SAMPLER 42 - ISOLOK 4 (HLW)			Disabled in WTP OR Model
ASX-42-ISO-5	ASX-42-ISO-5 BD	ASX SAMPLER 42 - ISOLOK 5 (HLW)			Disabled in WTP OR Model
ASX-42-ISO-6	ASX-42-ISO-6 BD	ASX SAMPLER 42 - ISOLOK 6 (HLW)			Disabled in WTP OR Model
ASX-25-ISO-1	ASX-25-ISO-1 BD	ASX SAMPLER 25 - ISOLOK 1 (PT)	9004	2.62	
ASX-25-ISO-2	ASX-25-ISO-2 BD	ASX SAMPLER 25 - ISOLOK 2 (PT)	9004	2.62	
ASX-25-ISO-3	ASX-25-ISO-3 BD	ASX SAMPLER 25 - ISOLOK 3 (PT)	9004	2.62	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-25-ISO-4	ASX-25-ISO-4 BD	ASX SAMPLER 25 - ISOLOK 4 (PT)	9004	2.62	
ASX-25-ISO-5	ASX-25-ISO-5 BD	ASX SAMPLER 25 - ISOLOK 5 (PT)	9004	2.62	
ASX-25-ISO-6	ASX-25-ISO-6 BD	ASX SAMPLER 25 - ISOLOK 6 (PT)	9004	2.62	
ASX-15-ISO-1	ASX-15-ISO-1 BD	ASX SAMPLER 15 - ISOLOK 1 (PT)	9004	2.62	
ASX-15-ISO-2	ASX-15-ISO-2 BD	ASX SAMPLER 15 - ISOLOK 2 (PT)	9004	2.62	
ASX-15-ISO-3	ASX-15-ISO-3 BD	ASX SAMPLER 15 - ISOLOK 3 (PT)	9004	2.62	
ASX-15-ISO-4	ASX-15-ISO-4 BD	ASX SAMPLER 15 - ISOLOK 4 (PT)	9004	2.62	
ASX-15-ISO-5	ASX-15-ISO-5 BD	ASX SAMPLER 15 - ISOLOK 5 (PT)	9004	2.62	
ASX-15-ISO-6	ASX-15-ISO-6 BD	ASX SAMPLER 15 - ISOLOK 6 (PT)			Disabled in WTP OR Model
ASX-17-ISO-1	ASX-17-ISO-1 BD	ASX SAMPLER 17 - ISOLOK 1 (PT)	9004	2.62	
ASX-17-ISO-2	ASX-17-ISO-2 BD	ASX SAMPLER 17 - ISOLOK 2 (PT)	9004	2.62	
ASX-17-ISO-3	ASX-17-ISO-3 BD	ASX SAMPLER 17 - ISOLOK 3 (PT)	9004	2.62	
ASX-17-ISO-4	ASX-17-ISO-4 BD	ASX SAMPLER 17 - ISOLOK 4 (PT)	9004	2.62	
ASX-17-ISO-5	ASX-17-ISO-5 BD	ASX SAMPLER 17 - ISOLOK 5 (PT)	9004	2.62	
ASX-17-ISO-6	ASX-17-ISO-6 BD	ASX SAMPLER 17 - ISOLOK6 (PT)			Disabled in WTP OR Model
ASX-19-ISO-1	ASX-19-ISO-1 BD	ASX SAMPLER 19 - ISOLOK 1 (PT)	9004	2.62	
ASX-19-ISO-2	ASX-19-ISO-2 BD	ASX SAMPLER 19 - ISOLOK 2 (PT)	9004	2.62	
ASX-19-ISO-3	ASX-19-ISO-3 BD	ASX SAMPLER 19 - ISOLOK 3 (PT)	9004	2.62	
ASX-19-ISO-4	ASX-19-ISO-4 BD	ASX SAMPLER 19 - ISOLOK 4 (PT)	9004	2.62	
ASX-19-ISO-5	ASX-19-ISO-5 BD	ASX SAMPLER 19 - ISOLOK 5 (PT)	9004	2.62	
ASX-19-ISO-6	ASX-19-ISO-6 BD	ASX SAMPLER 19 - ISOLOK 6 (PT)	9004	2.62	
ASX-20-ISO-1	ASX-20-ISO-1 BD	ASX SAMPLER 20 - ISOLOK 1 (PT)	9004	2.62	
ASX-20-ISO-2	ASX-20-ISO-2 BD	ASX SAMPLER 20 - ISOLOK 2 (PT)	9004	2.62	
ASX-20-ISO-3	ASX-20-ISO-3 BD	ASX SAMPLER 20 - ISOLOK 3 (PT)	9004	2.62	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-20-ISO-4	ASX-20-ISO-4 BD	ASX SAMPLER 20 - ISOLOK 4 (PT)	9004	2.62	
ASX-20-ISO-5	ASX-20-ISO-5 BD	ASX SAMPLER 20 - ISOLOK 5 (PT)	9004	2.62	
ASX-20-ISO-6	ASX-20-ISO-6 BD	ASX SAMPLER 20 - ISOLOK 6 (PT)	9004	2.62	
ASX-SMPLR-00012	ASX-SMPLR-00012 BD	ASX SAMPLER 12 (LAW)	2503	1.076	
ASX-SMPLR-00013	ASX-SMPLR-00013 BD	ASX SAMPLER 13 (LAW)	2503	1.076	
ASX-SMPLR-00028	ASX-SMPLR-00028 BD	ASX SAMPLER 28 (HLW)	2503	1.076	
ASX-SMPLR-00029	ASX-SMPLR-00029 BD	ASX SAMPLER 29 (HLW)	2503	1.076	
ASX-SMPLR-00042	ASX-SMPLR-00042 BD	ASX SAMPLER 42 (HLW)	2503	1.076	
ASX-SMPLR-00025	ASX-SMPLR-00025 BD	ASX SAMPLER 25 (PT)	2503	1.076	
ASX-SMPLR-00015	ASX-SMPLR-00015 BD	ASX SAMPLER 15 (PT)	2503	1.076	
ASX-SMPLR-00017	ASX-SMPLR-00017 BD	ASX SAMPLER 17 (PT)	2503	1.076	
ASX-SMPLR-00019	ASX-SMPLR-00019 BD	ASX SAMPLER 19 (PT)	2503	1.076	
ASX-SMPLR-00020	ASX-SMPLR-00020 BD	ASX SAMPLER 20 (PT)	2503	1.076	
LAW Pneumatic Line	LAW Pneumatic Line BD	LAW PNEUMATIC LINE	706	2	
HLW Pneumatic Line	HLW Pneumatic Line BD	HLW PNEUMATIC LINE	706	2	
PT Pneumatic Line	PT Pneumatic Line BD	PT PNEUMATIC LINE	706	2	
ASX-SMPLR-00039	ASX-SMPLR-00039 BD	ASX SAMPLER 39	34,944	0.2	
ASX-SMPLR-00043	ASX-SMPLR-00043 BD	ASX SAMPLER 43	34,944	0.2	
ASX System	ASX System BD 1	ASX OVERALL SYSTEM BREAKDOWN	22,852	2	
ASX System	ASX System BD 2	ASX OVERALL SYSTEM BREAKDOWN	22,852	2	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-12-ISO-1	ASX-12-ISO-1 Setup	ASX SAMPLER 12 - ISOLOK 1 (LAW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-12-ISO-2	ASX-12-ISO-2 Setup	ASX SAMPLER 12 - ISOLOK 2 (LAW) SETUP			Disabled in WTP OR Model
ASX-12-ISO-3	ASX-12-ISO-3 Setup	ASX SAMPLER 12 - ISOLOK 3 (LAW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-12-ISO-4	ASX-12-ISO-4 Setup	ASX SAMPLER 12 - ISOLOK 4 (LAW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-12-ISO-5	ASX-12-ISO-5 Setup	ASX SAMPLER 12 - ISOLOK 5 (LAW) SETUP			Disabled in WTP OR Model
ASX-12-ISO-6	ASX-12-ISO-6 Setup	ASX SAMPLER 12 - ISOLOK 6 (LAW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-13-ISO-1	ASX-13-ISO-1 Setup	ASX SAMPLER 13 - ISOLOK 1 (LAW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-13-ISO-2	ASX-13-ISO-2 Setup	ASX SAMPLER 13 - ISOLOK 2 (LAW) SETUP			Disabled in WTP OR Model

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-13-ISO-3	ASX-13-ISO-3 Setup	ASX SAMPLER 13 - ISOLOK 3 (LAW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-13-ISO-4	ASX-13-ISO-4 Setup	ASX SAMPLER 13 - ISOLOK 4 (LAW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-13-ISO-5	ASX-13-ISO-5 Setup	ASX SAMPLER 13 - ISOLOK 5 (LAW) SETUP			Disabled in WTP OR Model
ASX-13-ISO-6	ASX-13-ISO-6 Setup	ASX SAMPLER 13 - ISOLOK 6 (LAW) SETUP			Disabled in WTP OR Model
ASX-28-ISO-1	ASX-28-ISO-1 Setup	ASX SAMPLER 28 - ISOLOK 1 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-28-ISO-2	ASX-28-ISO-2 Setup	ASX SAMPLER 28 - ISOLOK 2 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-28-ISO-3	ASX-28-ISO-3 Setup	ASX SAMPLER 28 - ISOLOK 3 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-28-ISO-4	ASX-28-ISO-4 Setup	ASX SAMPLER 28 - ISOLOK 4 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-28-ISO-5	ASX-28-ISO-5 Setup	ASX SAMPLER 28 - ISOLOK 5 (HLW) SETUP			Disabled in WTP OR Model
ASX-28-ISO-6	ASX-28-ISO-6 Setup	ASX SAMPLER 28 - ISOLOK 6 (HLW) SETUP			Disabled in WTP OR Model
ASX-29-ISO-1	ASX-29-ISO-1 Setup	ASX SAMPLER 29 - ISOLOK 1 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-29-ISO-2	ASX-29-ISO-2 Setup	ASX SAMPLER 29 - ISOLOK 2 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-29-ISO-3	ASX-29-ISO-3 Setup	ASX SAMPLER 29 - ISOLOK 3 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-29-ISO-4	ASX-29-ISO-4 Setup	ASX SAMPLER 29 - ISOLOK 4 (HLW) SETUP			Disabled in WTP OR Model
ASX-29-ISO-5	ASX-29-ISO-5 Setup	ASX SAMPLER 29 - ISOLOK 5 (HLW) SETUP			Disabled in WTP OR Model
ASX-29-ISO-6	ASX-29-ISO-6 Setup	ASX SAMPLER 29 - ISOLOK 6 (HLW) SETUP			Disabled in WTP OR Model

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-42-ISO-1	ASX-42-ISO-1 Setup	ASX SAMPLER 42 - ISOLOK 1 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-42-ISO-2	ASX-42-ISO-2 Setup	ASX SAMPLER 42 - ISOLOK 2 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-42-ISO-3	ASX-42-ISO-3 Setup	ASX SAMPLER 42 - ISOLOK 3 (HLW) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-42-ISO-4	ASX-42-ISO-4 Setup	ASX SAMPLER 42 - ISOLOK 4 (HLW) SETUP			Disabled in WTP OR Model
ASX-42-ISO-5	ASX-42-ISO-5 Setup	ASX SAMPLER 42 - ISOLOK 5 (HLW) SETUP			Disabled in WTP OR Model
ASX-42-ISO-6	ASX-42-ISO-6 Setup	ASX SAMPLER 42 - ISOLOK 6 (HLW) SETUP			Disabled in WTP OR Model
ASX-25-ISO-1	ASX-25-ISO-1 Setup	ASX SAMPLER 25 - ISOLOK 1 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-25-ISO-2	ASX-25-ISO-2 Setup	ASX SAMPLER 25 - ISOLOK 2 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-25-ISO-3	ASX-25-ISO-3 Setup	ASX SAMPLER 25 - ISOLOK 3 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-25-ISO-4	ASX-25-ISO-4 Setup	ASX SAMPLER 25 - ISOLOK 4 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-25-ISO-5	ASX-25-ISO-5 Setup	ASX SAMPLER 25 - ISOLOK 5 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-25-ISO-6	ASX-25-ISO-6 Setup	ASX SAMPLER 25 - ISOLOK 6 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-15-ISO-1	ASX-15-ISO-1 Setup	ASX SAMPLER 15 - ISOLOK 1 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-15-ISO-2	ASX-15-ISO-2 Setup	ASX SAMPLER 15 - ISOLOK 2 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-15-ISO-3	ASX-15-ISO-3 Setup	ASX SAMPLER 15 - ISOLOK 3 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-15-ISO-4	ASX-15-ISO-4 Setup	ASX SAMPLER 15 - ISOLOK 4 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-15-ISO-5	ASX-15-ISO-5 Setup	ASX SAMPLER 15 - ISOLOK 5 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-15-ISO-6	ASX-15-ISO-6 Setup	ASX SAMPLER 15 - ISOLOK 6 (PT) SETUP			Disabled in WTP OR Model
ASX-17-ISO-1	ASX-17-ISO-1 Setup	ASX SAMPLER 17 - ISOLOK 1 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-17-ISO-2	ASX-17-ISO-2 Setup	ASX SAMPLER 17 - ISOLOK 2 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-17-ISO-3	ASX-17-ISO-3 Setup	ASX SAMPLER 17 - ISOLOK 3 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-17-ISO-4	ASX-17-ISO-4 Setup	ASX SAMPLER 17 - ISOLOK 4 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-17-ISO-5	ASX-17-ISO-5 Setup	ASX SAMPLER 17 - ISOLOK 5 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-17-ISO-6	ASX-17-ISO-6 Setup	ASX SAMPLER 17 - ISOLOK6 (PT) SETUP			Disabled in WTP OR Model
ASX-19-ISO-1	ASX-19-ISO-1 Setup	ASX SAMPLER 19 - ISOLOK 1 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-19-ISO-2	ASX-19-ISO-2 Setup	ASX SAMPLER 19 - ISOLOK 2 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-19-ISO-3	ASX-19-ISO-3 Setup	ASX SAMPLER 19 - ISOLOK 3 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-19-ISO-4	ASX-19-ISO-4 Setup	ASX SAMPLER 19 - ISOLOK 4 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-19-ISO-5	ASX-19-ISO-5 Setup	ASX SAMPLER 19 - ISOLOK 5 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-19-ISO-6	ASX-19-ISO-6 Setup	ASX SAMPLER 19 - ISOLOK 6 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-20-ISO-1	ASX-20-ISO-1 Setup	ASX SAMPLER 20 - ISOLOK 1 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-20-ISO-2	ASX-20-ISO-2 Setup	ASX SAMPLER 20 - ISOLOK 2 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-20-ISO-3	ASX-20-ISO-3 Setup	ASX SAMPLER 20 - ISOLOK 3 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-20-ISO-4	ASX-20-ISO-4 Setup	ASX SAMPLER 20 - ISOLOK 4 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
ASX-20-ISO-5	ASX-20-ISO-5 Setup	ASX SAMPLER 20 - ISOLOK 5 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.
ASX-20-ISO-6	ASX-20-ISO-6 Setup	ASX SAMPLER 20 - ISOLOK 6 (PT) SETUP	167	0.55	The value in the MTBF/MTBM column represents the number of samples between setups.

7 Glass Former RAM Data

7.1 Abbreviations

The following is a list of shortcuts/abbreviations used to create component tag names and affected equipment names for all the breakdown profiles used in the Glass Former Module of the WTP OR Model.

Shortcut	Module Name
GF	GlassFormer
SYSxxx	Systemxxx
LAWdust	LAWdustmitigation
HLWdust	HLWdustmitigation
InertFill	InertFill
SwitchCtrl	SwitchControl
Cv	ConveyBreakdowns
Ds	DynaslideBreakdowns
Sl	SiloBreakdowns
Tp	TransporterBreakdowns

Shortcut	Module Name
BA	BoricAcid
CS	CalciumSilicate
Ky	Kyanite
Su	Sucrose
LC	LithiumCarbonate
ZO	ZincOxide
Bo	Borax
SC	SodiumCarbonate
IO	IronOxide
MS	MagnesiumSilicate

Shortcut	Module Name
Wh	WeighHopperBreakdowns
Bl	BlenderBreakdowns

Shortcut	Module Name
TD	TitaniumDioxide
ZS	ZirconiumSilicate

7.2 Main Module

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-S100-21	GF-S100-21	43,800	18	
	GF-S100-21 Clean	GF-S100-21	4320	0.5	
	GF-S100-22	GF-S100-22	43,800	18	
	GF-S100-22 Clean	GF-S100-22	4320	0.5	
	GF-S1-1	GF-S1-1	43,800	18	
	GF-S1-1 Clean	GF-S1-1	4320	0.5	
	GF-S1-2	GF-S1-2	43,800	18	
	GF-S1-2 Clean	GF-S1-2	4320	0.5	
	GF-S1-3	GF-S1-3	43,800	18	
	GF-S1-3 Clean	GF-S1-3	4320	1	
	GF-S200-21	GF-S200-21	43,800	18	
	GF-S200-21 Clean	GF-S200-21	4320	0.5	
	GF-S200-22	GF-S200-22	43,800	18	
	GF-S200-22 Clean	GF-S200-22	4320	0.5	
	GF-S2-1	GF-S2-1	43,800	18	
	GF-S2-1 Clean	GF-S2-1	4320	0.5	
	GF-S2-2	GF-S2-2	43,800	18	
	GF-S2-2 Clean	GF-S2-2	4320	0.5	
	GF-S300-21	GF-S300-21	43,800	18	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-S300-21 Clean	GF-S300-21	4320	0.5	
	GF-S300-22	GF-S300-22	43,800	18	
	GF-S300-22 Clean	GF-S300-22	4320	0.5	
	GF-S3-1	GF-S3-1	43,800	18	
	GF-S3-1 Clean	GF-S3-1	4320	0.5	
	GF-S3-2	GF-S3-2	43,800	18	
	GF-S3-2 Clean	GF-S3-2	4320	0.5	
	GF-S400-21	GF-S400-21	43,800	18	
	GF-S400-21 Clean	GF-S400-21	4320	0.5	
	GF-S400-22	GF-S400-22	43,800	18	
	GF-S400-22 Clean	GF-S400-22	4320	0.5	
	GF-S4-1	GF-S4-1	43,800	18	
	GF-S4-1 Clean	GF-S4-1	4320	0.5	
	GF-S4-2	GF-S4-2	43,800	18	
	GF-S4-2 Clean	GF-S4-2	4320	0.5	
	GF-S5-1	GF-S5-1	43,800	18	
	GF-S5-1 Clean	GF-S5-1	4320	0.5	

7.3 System 100 - Weighing System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS100-DynaslideValve	GF-SYS100-DynaslideValve	43,800	14	
	GF-SYS100-TransporterValve	GF-SYS100-TransporterValve	43,800	14	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS100-WeighHopperValve	GF-SYS100-WeighHopperValve	43,800	14	
	GF-SYS100-Transporter	GF-SYS100-Transporter	26,280	15	
	GF-SYS100-WeighHopper	GF-SYS100-WeighHopper	43,800	14	
	GF-SYS100-Dynaslide	GF-SYS100-Dynaslide	35,040	15	
	GF-SYS100-Pipe001	GF-SYS100-Pipe001	43,800	18	
	GF-SYS100-Pipe001 Clean	GF-SYS100-Pipe001	4320	0.5	
	GF-SYS100-Cv-BlendBends	GF-S100-21, GF-S100-22	17,520	18	
	GF-SYS100-Cv-BlendBends Maint	GF-S100-21, GF-S100-22	4320	0.5	
	GF-SYS100-Cv-FirstBends	GF-SYS100-Pipe001	17,520	18	
	GF-SYS100-Cv-FirstBends Maint	GF-SYS100-Pipe001	4320	0.5	
	GF-SYS100-Cv-SecondBends	GF-S1-1, GF-S1-2	17,520	18	
	GF-SYS100-Cv-SecondBends Maint	GF-S1-1, GF-S1-2	4320	0.5	
	GF-SYS100-Ds-DS Maint	GF-SYS100-Dynaslide	4320	0.5	
	GF-SYS100-Ds-DS Outlet Maint	GF-SYS100-Dynaslide	4320	0.5	
	GF-SYS100-Sl-Silo	GF-SYS100-Silo	43,800	14	
	GF-SYS100-Sl-Silo DF Maint	GF-SYS100-Silo	4320	1	
	GF-SYS100-Sl-Silo DF	GF-SYS100-Silo	26,280	14	
	GF-SYS100-Sl-Silo Maint	GF-SYS100-Silo	4320	2	
	GF-SYS100-Tp-Tran Inlet Maint	GF-SYS100-Transporter	4320	0.5	
	GF-SYS100-Tp-Tran Maint	GF-SYS100-Transporter	4320	1	
	GF-SYS100-Wh-WeighHopper DF	GF-SYS100-WeighHopper	26,280	14	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS100-Wh-WeighHopper DF Maint	GF-SYS100-WeighHopper	4320	1	
	GF-SYS100-Wh-WeighHopper Maint	GF-SYS100-WeighHopper	4320	2	
	GF-SYS100-Wh-WeighHopper Out Maint	GF-SYS100-WeighHopper	4320	0.5	

7.4 System 200 - Weighing System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS200-TransporterValve	GF-SYS200-TransporterValve	43,800	14	
	GF-SYS200-WeighHopperValve	GF-SYS200-WeighHopperValve	43,800	14	
	GF-SYS200-Transporter	GF-SYS200-Transporter	26,280	15	
	GF-SYS200-WeighHopper	GF-SYS200-WeighHopper	43,800	14	
	GF-SYS200-Pipe001	GF-SYS200-Pipe001	43,800	18	
	GF-SYS200-Pipe001 Clean	GF-SYS200-Pipe001	4320	0.5	
	GF-SYS200-BA-DynaslideValve	GF-SYS200-BA-DynaslideValve	43,800	14	
	GF-SYS200-BA-Dynaslide	GF-SYS200-BA-Dynaslide	35,040	15	
	GF-SYS200-BA-Ds-DS Maint	GF-SYS200-BA-Dynaslide	4320	0.5	
	GF-SYS200-BA-Ds-DS Outlet Maint	GF-SYS200-BA-Dynaslide	4320	0.5	
	GF-SYS200-BA-Sl-Silo	GF-SYS200-BA-Silo	43,800	14	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS200-BA-Sl-Silo DF Maint	GF-SYS200-BA-Silo	4320	1	
	GF-SYS200-BA-Sl-Silo DF	GF-SYS200-BA-Silo	26,280	14	
	GF-SYS200-BA-Sl-Silo Maint	GF-SYS200-BA-Silo	4320	2	
	GF-SYS200-CS-DynaslideValve	GF-SYS200-CS-DynaslideValve	43,800	14	
	GF-SYS200-CS-Dynaslide	GF-SYS200-CS-Dynaslide	35,040	15	
	GF-SYS200-CS-Ds-DS Maint	GF-SYS200-CS-Dynaslide	4320	0.5	
	GF-SYS200-CS-Ds-DS Outlet Maint	GF-SYS200-CS-Dynaslide	4320	0.5	
	GF-SYS200-CS-Sl-Silo	GF-SYS200-CS-Silo	43,800	14	
	GF-SYS200-CS-Sl-Silo DF Maint	GF-SYS200-CS-Silo	4380	1	
	GF-SYS200-CS-Sl-Silo DF	GF-SYS200-CS-Silo	26,280	14	
	GF-SYS200-CS-Sl-Silo Maint	GF-SYS200-CS-Silo	4380	2	
	GF-SYS200-Cv-BlendBends	GF-S200-21, GF-S200-22	17,520	18	
	GF-SYS200-Cv-BlendBends Maint	GF-S200-21, GF-S200-22	4320	0.5	
	GF-SYS200-Cv-FirstBends	GF-SYS200-Pipe001	17,520	18	
	GF-SYS200-Cv-FirstBends Maint	GF-SYS200-Pipe001	4320	0.5	
	GF-SYS200-Cv-SecondBends	GF-S2-1, GF-S2-2	17,520	18	
	GF-SYS200-Cv-SecondBends Maint	GF-S2-1, GF-S2-2	4320	0.5	
	GF-SYS200-Ky-DynaslideValve	GF-SYS200-Ky-DynaslideValve	43,800	14	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS200-Ky-Dynaslide	GF-SYS200-Ky-Dynaslide	35,040	15	
	GF-SYS200-Ky-Ds-DS Maint	GF-SYS200-Ky-Dynaslide	4320	0.5	
	GF-SYS200-Ky-Ds-DS Outlet Maint	GF-SYS200-Ky-Dynaslide	4320	0.5	
	GF-SYS200-Ky-Sl-Silo	GF-SYS200-Ky-Silo	43,800	14	
	GF-SYS200-Ky-Sl-Silo DF Maint	GF-SYS200-Ky-Silo	4380	1	
	GF-SYS200-Ky-Sl-Silo DF	GF-SYS200-Ky-Silo	26,280	14	
	GF-SYS200-Ky-Sl-Silo Maint	GF-SYS200-Ky-Silo	4380	2	
	GF-SYS200-Su-DynaslideValve	GF-SYS200-Su-DynaslideValve	43,800	14	
	GF-SYS200-Su-Dynaslide	GF-SYS200-Su-Dynaslide	35,040	15	
	GF-SYS200-Su-Ds-DS Maint	GF-SYS200-Su-Dynaslide	4320	0.5	
	GF-SYS200-Su-Ds-DS Outlet Maint	GF-SYS200-Su-Dynaslide	4280	0.5	
	GF-SYS200-Su-Sl-Silo	GF-SYS200-Su-Silo	43,800	14	
	GF-SYS200-Su-Sl-Silo DF Maint	GF-SYS200-Su-Silo	4320	1	
	GF-SYS200-Su-Sl-Silo DF	GF-SYS200-Su-Silo	26,280	14	
	GF-SYS200-Su-Sl-Silo Maint	GF-SYS200-Su-Silo	4320	2	
	GF-SYS200-Tp-Tran Inlet Maint	GF-SYS200-Transporter	4320	0.5	
	GF-SYS200-Tp-Tran Maint	GF-SYS200-Transporter	4320	1	
	GF-SYS200-Wh-WeighHopper DF	GF-SYS200-WeighHopper	26,280	14	
	GF-SYS200-Wh-WeighHopper DF Maint	GF-SYS200-WeighHopper	4320	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS200-Wh-WeighHopper Maint	GF-SYS200-WeighHopper	4320	2	
	GF-SYS200-Wh-WeighHopper Out Maint	GF-SYS200-WeighHopper	4320	0.5	

7.5 System 300 - Weighing System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS300-TransporterValve	GF-SYS300-TransporterValve	43,800	14	
	GF-SYS300-WeighHopperValve	GF-SYS300-WeighHopperValve	43,800	14	
	GF-SYS300-Transporter	GF-SYS300-Transporter	26,280	15	
	GF-SYS300-WeighHopper	GF-SYS300-WeighHopper	43,800	14	
	GF-SYS300-Pipe001	GF-SYS300-Pipe001	43,800	18	
	GF-SYS300-Pipe001 Clean	GF-SYS300-Pipe001	4320	0.5	
	GF-SYS300-Cv-BlendBends	GF-S300-21, GF-S300-22	17,520	18	
	GF-SYS300-Cv-BlendBends Maint	GF-S300-21, GF-S300-22	4320	0.5	
	GF-SYS300-Cv-FirstBends	GF-SYS300-Pipe001	17,520	18	
	GF-SYS300-Cv-FirstBends Maint	GF-SYS300-Pipe001	4320	0.5	
	GF-SYS300-Cv-SecondBends	GF-S3-1, GF-S3-2	17,520	18	
	GF-SYS300-Cv-SecondBends Maint	GF-S3-1, GF-S3-2	4320	0.5	
	GF-SYS300-LC-DynaslideValve	GF-SYS300-LC-DynaslideValve	43,800	14	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS300-LC-Dynaslide	GF-SYS300-LC-Dynaslide	35,040	15	
	GF-SYS300-LC-Ds-DS Maint	GF-SYS300-LC-Dynaslide	4320	1	
	GF-SYS300-LC-Ds-DS Outlet Maint	GF-SYS300-LC-Dynaslide	4320	0.5	
	GF-SYS300-LC-Sl-Silo	GF-SYS300-LC-Silo	43,800	14	
	GF-SYS300-LC-Sl-Silo DF Maint	GF-SYS300-LC-Silo	4320	1	
	GF-SYS300-LC-Sl-Silo DF	GF-SYS300-LC-Silo	26,280	14	
	GF-SYS300-LC-Sl-Silo Maint	GF-SYS300-LC-Silo	4320	2	
	GF-SYS300-Tp-Tran Inlet Maint	GF-SYS300-Transporter	4320	0.5	
	GF-SYS300-Tp-Tran Maint	GF-SYS300-Transporter	4320	1	
	GF-SYS300-Wh-WeighHopper DF	GF-SYS300-WeighHopper	26,280	14	
	GF-SYS300-Wh-WeighHopper DF Maint	GF-SYS300-WeighHopper	4320	1	
	GF-SYS300-Wh-WeighHopper Maint	GF-SYS300-WeighHopper	4320	2	
	GF-SYS300-Wh-WeighHopper Out Maint	GF-SYS300-WeighHopper	4320	0.5	
	GF-SYS300-ZO-ScrewFeederValve	GF-SYS300-ZO-ScrewFeederValve	43,800	14	
	GF-SYS300-ZO-ScrewFeeder	GF-SYS300-ZO-ScrewFeeder	17,520	16	
	GF-SYS300-ZO-Ds-SF Maint	GF-SYS300-ZO-ScrewFeeder	4320	1	
	GF-SYS300-ZO-Ds-SF Outlet Maint	GF-SYS300-ZO-ScrewFeeder	4320	0.5	
	GF-SYS300-ZO-Sl-Silo	GF-SYS300-ZO-Silo	43,800	14	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS300-ZO-Sl-Silo DF Maint	GF-SYS300-ZO-Silo	4320	1	
	GF-SYS300-ZO-Sl-Silo DF	GF-SYS300-ZO-Silo	26,280	14	
	GF-SYS300-ZO-Sl-Silo Maint	GF-SYS300-ZO-Silo	4320	2	

7.6 System 400 - Weighing System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS400-TransporterValve	GF-SYS400-TransporterValve	43,800	14	
	GF-SYS400-WeighHopperValve	GF-SYS400-WeighHopperValve	43,800	14	
	GF-SYS400-Transporter	GF-SYS400-Transporter	26,280	15	
	GF-SYS400-WeighHopper	GF-SYS400-WeighHopper	43,800	14	
	GF-SYS400-Pipe001	GF-SYS400-Pipe001	43,800	18	
	GF-SYS400-Pipe001 Clean	GF-SYS400-Pipe001	4320	0.5	
	GF-SYS400-Bo-DynaslideValve	GF-SYS400-Bo-DynaslideValve	43,800	14	
	GF-SYS400-Bo-Dynaslide	GF-SYS400-Bo-Dynaslide	35,040	15	
	GF-SYS400-Bo-Ds-DS Maint	GF-SYS400-Bo-Dynaslide	4320	0.5	
	GF-SYS400-Bo-Ds-DS Outlet Maint	GF-SYS400-Bo-Dynaslide	4320	0.5	
	GF-SYS400-Bo-Sl-Silo	GF-SYS400-Bo-Silo	43,800	14	
	GF-SYS400-Bo-Sl-Silo DF Maint	GF-SYS400-Bo-Silo	4320	1	
	GF-SYS400-Bo-Sl-Silo DF	GF-SYS400-Bo-Silo	26,280	14	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS400-Bo-Sl-Silo Maint	GF-SYS400-Bo-Silo	4320	2	
	GF-SYS400-Cv-BlendBends	GF-S400-21, GF-S400-22	17,520	18	
	GF-SYS400-Cv-BlendBends Maint	GF-S400-21, GF-S400-22	4380	0.5	
	GF-SYS400-Cv-FirstBends	GF-SYS400-Pipe001	17,520	18	
	GF-SYS400-Cv-FirstBends Maint	GF-SYS400-Pipe001	4380	0.5	
	GF-SYS400-Cv-SecondBends	GF-S4-1, GF-S4-2	17,520	18	
	GF-SYS400-Cv-SecondBends Maint	GF-S4-1, GF-S4-2	4380	0.5	
	GF-SYS400-SC-DynaslideValve	GF-SYS400-SC-DynaslideValve	43,800	14	
	GF-SYS400-SC-Dynaslide	GF-SYS400-SC-Dynaslide	35,040	15	
	GF-SYS400-SC-Ds-DS Maint	GF-SYS400-SC-Dynaslide	4380	0.5	
	GF-SYS400-SC-Ds-DS Outlet Maint	GF-SYS400-SC-Dynaslide	4380	0.5	
	GF-SYS400-SC-Sl-Silo	GF-SYS400-SC-Silo	43,800	14	
	GF-SYS400-SC-Sl-Silo DF Maint	GF-SYS400-SC-Silo	4380	1	
	GF-SYS400-SC-Sl-Silo DF	GF-SYS400-SC-Silo	26,280	14	
	GF-SYS400-SC-Silo Maint	GF-SYS400-SC-Silo	4380	2	
	GF-SYS400-Tp-Tran Inlet Maint	GF-SYS400-Transporter	4380	0.5	
	GF-SYS400-Tp-Tran Maint	GF-SYS400-Transporter	4380	1	
	GF-SYS400-Wh-WeighHopper DF	GF-SYS400-WeighHopper	26,280	14	
	GF-SYS400-Wh-WeighHopper DF Maint	GF-SYS400-WeighHopper	4380	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS400-Wh-WeighHopper Maint	GF-SYS400-WeighHopper	4380	2	
	GF-SYS400-Wh-WeighHopper Out Maint	GF-SYS400-WeighHopper	4380	0.5	

7.7 System 500 - Weighing System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS500-TransporterValve	GF-SYS500-TransporterValve	43,800	14	
	GF-SYS500-WeighHopperValve	GF-SYS500-WeighHopperValve	43,800	14	
	GF-SYS500-Transporter	GF-SYS500-Transporter	26,280	15	
	GF-SYS500-WeighHopper	GF-SYS500-WeighHopper	43,800	14	
	GF-SYS500-Pipe001	GF-SYS500-Pipe001	43,800	18	
	GF-SYS500-Pipe001 Clean	GF-SYS500-Pipe001	4320	0.5	
	GF-SYS500-Cv-FirstBends	GF-SYS500-Pipe001	17,520	18	
	GF-SYS500-Cv-FirstBends Maint	GF-SYS500-Pipe001	4380	0.5	
	GF-SYS500-Cv-SecondBends	GF-S5-1	17,520	18	
	GF-SYS500-Cv-SecondBends Maint	GF-S5-1	4380	0.5	
	GF-SYS500-IO-ScrewFeederValve	GF-SYS500-IO-ScrewFeederValve	43,800	14	
	GF-SYS500-IO-ScrewFeeder	GF-SYS500-IO-ScrewFeeder	17,520	16	
	GF-SYS500-IO-Ds-SF Maint	GF-SYS500-IO-ScrewFeeder	4380	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS500-IO-Ds-SF Outlet Maint	GF-SYS500-IO-ScrewFeeder	4380	0.5	
	GF-SYS500-IO-Sl-Silo	GF-SYS500-IO-Silo	43,800	14	
	GF-SYS500-IO-Sl-Silo DF Maint	GF-SYS500-IO-Silo	4380	1	
	GF-SYS500-IO-Sl-Silo DF	GF-SYS500-IO-Silo	26,280	14	
	GF-SYS500-IO-Sl-Silo Maint	GF-SYS500-IO-Silo	4380	2	
	GF-SYS500-MS-DynaslideValve	GF-SYS500-MS-DynaslideValve	43,800	14	
	GF-SYS500-MS-Dynaslide	GF-SYS500-MS-Dynaslide	35,040	15	
	GF-SYS500-MS-Ds-DS Maint	GF-SYS500-MS-Dynaslide	4380	0.5	
	GF-SYS500-MS-Ds-DS Outlet Maint	GF-SYS500-MS-Dynaslide	4380	0.5	
	GF-SYS500-MS-Sl-Silo	GF-SYS500-MS-Silo	43,800	14	
	GF-SYS500-MS-Sl-Silo DF Maint	GF-SYS500-MS-Silo	4380	1	
	GF-SYS500-MS-Sl-Silo DF	GF-SYS500-MS-Silo	26,280	14	
	GF-SYS500-MS-Silo Maint	GF-SYS500-MS-Silo	4380	2	
	GF-SYS500-TD-ScrewFeederValve	GF-SYS500-TD-ScrewFeederValve	43,800	14	
	GF-SYS500-TD-ScrewFeeder	GF-SYS500-TD-ScrewFeeder	17,520	16	
	GF-SYS500-TD-Ds-SF Maint	GF-SYS500-TD-ScrewFeeder	4380	1	
	GF-SYS500-TD-Ds-SF Outlet Maint	GF-SYS500-TD-ScrewFeeder	4380	0.5	
	GF-SYS500-TD-Sl-Silo	GF-SYS500-TD-Silo	43,800	14	
	GF-SYS500-TD-Sl-Silo DF Maint	GF-SYS500-TD-Silo	4380	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS500-TD-Sl-Silo DF	GF-SYS500-TD-Silo	26,280	14	
	GF-SYS500-TD-Sl-Silo Maint	GF-SYS500-TD-Silo	4380	2	
	GF-SYS500-Tp-Tran Inlet Maint	GF-SYS500-Transporter	4380	0.5	
	GF-SYS500-Tp-Tran Maint	GF-SYS500-Transporter	4380	1	
	GF-SYS500-Wh-WeighHopper DF	GF-SYS500-WeighHopper	26,280	14	
	GF-SYS500-Wh-WeighHopper DF Maint	GF-SYS500-WeighHopper	4380	1	
	GF-SYS500-Wh-WeighHopper Maint	GF-SYS500-WeighHopper	4380	2	
	GF-SYS500-Wh-WeighHopper Out Maint	GF-SYS500-WeighHopper	4380	0.5	
	GF-SYS500-ZS-DynaslideValve	GF-SYS500-ZS-DynaslideValve	43,800	14	
	GF-SYS500-ZS-Dynaslide	GF-SYS500-ZS-Dynaslide	35,040	15	
	GF-SYS500-ZS-Ds-DS Maint	GF-SYS500-ZS-Dynaslide	4380	0.5	
	GF-SYS500-ZS-Ds-DS Outlet Maint	GF-SYS500-ZS-Dynaslide	4380	0.5	
	GF-SYS500-ZS-Sl-Silo	GF-SYS500-ZS-Silo	43,800	14	
	GF-SYS500-ZS-Sl-Silo DF Maint	GF-SYS500-ZS-Silo	4380	1	
	GF-SYS500-ZS-Sl-Silo DF	GF-SYS500-ZS-Silo	26,280	14	
	GF-SYS500-ZS-Silo Maint	GF-SYS500-ZS-Silo	4380	2	

7.8 System 600 - Blending System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS600-BlenderValve	GF-SYS600-BlenderValve	43,800	14	
	GF-SYS600-TransporterValve	GF-SYS600-TransporterValve	43,800	14	
	GF-SYS600-Blender	GF-SYS600-Blender	17,520	14.5	
	GF-SYS600-Transporter	GF-SYS600-Transporter	26,280	15	
	GF-SYS600-Pipe001	GF-SYS600-Pipe001	43,800	18	
	GF-SYS600-Pipe001 Clean	GF-SYS600-Pipe001	4320	1	
	GF-SYS600-Bl-Blender DF	GF-SYS600-Blender	26,280	14	
	GF-SYS600-Bl-Blender DF Maint	GF-SYS600-Blender	4380	1	
	GF-SYS600-Bl-Blender Maint	GF-SYS600-Blender	4380	0.5	
	GF-SYS600-Bl-Blender Out Maint	GF-SYS600-Blender	4380	0.5	
	GF-SYS600-Cv-Bends SwitchToEnd	GF-LAWdust-Pipe002	17,520	18	
	GF-SYS600-Cv-Bends SwitchToEnd Maint	GF-LAWdust-Pipe002	4380	2	
	GF-SYS600-Cv-Bends TransToSwitch	GF-SYS600-Pipe001	17,520	18	
	GF-SYS600-Cv-Bends TransToSwitch Maint	GF-SYS600-Pipe001	4380	0.5	
	GF-SYS600-Cv-SwitchReceiver	GF-SYS600-Pipe001	43,800	14	
	GF-SYS600-Cv-SwitchReceiver Maint	GF-SYS600-Pipe001	4380	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS600-Tp-Tran Inlet Maint	GF-SYS600-Transporter	4380	0.5	
	GF-SYS600-Tp-Tran Maint	GF-SYS600-Transporter	4380	1	

7.9 System 700 - Blending System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS700-BlenderValve	GF-SYS700-BlenderValve	43,800	14	
	GF-SYS700-TransporterValve	GF-SYS700-TransporterValve	43,800	14	
	GF-SYS700-Blender	GF-SYS700-Blender	17,520	14.5	
	GF-SYS700-Transporter	GF-SYS700-Transporter	26,280	15	
	GF-SYS700-Pipe001	GF-SYS700-Pipe001	43,800	18	
	GF-SYS700-Pipe001 Clean	GF-SYS700-Pipe001	4320	1	
	GF-SYS700-Bl-Blender DF	GF-SYS700-Blender	26,280	14	
	GF-SYS700-Bl-Blender DF Maint	GF-SYS700-Blender	4380	1	
	GF-SYS700-Bl-Blender Maint	GF-SYS700-Blender	4380	0.5	
	GF-SYS700-Bl-Blender Out Maint	GF-SYS700-Blender	4380	0.5	
	GF-SYS700-Cv-Bends SwitchToEnd	GF-HLWdust-Pipe002	17,520	18	
	GF-SYS700-Cv-Bends SwitchToEnd Maint	GF-HLWdust-Pipe002	4380	2	
	GF-SYS700-Cv-Bends TransToSwitch	GF-SYS700-Pipe001	17,520	18	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SYS700-Cv-Bends TransToSwitch Maint	GF-SYS700-Pipe001	4380	0.5	
	GF-SYS700-Cv-SwitchReceiver	GF-SYS700-Pipe001	43,800	14	
	GF-SYS700-Cv-SwitchReceiver Maint	GF-SYS700-Pipe001	4380	1	
	GF-SYS700-Tp-Tran Inlet Maint	GF-SYS700-Transporter	4380	0.5	
	GF-SYS700-Tp-Tran Maint	GF-SYS700-Transporter	4380	1	

7.10 System 800 - Trimming System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hrs)	MTTR/MTTM (hrs)	Comments
	GF-SYS800-TransporterValve	GF-SYS800-TransporterValve	43,800	14	
	GF-SYS800-TrimValve	GF-SYS800-TrimValve	43,800	14	
	GF-SYS800-Transporter	GF-SYS800-Transporter	26,280	15	
	GF-SYS800-TrimHopper	GF-SYS800-TrimHopper	43,800	14	
	GF-SYS800-Pipe001	GF-SYS800-Pipe001	43,800	18	
	GF-SYS800-Pipe001 Clean	GF-SYS800-Pipe001	4320	1	
	GF-SYS800-Bl-Trim DF	GF-SYS800-TrimHopper	26,280	14	
	GF-SYS800-Bl-Trim DF Maint	GF-SYS800-TrimHopper	4380	1	
	GF-SYS800-Bl-Trim Maint	GF-SYS800-TrimHopper	4380	1	
	GF-SYS800-Cv-Bends SwitchToEnd	GF-HLWdust-Pipe003	17,520	18	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hrs)	MTTR/MTTM (hrs)	Comments
	GF-SYS800-Cv-Bends SwitchToEnd Maint	GF-HLWdust-Pipe003	4380	1	
	GF-SYS800-Cv-BendsToSwitch	GF-SYS800-Pipe001	17,520	18	
	GF-SYS800-Cv-BendsToSwitch Maint	GF-SYS800-Pipe001	4380	1	
	GF-SYS800-Cv-SwitchReceiver	GF-HLWdust-Pipe003	43,800	14	
	GF-SYS800-Cv-SwitchReceiver Maint	GF-HLWdust-Pipe003	4380	1	
	GF-SYS800-Tp-Tran Inlet Maint	GF-SYS800-Transporter	4380	0.5	
	GF-SYS800-Tp-Tran Maint	GF-SYS800-Transporter	4380	1	

7.11 HLW Dust Mitigation System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-HLWdust-Pipe002	GF-HLWdust-Pipe002	43,800	18	
	GF-HLWdust-Pipe002 Clean	GF-HLWdust-Pipe002	4320	1	
	GF-HLWdust-Pipe003	GF-HLWdust-Pipe003	43,800	18	
	GF-HLWdust-Pipe003 Clean	GF-HLWdust-Pipe003	4320	1	
	GF-HLWdust-DM1-HLW DM	GF-HLWdust-DM1-HLW DM	35,040	16	
	GF-HLWdust-DM1-DM DF	GF-HLWdust-DM1-HLW DM	26,280	14	
	GF-HLWdust-DM1-DM DF Maint	GF-HLWdust-DM1-HLW DM	4320	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-HLWdust-DM1-DM Maint	GF-HLWdust-DM1-HLW DM	3600	1	
	GF-HLWdust-DM1-RotaryFeeder	GF-HLWdust-DM1-HLW DM	17,520	16	
	GF-HLWdust-DM1-RotaryFeeder Maint	GF-HLWdust-DM1-HLW DM	4320	1	
	GF-HLWdust-DM1-ScrewFeeder	GF-HLWdust-DM1-HLW DM	17,520	16	
	GF-HLWdust-DM1-ScrewFeeder Maint	GF-HLWdust-DM1-HLW DM	4320	1	
	GF-HLWdust-DM2-HLW DM	GF-HLWdust-DM2-HLW DM	35,040	16	
	GF-HLWdust-DM2-DM DF	GF-HLWdust-DM2-HLW DM	26,280	14	
	GF-HLWdust-DM2-DM DF Maint	GF-HLWdust-DM2-HLW DM	4320	1	
	GF-HLWdust-DM2-DM Maint	GF-HLWdust-DM2-HLW DM	3600	1	
	GF-HLWdust-DM2-RotaryFeeder	GF-HLWdust-DM2-HLW DM	17,520	16	
	GF-HLWdust-DM2-RotaryFeeder Maint	GF-HLWdust-DM2-HLW DM	4320	1	
	GF-HLWdust-DM2-ScrewFeeder	GF-HLWdust-DM2-HLW DM	17,520	16	
	GF-HLWdust-DM2-ScrewFeeder Maint	GF-HLWdust-DM2-HLW DM	4320	1	

7.12 LAW Dust Mitigation System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-LAWdust-Pipe002	GF-LAWdust-Pipe002	43,800	18	
	GF-LAWdust-Pipe002 Clean	GF-LAWdust-Pipe002	4320	1	
	GF-LAWdust-DM1-LAW DM	GF-LAWdust-DM1-LAW DM	35,040	16	
	GF-LAWdust-DM1-DM DF	GF-LAWdust-DM1-LAW DM	26,280	14	
	GF-LAWdust-DM1-DM DF Maint	GF-LAWdust-DM1-LAW DM	4320	1	
	GF-LAWdust-DM1-DM Maint	GF-LAWdust-DM1-LAW DM	3600	1	
	GF-LAWdust-DM1-RotaryFeeder	GF-LAWdust-DM1-LAW DM	17,520	16	
	GF-LAWdust-DM1-RotaryFeeder Maint	GF-LAWdust-DM1-LAW DM	4320	1	
	GF-LAWdust-DM1-ScrewFeeder	GF-LAWdust-DM1-LAW DM	17,520	16	
	GF-LAWdust-DM1-ScrewFeeder Maint	GF-LAWdust-DM1-LAW DM	4320	1	
	GF-LAWdust-DM2-LAW DM	GF-LAWdust-DM2-LAW DM	35,040	16	
	GF-LAWdust-DM2-DM DF	GF-LAWdust-DM2-LAW DM	26,280	14	
	GF-LAWdust-DM2-DM DF Maint	GF-LAWdust-DM2-LAW DM	4320	1	
	GF-LAWdust-DM2-DM Maint	GF-LAWdust-DM2-LAW DM	3600	1	
	GF-LAWdust-DM2-RotaryFeeder	GF-LAWdust-DM2-LAW DM	17,520	16	
	GF-LAWdust-DM2-RotaryFeeder Maint	GF-LAWdust-DM2-LAW DM	4320	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-LAWdust-DM2-ScrewFeeder	GF-LAWdust-DM2-LAW DM	17,520	16	
	GF-LAWdust-DM2-ScrewFeeder Maint	GF-LAWdust-DM2-LAW DM	4320	1	

7.13 LAW Inert Fill System

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-InertFill-Pipe001	GF-InertFill-Pipe001	43,800	18	
	GF-InertFill-Pipe001 Clean	GF-InertFill-Pipe001	4320	1	
	GF-InertFill-BDMaint1-Inert DF Maint	GF-S1-3	4320	1	
	GF-InertFill-BDMaint1-Inert DF	GF-S1-3	26,280	14	
	GF-InertFill-BDMaint1-Inert Hopper Maint	GF-S1-3	4320	2	
	GF-InertFill-BDMaint1-Inert Hopper	GF-S1-3	43,800	14	
	GF-InertFill-BDMaint1-Inert Switch Maint	GF-S1-3	4320	1	
	GF-InertFill-BDMaint1-Inert Switch	GF-S1-3 and GF-InertFill-InertFillHopper1	43,800	14	
	GF-InertFill-BDMaint1-Rotary	GF-S1-3	17,520	16	
	GF-InertFill-BDMaint1-Rotary Maint	GF-S1-3	4320	1	
	GF-InertFill-BDMaint2-Inert DF Maint	GF-InertFill-Pipe001	4320	1	

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-InertFill-BDMaint2-Inert DF	GF-InertFill-Pipe001	26,280	14	
	GF-InertFill-BDMaint2-Inert Hopper Maint	GF-InertFill-Pipe001	4320	2	
	GF-InertFill-BDMaint2-Inert Hopper	GF-InertFill-Pipe001	43,800	14	
	GF-InertFill-BDMaint2-Inert Switch Maint	GF-InertFill-Pipe001	4320	1	
	GF-InertFill-BDMaint2-Inert Switch	GF-InertFill-Pipe001 and GF-InertFill-InertFillHopper2	43,800	14	
	GF-InertFill-BDMaint2-Rotary	GF-InertFill-Pipe001	17,520	16	
	GF-InertFill-BDMaint2-Rotary Maint	GF-InertFill-Pipe001	4320	1	
	GF-InertFill-Cv-Bends SwitchRecToEnd	GF-InertFill-Pipe001	17,520	18	
	GF-InertFill-Cv-Bends SwitchRecToEnd Maint	GF-InertFill-Pipe001	4320	1	
	GF-InertFill-Cv-BendsToSwitchRec	GF-S1-3	17,520	18	
	GF-InertFill-Cv-BendsToSwitchRec Maint	GF-S1-3	4320	1	
	GF-InertFill-Cv-SwitchReceiver	GF-S1-3	43,800	14	
	GF-InertFill-Cv-SwitchReceiver Maint	GF-S1-3	4320	1	

7.14 Switch Controls

Operable Unit or Component Impact	Component	Affected Breakdown Vessels or Equipment	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	GF-SwitchCtrl-S100 2way	GF-S1-2	17,520	15	
	GF-SwitchCtrl-S100 2way Maint	GF-S1-2	4320	0.5	
	GF-SwitchCtrl-S100 3way	GF-SYS100-Pipe001	17,520	16	
	GF-SwitchCtrl-S100 3way Maint	GF-SYS100-Pipe001	4320	0.5	
	GF-SwitchCtrl-S200 2way	GF-S2-2	17,520	15	
	GF-SwitchCtrl-S200 2way Maint	GF-S2-2	4320	0.5	
	GF-SwitchCtrl-S200 3way	GF-SYS200-Pipe001	17,520	16	
	GF-SwitchCtrl-S200 3way Maint	GF-SYS200-Pipe001	4320	0.5	
	GF-SwitchCtrl-S300 2way	GF-S3-2	17,520	15	
	GF-SwitchCtrl-S300 2way Maint	GF-S3-2	4320	0.5	
	GF-SwitchCtrl-S300 3way	GF-SYS300-Pipe001	17,520	16	
	GF-SwitchCtrl-S300 3way Maint	GF-SYS300-Pipe001	4320	0.5	
	GF-SwitchCtrl-S400 2way	GF-S4-2	17,520	15	
	GF-SwitchCtrl-S400 2way Maint	GF-S4-2	4320	0.5	
	GF-SwitchCtrl-S400 3way	GF-SYS400-Pipe001	17,520	16	
	GF-SwitchCtrl-S400 3way Maint	GF-SYS400-Pipe001	4320	0.5	

8 Laboratory RAM Data

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
Master Slave Manipulators (MSM)	HC1-1		6935	6	
	HC1-2		6935	6	
	HC1 Egress-1		6935	6	
	HC1 Egress-2		6935	6	
	HC2		6935	6	
	HC3		6935	6	
	HC4		6935	6	Not utilized
	HC5		6935	6	
	HC6		6935	6	
	HC7		6935	6	
	HC8-1		6935	6	
	HC8-2		6935	6	
	HC9-1		6935	6	
	HC9-2		6935	6	
	HC10		6935	6	
	HC11		6935	6	Not utilized
	HC12		6935	6	
	HC13		6935	6	
	HC14 East-1		6935	6	
	HC14 East-2		6935	6	
	HC14 West-1		6935	6	
	HC14 West-2		6935	6	

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
Trolleys	Trolley_West-1		175,200	60	
	Trolley_West-2		43,800	6	
	Trolley_East-1		175,200	60	
	Trolley_East-2		43,800	6	
Workstations	HC 1 (1-1)	HC 1	43,800	6	Instance 1 - Breakdown 1
	HC 1 Egress (1-1)	HC 1	43,800	6	Instance 1 - Breakdown 1
	HC 10 -(1-1)	HC 10	43,800	6	Instance 1 - Breakdown 1
	HC 12 (1-1)	HC 12 ICP/AES	8760	168	Instance 1 - Breakdown 1
	HC 12 (1-2)	HC 12 ICP/AES	43,800	6	Instance 1 - Breakdown 2
	HC 12 (2-1)	HC 12 ICP/AES	8760	168	Instance 2 - Breakdown 1
	HC 12 (2-2)	HC 12 ICP/AES	43,800	6	Instance 2 - Breakdown 2
	HC 13 (1-1)	HC 13 ICP/MS	8760	168	Instance 1 - Breakdown 1
	HC 13 (1-2)	HC 13 ICP/MS	43,800	6	Instance 1 - Breakdown 2
	HC 13 (2-1)	HC 13 ICP/MS	8760	168	Instance 2 - Breakdown 1
	HC 13 (2-2)	HC 13 ICP/MS	43,800	6	Instance 2 - Breakdown 2
	HC 2 (1-1)	Drying Oven & Acid-Base Titrator	43,800	6	Instance 1 - Breakdown 1

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	HC 3 (1-1)	Drying Oven & Acid-Base Titrator	43,800	6	Instance 1 - Breakdown 1
	HC 5 (1-1)	Rheometer Analyzer & Particle Size Analyzer	43,800	6	Instance 1 - Breakdown 1
	HC 5 (1-2)	Rheometer Analyzer & Particle Size Analyzer	17,520	72	Instance 1 - Breakdown 2
	HC 6 (1-1)	2 Fusion Furnace & 1 Microwave Oven	8760	72	Instance 1 - Breakdown 1
	HC 6 (1-2)	2 Fusion Furnace & 1 Microwave Oven	43,800	6	Instance 1 - Breakdown 2
	HC 7 (1-1)	2 Fusion Furnace & 1 Microwave Oven	8760	72	Instance 1 - Breakdown 1
	HC 7 (1-2)	2 Fusion Furnace & 1 Microwave Oven	43,800	6	Instance 1 - Breakdown 2
	HC 8 (1-1)	Rad Prep e.g. Strip Cs-137	43,800	6	Instance 1 - Breakdown 1
	HC 9 (1-1)	Rad Prep e.g. Strip Cs-137	43,800	6	Instance 1 - Breakdown 1
	RL 1 (1-1)	Sample Radiation Detector (1)	8760	24	Instance 1 - Breakdown 1
	RL 10 Workstation 5 (1-1)	Ion Chromatograph (1)	43,800	168	Instance 1 - Breakdown 1
	RL 10 Workstation 6 (1-1)	Ion Chromatograph (2)	43,800	168	Instance 1 - Breakdown 1
	RL 10 Workstation 6 (2-1)	Ion Chromatograph (2)	43,800	168	Instance 2 - Breakdown 1
	RL 10 Workstation 1 (1-1)	TIC/TOC (2)	26,280	168	Instance 1 - Breakdown 1
	RL 10 Workstation 1 (2-1)	TIC/TOC (2)	26,280	168	Instance 2 - Breakdown 1

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	RL 10 Workstation 2 (1-1)	TIC/TOC (2)	26,280	168	Instance 1 - Breakdown 1
	RL 10 Workstation 2 (2-1)	TIC/TOC (2)	26,280	168	Instance 2 - Breakdown 1
	RL 13 GPC Single Detector (1-1)	RL 13 GPC (Single Detector)	43,800	168	Instance 1 - Breakdown 1
	RL 13 GPC (1-1)	GPC-16 detector	43,800	168	Instance 1 - Breakdown 1
	RL 13 GPC (2-1)	GPC-16 detector	43,800	168	Instance 2 - Breakdown 1
	RL 13 GS (1-1)	RL 13 GS	43,800	168	Instance 1 - Breakdown 1
	RL 13 GS (2-1)	RL 13 GS	43,800	168	Instance 2 - Breakdown 1
	RL 13 LSC (1-1)	Liquid Scintillation Counter	26,280	168	Instance 1 - Breakdown 1
	RL 13 LSC (2-1)	Liquid Scintillation Counter	26,280	168	Instance 2 - Breakdown 1
	RL 13 AS (1-1)	Alpha Spectrometer-24 detect (2)	43,800	168	Instance 1 - Breakdown 1
	RL 13 AS (2-1)	Alpha Spectrometer-24 detect (2)	43,800	168	Instance 2 - Breakdown 1
	RL 2 Workstation 5 (1-1)	Fusion Furnace (1)	8760	24	Instance 1 - Breakdown 1
	RL 2 Workstation 1 (1-1)	Microwave (1) & Drying Oven (1)	8760	24	Instance 1 - Breakdown 1
	RL 9 Workstation 3 (1-1)	ICP/AES (1)	8760	168	Instance 1 - Breakdown 1
	RL 9 Workstation 3 (2-1)	ICP/AES (1)	8760	168	Instance 2 - Breakdown 1

Operable Unit or Component Impact	Component	Description	MTBF/MTBM (hr)	MTTR/MTTM (hr)	Comments
	RL 9 Workstation 4 (1-1)	ICP/MS (1)	8760	168	Instance 1 - Breakdown 1
	RL 9 Workstation 4 (2-1)	ICP/MS (1)	8760	168	Instance 2 - Breakdown 1
	East Trolley (1-1)	HC Trolley - East	175,200	60	Instance 1 - Breakdown 1
	West Trolley (1-1)	HC Trolley - West	175,200	60	Instance 1 - Breakdown 1
	HC 14 East (1-1)	Hot Cell 14 - East	43,800	6	Instance 1 - Breakdown 1
	HC 14 West (1-1)	Hot Cell 14 - West	43,800	6	Instance 1 - Breakdown 1

Appendix E

Status of Review Tracking Coversheets (RTCs) for R&T Reports

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
1	Closed	1	SCT-M0SRLE60-00-08-02	00C	WSRC-TR-2002-00588	0	High-Temperature Corrosion Study for the RPP Low Activity Waste (LAW) Melter (U)				
2	Closed	1	24590-101-TSA-W000-0009-69-03	00B	VSL-03R3470-1	0	LAW Glass Formulation to Support AZ-102 Actual Waste Testing				
3	Closed	1	24590-101-TSA-W000-0009-69-04	00B	VSL-03R3470-2	0	LAW Glass Formulation to Support AP-101 Actual Waste Testing			01-001	
4	Closed	1	SCT-M0SRLE60-00-95-01	00B	WSRC-TR-2001-00109	1	Results from Analysis of a Hanford Envelope A Radioactive Glass Waste Form				
5	Closed	1	SCT-M0SRLE60-00-99-07	N/A	WSRC-TR-2002-00119	0	LAW Vendor Coupon CO^2 Blasting Tests				
6	Closed	1	24590-101-TSA-W000-0009-49-01	0	TRR-PLT-060	2	Pilot Melter Sub-Envelope A3 Variation Test Result Report				
7	Closed	1	SCT-M0SRLE60-00-02-04	00B	WSRC-TR-2002-00093	0	Large Scale Vitrification of 241-AN-102 (Envelope C) Sample				
8	Closed	2	SCT-M0SRLE60-00-133-01B	00B	WSRC-TR-2001-00584	0	Results from Analysis of a Hanford Tank 241-AN-102 Melter-Scale Glass Waste Form	188-302			
9	Closed	1	24590-101-TSA-W000-0009-84-01A	0	REP-PLT-003	0	Pilot Melter Sub-Envelope C1 Variation Test Summary Report				
10	Closed	1	24590-101-TSA-W000-0010-06-03A	N/A	VSL-01R3560-2	0	Glass Formulation and Testing with RPP-WTP-LAW Simulants	96-301			
11	Closed	1	24590-101-TSA-W000-0004-93-02	00B	WTP-RPT-039	0	Preliminary Disposal of Spent Silver Mordenite Disposal Forms Resulting from Gaseous Radioiodine Control at Hanford's Waste Treatment Plant				
12	Closed	1	24590-101-TSA-W000-0009-98-06	00B	VSL-02R62N0-2	0	Compositional variation Tests on DuraMelter 100 with LAW Sub-Envelope C1 Feed (LAW C22 Glass) in Support of the LAW Pilot Melter	18-301			See also RTC-0145.
13	Closed	1	24590-101-TSA-W000-0009-120-07	00C	TRR-PLT-074	0	RTP-WTP Pilot Melter Sub-Envelope B1 Variation Test Results Report				
14	Closed	2	24590-101-TSA-W000-0009-102-01	00D	VSL-01R62N0-1	2	Compositional Variation Test on DuraMelter 100 with LAW Sub-Envelope A3 Feed in Support of the LAW Pilot Melter	189-301			See also RTC-0231.
15	Closed	1	24590-101-TSA-W000-0004-101-02A	00B	WTP-RPT-029	0	Optimization of Sr/TRU Removal Conditions with Samples of AN-102 Tank Waste				
16	Closed	1	SCT-M0SRLE60-00-144-02	N/A	WSRC-TR-2001-00561	0	Foaming in Hanford River Protection Project Waste Treatment Plant LAW Evaporation Processes - FY01 Summary Report				
17	Closed	1	24590-101-TSA-W000-0004-128-02	N/A	WTP-RPT-034	0	Verification of Process Conditions for Sr/TRU Removal from AN-102/C-104 Waste Blend				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
18	Closed	1	SCT-M0SRLE60-00-61-01	00B	WSRC-TR-2001-00288	1	Sample Analysis Results for a BenchScale Evaporator Test Using a Hanford Tank 241-AN-102 Sample				
19	VOID		VOID		VOID		VOID				
20	Closed	1	SCT-M0SRLE60-00-170-01	00B	WSRC-TR-2002-00258	0	Optimization Study for Strontium and Actinide Removal from 241-AN-107 Supernate				
21	VOID		VOID		VOID		VOID				
22	VOID		VOID		VOID		VOID				
23	VOID		VOID		VOID		VOID				
24	Closed	1	SCT-M0SRLE60-00-104-02	N/A	WSRC-TR-2001-00156	0	RPP-WTP Slurry Wear Evaluation: Literature Review				
25	Closed	1	SCT-M0SRLE60-00-160-01	00C	WSRC-TR-2001-00591	0	Design Analysis for a Scaled Erosion Test				
26	Closed	2	SCT-M0SRLE60-00-96-01	00E	WSRC-TR-2002-00108	0	Evaluating the Effects of Tri-Butyl Phosphate and Normal Paraffin Hydrocarbon in Simulated Low-Activity Waste Solution on Ultrafiltration	94-203			
27	Closed	1	24590-101-TSA-W000-0004-87-09	00C	WTP-RPT-043	0	Filtration, Washing, and Caustic Leaching of Hanford Tank AZ-101 Sludge		05-0010		
28	Closed	1	24590-101-TSA-W000-0004-119-01	00B	WTP-RPT-019	0	Performance of Tubular Porous Metal Crossflow Filters				
29	Closed	1	CCN 045580	N/A	WTP-RPT-027	0	Thermal and Radiolytic Gas Generation from Washed AN-102 Sludge				
30	Closed	1	24590-101-TSA-W000-0004-89-01	00D	WTP-RPT-020	0	Chemical Analysis and Physical Property Testing of 241-AN-102 Tank Waste - Supernatant and Centrifuged Solids				
31	Closed	1	24590-101-TSA-W000-0004-86-02A	N/A	WTP-RPT-025	0	Development and Testing of the Automated 99Tc Monitor. Fiscal Year 2001 Progress Report				
32	Closed	1	SCT-M0SRLE60-00-71-01A	N/A	WSRC-TR-2001-00235	0	Evaluating Effects from Contacting SuperLig 644 Resin with Sodium Permanganate	57-205			
33	Closed	1	SCT-M0SRLE60-00-66-01	00C	WSRC-TR-2000-00411	0	SuperLig 644 Ion Exchange Resin Stability in Nitric Acid at Elevated Temperatures	57-205			
34	Closed	1	24590-101-TSA-W000-0004-117-01	00B	WTP-RPT-015	0	Aging Study and Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Simulated AW-101 Hanford Tank Waste	57-205			
35	Closed	1	24590-101-TSA-W000-0004-114-01A	00D	WTP-RPT-016	0	Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Hanford Waste Tank 241-AP-101 Diluted Feed (Envelope A)	57-205			

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
36	Closed	1	SCT-M0SRLE60-00-91-01	00B	WSRC-TR-2001-00400	0	Preliminary Ion Exchange Modeling for Removal of Cesium from Hanford Waste Using Hydrous Crystalline Silicotitanate Material				
37	Closed	1	24590-101-TSA-W000-0004-86-04	00B	WTP-RPT-042	0	Development and Testing of the Automated 99Tc Monitor				
38	Closed	1	SCT-M0SRLE60-00-70-01	00D	WSRC-TR-2000-00304	1	Studies of Ion Exchange Resin Integrity under Flowsheet Extremes: Part II	57-205			
39	Closed	1	24590-101-TSA-W000-0004-116-01A	N/A	WTP-RPT-032	0	Effect of Eluant Flow Direction on the Elution Characteristics of SuperLig 644 Ion Exchange Resin	57-205			
40	Closed	1	24590-101-TSA-W000-0004-114-03	00B	WTP-RPT-030	0	Small Column Testing of SuperLig 639 for Removing 99Tc from Hanford Tank Waste Envelope A (Tank 241-AP-101)				
41	Closed	1	SCT-M0SRLE60-00-124-02	00B	WSRC-TR-2002-00319	A	Preliminary Modeling Results of Evaporated Tc-Eluate Physical Properties				
42	Closed	1	24590-101-TSA-W000-0009-88-01	00B	REP-PLT-003	0	Pilot Melter Sub-Envelope C1 Variation Test Summary Report				See also RTC-0009.
43	Closed	1	SCT-M0SRLE60-00-99-03	00B	WSRC-TR-2002-00273	0	Cesium Eluate Evaporation Solubility and Physical Property Behavior		05-0010		
44	Closed	1	SCT-M0SRLE60-00-171-01	00B	WSRC-TR-2002-00309	0	3-Dimensional Flow Modeling of a Proposed Hanford Waste Treatment Plant Ion-Exchange Design		05-0010		
45	Closed	1	SCT-M0SRLE60-00-32-03	00C	WSRC-TR-2002-00411	0	Cesium Eluate Evaporation Solubility and Physical Property Behavior	30-206	02-299, 02-300		
46	Closed	1	24590-101-TSA-W000-0004-91-01	00D	WTP-RPT-021	1	Chemical and Physical Properties Testing of 241-AN-102 Tank Waste Blended with 241-C-104 Wash/Leachate Solutions				See also RTC-0068.
47	VOID		VOID		VOID		VOID				
48	Closed	2	24590-101-TSA-W000-0004-87-08	00B	WTP-RPT-048	0	Chemical Analysis and Physical Property Testing of 241-AZ-101 Tank Waste - Supernatant and Centrifuged Solids	124-201			
49	Closed	2	24590-101-TSA-W000-0004-97-01C	N/A	WTP-RPT-022	0	Chemical Analysis and Physical Property Testing of Diluted 241-AP-101 Tank Waste	124-201			
50	Closed	1	24590-101-TSA-W000-0004-77-04	00B	WTP-RPT-038	0	Regulatory DQO Step 1 Method Detection Limit and Estimated Quantitation Limit Evaluation for Inorganic Analyses: Summary Report - Part 1				
51	Closed	1	SCT-M0SRLE60-00-21-05	00B	WSRC-TR-2001-00252	0	Crucible Scale Vitrification of Pretreated C-106 Sludge Mixed with Secondary Wastes				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
52	Closed	1	24590-101-TSA-W000-0009-41-02	00A	TRR-PLT-070	0	Pilot Melter Sub-Envelope A2 Variation Test Results Report				
53	Closed	1	24590-101-TSA-W000-0009-32-07	0	TRR-PLT-072	0	Pilot Melter - Sub-Envelope C2 Variation Test Results Report				
54	Closed	1	24590-101-TSA-W000-0004-65-04	00B	WTP-RPT-045	1	Statistical Assessment of Preliminary Property-Composition data and Models for IHLW PCT and TCLP				
55	Closed	1	24590-101-TSA-W000-0004-99-06	00B	WTP-RPT-071	0	Statistical Assessment of Preliminary Property-Composition Data and Models for ILAW PCT and VHT				See also RTC-0109.
56	Closed	1	SCT-M0SRLE60-00-83-01A	N/A	WSRC-TR-2000-00352	0	Physical Characterization for Hanford Tank Waste Samples AN-102, AN-103, and AZ-102				
57	Closed	1	SCT-M0SRLE60-00-104-04	00C	WSRC-TR-2002-00062	0	RPP-WTP Submittal of RPP-WTP Slurry Wear Evaluation: Slurry Abrasivity Report				
58	VOID		VOID		VOID		VOID				
59	VOID		VOID		VOID		VOID				
60	VOID		VOID		VOID		VOID				
61	Closed	1	SCT-M0SRLE60-00-175-01	00A	WSRC-TR-2002-00282	0	Characterization of HLW and LAW Glass Formers and Design of Initial Silo - Final Report - (U)				
62	Closed	1	SCT-M0SRLE60-00-48-02	00B	WSRC-TR-2001-00395	0	Interim Report for Crucible Scale Active Vitrification of Waste Envelope B (AZ-102)(U)				
63	Closed	1	24590-101-TSA-W000-0010-06-04A	N/A	VSL-01R2540-2	0	Glass Formulation and Testing with RPP-WTP HLW Simulants		03-038, 04-0037		
64	Closed	1	24590-101-TSA-W000-0004-65-03	N/A	WTP-RPT-013	0	X%/Y% Tolerance Interval Approach to Determine Sample Sizes and Demonstrate IHLW or ILAW Produced Over a Waste Type is Compliant with Chemical Durability Specifications				
65	Closed	2	SCT-M0SRLE60-00-185-01	00B	WSRC-TR-2003-00135	0	Cesium Eluate Semi-Batch Evaporation Performance	107-206	04-0008, 04-0009	03-151,04-0005	
66	VOID		VOID		VOID		VOID				
67	VOID		VOID		VOID		VOID				
68	Closed	0	24590-101-TSA-W000-0004-91-01	00E	WTP-RPT-021	1	Chemical and Physical Properties Testing of 241-AN-102 Tank Waste Blended with 241-C-104 Wash/Leachate Solutions				
69	VOID		VOID		VOID		VOID				
70	VOID		VOID		VOID		VOID				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
71	Closed	0	24590-101-TSA-W000-0009-87-14	00A	VSL-03S3800-2	0	Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers				
72	Closed	0	24590-LAW-TSP-RT-02-005	0	24590-LAW-TSP-RT-02-005	0	LAW Radioactive Coupon CO2 Decontamination Test				See also RTCs 0107 and 0247.
73	Closed	0	24590-101-TSA-W000-0004-70-03	00B	WTP-RPT-037	0	Batch Contact Testing of SuperLig 644	57-205			
74	Closed	0	24590-101-TSA-W000-0004-82-03	00C	WTP-RPT-024	0	Radiation Stability Testing of SuperLig 639 and SuperLig 644 Resins	57-205			
75	Closed	0	24590-101-TSA-W000-0004-114-05	00B	WTP-RPT-041	0	Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Hanford Waste Tank 241-AZ-102 Concentrate	57-205			
76	Closed	0	24590-101-TSA-W000-0004-114-11	00A	WTP-RPT-053	0	Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Hanford Waste Tank 241-AZ-101 Concentrate (Envelope B)	57-205			
77	Closed	0	SCT-M0SRLE60-00-110-11	00B	WSRC-TR-2002-00257	0	Evaluating Residence Time for SuperLig 644 Columns with Simulated LAW Envelope C (AN-107) Solution	57-205			
78	Closed	0	SCT-M0SRLE60-00-110-10	00E	WSRC-TR-2001-00606	0	Effects of Resin Particle Size and Solution Temperature on SuperLig 644 Resin Performance with AN-105 Simulant	57-205			
79	Closed	0	SCT-M0SRLE60-00-88-02	00A	WSRC-TR-2002-00163	0	Evaluating Residence Time for SuperLig 644 Columns with Simulated LAW Envelope B Solution	57-205			
80	Closed	0	24590-101-TSA-W000-0004-114-02	00B	WTP-RPT-033	0	Small Column Ion Exchange Testing of SuperLig 644 for Removing 137Cs from Hanford Waste Tank 241-AN-102 Supernate (Envelope C) Mixed with Tank 241-C-104 Solids and Permeate Solutions	57-205			
81	Closed	2	24590-101-TSA-W000-0004-114-15	00A	WTP-RPT-046	0	Chemical Degradation of SuperLig 644 Ion Exchange Resin	57-205, 90-205			
82	Closed	0	24590-101-TSA-W000-0004-02-01	00B	WTP-RPT-040	0	Proposed Holding Time and Storage Condition Study Strategy				
83	Closed	0	24590-101-TSA-W000-0004-125-02	00B	WTP-RPT-070	3	The Corrosion Effects of Mercury and Mercury Compounds on WTP Materials: ElectroChemical Tests				
84	Closed	1	24590-101-TSA-W000-0009-66-06	00B	VSL-02R62N0-5	0	Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope B1 Feed in Support of the LAW Pilot Melter	96-301	03-064, 03-065		
85	Closed	0	24590-101-TSA-W000-0009-104-02	00D	TRR-PLT-076	1	RPP-WTP Pilot Melter 40% Height LAW Container Pour Level Detection Test Results Report				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
86	Closed	0	24590-101-TSA-W000-0009-145-01	00A	REP-PLT-020	0	RPP-WTP Pilot Melter Sub-Envelope C1 Production Verification				
87	VOID		VOID		VOID		VOID				
88	VOID		VOID		VOID		VOID				
89	Closed	0	SCT-M0SRLE60-00-99-03	00D	WSRC-TR-2002-00273	1	Cesium Eluate Evaporation Solubility and Physical Property Behavior	30-206			
90	Closed	0	SCT-M0SRLE60-00-05-01	0	BNF-003-98-0220	0	Preliminary Ion Exchange Modeling for Removal of Cesium from Hanford Waste Using SuperLig 644 Resin				
91	Closed	0	CCN 002633	N/A	BNF-003-98-0051	0	Ion Exchange Resins Swelling and Buoyancy Study				
92	Closed	0	N/A	N/A	BNF-003-98-0146	1	Small-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-103	57-205			
93	Closed	0	N/A	N/A	BNF-003-98-0219	0	Small-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102	57-205			
94	Closed	0	SCT-M0SRLE60-00-24-01	N/A	WSRC-TR-2000-00419	0	Small-Scale Ion Exchange Removal of Cesium and Technetium from Envelope B Hanford Tank 241-AZ-102	57-205			
95	Closed	0	SCT-M0SRLE60-00-44-02	00B	WSRC-TR-2000-00420	1	Intermediate-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102	57-205			
96	Closed	0	N/A	N/A	BNFL-RPT-024	0	Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Hanford Tank Waste Envelope C (Tank 241-AN-107)				
97	Closed	0	N/A	N/A	BNFL-RPT-014	0	Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Hanford Tank Waste Envelope A (Tank 241-AW-101)	57-205			
98	Closed	0	N/A	N/A	BNFL-RPT-028	0	Analysis of Spent Ion Exchange Media: SuperLig 639 and SuperLig 644	57-205			
99	Closed	0	SCT-M0SRLE60-00-45-01	N/A	WSRC-TR-2000-00422	0	Effects of Radiation on the Physical Properties of SuperLig 644 Resin	57-205			
100	Closed	0	SCT-M0SRLE60-00-184-01	00C	WSRC-TR-2003-00119	0	Treated LAW Feed Evaporation: Physical Properties and Solubility Determination				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
101	Closed	1	24590-101-TSA-W000-0004-104-05	00B	WTP-RPT-064	0	Rheological and Physical Properties of AP-101 LAW Pretreated Waste and Melter Feed	77-301	03-049, 03-051	03-017, 03-018,03-019, 03-020, 03-021, 03-022, 03-023, 03-024, 03-025, 03-026, 03-027, 03-028, 03-040	
102	VOID		VOID		VOID		VOID				
103	Closed	1	24590-101-TSA-W000-0009-144-02	00B	VSL-03R3800-2	0	Integrated DM1200 Melter Testing of HLW AZ-102 Compositions Using Bubblers	87-402			
104	Closed	0	24590-101-TSA-W000-0009-135-02	00A	VSL-03S3410-2	0	Compositional Variation Tests on DuraMelter 100 With LAW Sub-Envelope B2 Feed in Support of the LAW Pilot Melter				
105	Closed	0	24590-101-TSA-W000-0009-106-12	00A	VSL-03S3410-1	0	DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelopes A2 and B1 Feeds in Support of the LAW Pilot Melter				
106	VOID		VOID		VOID		VOID				
107	Closed	0	SCT-M0SRLE60-00-110-12	00B	WSRC-TR-2003-00084	0	LAW Radioactive Coupon CO2 Decontamination Test				See also RTC-0247.
108	Closed	0	24590-101-TSA-W000-0004-115-01	N/A	WTP-RPT-035	0	Relationship of Statistics WFQ Work to RPP-WTP Work in the Report Verification of IHLW Product Quality by Analysis of Uncertainty and Reliability in the HLW Process Control System				
109	Closed	0	24590-101-TSA-W000-0004-99-06	00A	WTP-RPT-071	0	Statistical Assessment of Preliminary Property - Composition Data and Models for ILAW PCT and VHT				See also RTC-0055.
110	Closed	1	SCT-M0SRLE60-00-01-02	00B	WSRC-TR-2001-00566	0	Results from Analysis of a Hanford Tank 241-AN-102 Crucible-Scale Glass Waste Form	103-302			
111	Closed	0	24590-101-TSA-W000-0004-101-03	00B	WTP-RPT-044	0	Combined Entrained Solids and Sr/TRU Removal from AN-102 Waste Blend				
112	Closed	0	24590-101-TSA-W000-0004-129-02	00B	WTP-RPT-049	0	Methodology for Adjusting and Normalizing Analyzed Glass Components				
113	Closed	0	24590-101-TSA-W000-0004-113-02	00B	WTP-RPT-051	0	Evaluation of Corona Oxidation as Back-up Technology for Organic Destruction of Secondary Off-Gas Treatment System				
114	Closed	0	24590-101-TSA-W000-0004-99-02	00B	WTP-RPT-052	0	Evaluation of Temperature and Caustic Effects on Tank Waste Solubility for Hanford Tank 241-AN-102				
115	Closed	0	24590-101-TSA-W000-0004-130-01	00B	WTP-RPT-054	0	Hanford Tank 241-AZ-102 Waste Concentration and Composition				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
116	Closed	0	24590-101-TSA-W000-0004-98-02	00C	WTP-RPT-055	C	Regulatory DQO Step 1 Method Detection Limit and Estimated Quantitation Limit Evaluation for Inorganic Metals Analyses: Summary Report Part 2				
117	Closed	0	24590-101-TSA-W000-0004-77-07	00B	WTP-RPT-056	B	Regulatory DQO Step 1 Method Detection Limit and Estimated Quantitation Limit Evaluation for Organic Analyses: Summary Report Part 1				
118	Closed	0	24590-101-TSA-W000-0004-97-02	00B	WTP-RPT-057	0	AP-101 Diluted Feed (Envelope A) Simulant Development Report				
119	Closed	0	24590-101-TSA-W000-0004-114-08	00A	WTP-RPT-058	0	Small Column Testing of SuperLig 639 for Removing 99Tc from Hanford Tank Waste Envelope B (Tank-AZ-101)				
120	Closed	0	24590-101-TSA-W000-0004-101-04	00B	WTP-RPT-060	0	Filtration of Envelope C Waste Simulant Treated by the Sr/TRU Precipitation Process				
121	Closed	0	24590-101-TSA-W000-0004-120-02	00B	WTP-RPT-061	0	Development and Assessment of the TEMPEST CFD Model of the Pulsed Jet Mixing Systems				
122	Closed	0	24590-101-TSA-W000-0004-77-08	00B	WTP-RPT-062	0	Regulatory DQO Step 1 Method Detection Limit and Estimated Quantitation Limit Evaluation for Organic Analyses: Summary Report Part 2				
123	Closed	0	24590-101-TSA-W000-0004-101-05	00B	WTP-RPT-063	0	Gas Generation and Energetics Studies of an Envelope C Waste Treated by the Sr/TRU Precipitation Process				
124	Closed	0	24590-101-TSA-W000-0004-104-05	00B	WTP-RPT-064	0	Rheological and Physical Properties of AP-101 LAW Pretreated Waste and Melter Feed				See also RTC 101
125	Closed	0	24590-101-TSA-W000-0004-114-09	00A	WTP-RPT-065	0	An Aqueous Thermodynamic Model for the Complexation of Sodium and Strontium with Organic Chelates Valid to High Ionic Strength. I Ethylenedinitrilotetraacetic Acid (EDTA)				
126	Closed	0	24590-101-TSA-W000-0004-114-07	00B	WTP-RPT-067	0	Thermodynamic Modeling of AZ-101 Slurry Leaching				
127	Closed	0	24590-101-TSA-W000-0004-98-03	00B	WTP-RPT-068	0	Assessment of the Sr/TRU Removal Precipitation Reaction Mechanism Using Waste Simulant Solutions				
128	Closed	0	24590-101-TSA-W000-0004-86-05	00B	WTP-RPT-074	0	Development and Testing of the Automated 99Tc Monitor				
129	Closed	0	24590-101-TSA-W000-0004-99-04	00B	WTP-RPT-075	0	Development of LAW and HLW Vitrification Physical Property Bounding Conditions and Simulant Verification Criteria				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
130	Closed	0	24590-101-TSA-W000-0004-134-01	00C	WTP-RPT-076	0	Identification of Washed Solids from Hanford Tanks 241-AN-102 and 241-AZ-101 with X-Ray Diffraction, Scanning Electron Microscopy, and Light-Scattering Particle Analysis				
131	Closed	0	24590-101-TSA-W000-0004-124-03	00B	WTP-RPT-077	0	Demonstration of Ability to Mix in a Small-Scale Pulsed-Jet Mixer Facility				
132	Closed	0	Business Sensitive- Not in PADC	NA	WTP-RPT-079	0	Generation of Semi-Volatile Organic Compounds Tentatively Identified from Irradiating SuperLig (R) 639 and SuperLig (R) 644 Ion Exchange Resins				
133	Closed	0	24590-101-TSA-W000-0004-118-02	00B	WTP-RPT-081	0	Large Tank Experimental Data for Validation of the FLUENT CFD Model of Pulsed Jet Mixers				
134	Closed	0	Business Sensitive- Not in PADC	NA	WTP-RPT-086	0	Nuclear Magnetic Resonance Analysis of Ages Irradiated and Chemically Exposed SuperLig 644 Ion Exchange Resin				
135	Closed	0	24590-101-TSA-W000-0004-85-09	00C	WTP-RPT-097	0	Initial Suitability Evaluation of Steam-Reformed Low Activity Waste for Direct Land Disposal				
136	Closed	0	24590-101-TSA-W000-0009-23-09	00D	TRR-PLT-068	1	Pilot Melter Bubbler Consumable Changeout Box Test Results Report				See also RTC-0350.
137	Closed	0	24590-101-TSA-W000-0009-120-08	00A	REP-PLT-018	0	RPP-WTP Pilot Melter Sub-Envelope B2 Variation Test Summary Report				
138	Closed	1	24590-101-TSA-W000-0009-32-06	00D	TRR-PLT-069	0	RPP-WTP Pilot Melter Sub-Envelope C1 Variation Test Results Report	260-301, 276-301			
139	Closed	0	24590-101-TSA-W000-0009-68-04	00B	TRR-PLT-071	0	Pilot Melter Sub-Envelope A-1 Variation Test Results Report				
140	Closed	2	24590-101-TSA-W000-0009-106-18	00C	TRR-PLT-077	1	RPP-WTP Pilot Melter Envelope C Melter Emissions Test Results Report	120-302, 121-303, 122-402, 123-403, 136-402_Rev_1, 137-403_Rev_1, 153-302, 154-303	04-0018, 04-0024, 05-0010	04-0055	
141	Closed	0	24590-101-TSA-W000-0009-48-01	00E	VSL-01R10N0-1	1	Final Report - Melter Tests with AZ-101 HLW Simulant Using a DuraMelter 100 Vitrification System				
142	Closed	0	24590-101-TSA-W000-0009-54-00001	00B	VSL-01R2200-1	0	Submerged Bed Scrubber (SBS): Off-line Component Testing of DM1200 SBS Unit				
143	Closed	0	24590-101-TSA-W000-0009-34-03	00C	VSL-02R0100-2	1	Tests on the DuraMelter 1200 HLW Pilot Melter System Using HLW AZ-101 Simulants				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
144	Closed	0	24590-101-TSA-W000-0009-64-02	00C	VSL-02R3770-1	0	HLW Glass Formulation to Support AZ-101 Actual Waste Testing				
145	Closed	1	24590-101-TSA-W000-0009-98-06	00A	VSL-02R62N0-2	0	Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope C1 Feed (LAW C22 Glass) in Support of the LAW Pilot Melter	249-302, 250-303, 255-305, 260-301	07-0029, 07-0030, 07-0032, 07-0033, 07-0037, 07-0038		See also RTC-0012.
146	Closed	0	24590-101-TSA-W000-0009-53-01	00E	VSL-02R62N0-3	1	Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A2 Feed (LAW A88 Glass) in Support of the LAW Pilot Melter				
147	Closed	0	24590-101-TSA-W000-0009-128-02	00C	VSL-02R62N0-4	0	Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A1 Feed (LAW A44 Glass) in Support of the LAW Pilot Melter				
148	Closed	1	24590-101-TSA-W000-0009-87-09	00B	VSL-02R8200-1	0	Off-line Test of the DM1200 Thermal Catalytic Oxidation (TCO) Unit	93-303			
149	VOID		VOID		VOID		VOID				
150	Closed	1	24590-101-TSA-W000-0009-102-02	00B	VSL-03R3460-1	0	Baseline LAW Glass Formulation Testing	104-301			
151	Closed	1	24590-101-TSA-W000-0009-72-05	00D	VSL-03R3760-1	1	Regulatory Spike Testing for RPP-WTP LAW and HLW Glasses for Compliance with Land Disposal Restrictions	91-302, 92-402			
152	Closed	0	24590-101-TSA-W000-0009-105-04	00B	VSL-03S3780-1	0	Augmentation Test Matrix to Support TCLP Model Development for RPP-WTP HLW Glasses				
153	VOID		VOID		VOID		VOID				
154	Closed	0	SCT-M0SRLE60-00-44-03	00B	WSRC-TR-2002-00040	0	Development of a Supernate Simulant for Hanford Tank 241-AN-102 Waste (U)				
155	Closed	0	SCT-M0SRLE60-00-110-03	00B	WSRC-TR-2002-00122	0	Pilot Scale Precipitation Test of AN-107 Simulant Without Caustic Adjustment at 50 Degrees C (U)				See also RTC-0304.
156	Closed	0	SCT-M0SRLE60-00-145-07	00B	WSRC-TR-2002-00364	0	Real-Time Chord Length Analysis of Strontium and Manganese Precipitates Formed From Hanford Tank 241-AN-107 Simulant (U)				
157	Closed	1	SCT-M0SRLE60-00-183-01	00D	WSRC-TR-2002-00424	0	Physical Property Models of Concentrated Cesium Eluate Solutions				
158	Closed	0	SCT-M0SRLE60-00-141-02	00F	WSRC-TR-2002-00447	0	Technetium Monitor (U) Long Term Runs with ICPES Spectrometer				
159	Closed	1	SCT-M0SRLE60-00-96-03	00B	WSRC-TR-2002-00495	0	Evaluating the Effects of Tri-Butyl Phosphate (TBP) and Normal Paraffin Hydrocarbon (NPH) in Simulated Low-Activity Waste Solution on Ion Exchange	98-205			

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
160	Closed	0	SCT-M0SRLE60-00-182-01	00D	WSRC-TR-2002-00509	0	Compositing, Characterization, and Dilution of Samples from Hanford Tank 241-AW-101				
161	Closed	0	SCT-M0SRLE60-00-180-01	00B	WSRC-TR-2002-00530	0	Filtration of a Hanford AW-101 Waste Sample (U)				
162	Closed	0	SCT-M0SRLE60-00-110-07	00D	WSRC-TR-2002-00548	0	Determination of Perrhenate (Re04) Adsorption Kinetics from Hanford Waste Simulants Using SuperLig 639 Resin (U)				
163	Closed	0	SCT-M0SRLE60-00-154-05	00B	WSRC-TR-2002-00550	0	Waste Feed Evaporator Off-Gas Emissions Modeling				
164	Closed	0	SCT-M0SRLE60-00-110-08	00B	WSRC-TR-2002-00580	0	Laboratory-Scale SuperLig 639 Column Tests with Hanford Waste Simulants (U)				
165	Closed	0	SCT-M0SRLE60-00-132-05	00C	WSRC-TR-2003-00037	0	Pilot Scale Testing - Transport of HLW Glass Former Chemicals Proof of Principle Test Results (U)				See also RTC-0170.
166	Closed	0	SCT-M0SRLE60-00-129-02	00B	WSRC-TR-2003-00056	0	AN-102 Simulant SR/TRU Precipitation and Ultrafiltration (U)				
167	Closed	0	SCT-M0SRLE60-00-188-02	00C	WSRC-TR-2003-00160	0	Complexant Identification in Hanford Waste Simulant Sr/TRU Filtrate				
168	Closed	0	SCT-M0SRLE60-00-154-07	00C	WSRC-TR-2003-00172	0	Waste Feed Evaporation Physical Properties Modeling				
169	Closed	1	SCT-M0SRLE-60-00-141-03	00C	WSRC-TR-2003-00204	0	Pilot-Scale Cross-Flow Ultrafiltration Test Using a Hanford Site Tank 241-AN-102 Waste Simulant (U)	102-203	04-0001, 04-0012, 05-0002	04-0047	
170	Closed	1	SCT-M0SRLE60-00-187-02	00C	WSRC-TR-2003-00209	0	Evaluation of Wetting Agents to Mitigate Dusting of Glass Forming Chemicals During Delivery to the Melter Feed Preparation Vessel (U)	110-301, 111-401	03-063, 04-0003, 04-0004	03-086, 03-087	
171	Closed	0	SCT-M0SRLE60-00-154-06	00C	WSRC-TR-2003-00212	0	Waste Feed Evaporation Physical Properties and Solubility Determination				
172	Closed	1	SCT-M0SRLE60-00-150-01	00E	WSRC-TR-2003-00254	0	Integrated Sr/TRU Precipitation and Cs Ion Exchange Process Validation (U)	100-205			
173	Closed	0	24590-101-TSA-W000-0004-70-02	00B	WTP-RPT-026	0	Equilibrium Batch Contact Testing of SuperLig 639				
174	Closed	0	24590-101-TSA-W000-0004-114-04	00B	WTP-RPT-031	0	Small Column Testing of SuperLig 639 for Removing 99Tc from Hanford Tank 241-AN-102 Supernate (Envelope C) Mixed with Tank 241-C-104 Solids (Envelope D) Wash and Permeate Solutions				
175	Closed	0	24590-101-TSA-W000-0009-72-06	00A	VSL-03L3780-2	0	Summary and Recommendations on TCLP Model Form to Support HLW Delisting				
176	VOID		VOID		VOID		VOID				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
177	Closed	0	24590-101-TSA-W000-0009-87-15	00A	VSL-03S3730-1	0	High Level Waste Melter System Materials of Construction Testing				
178	Closed	0	24590-101-TSA-W000-0004-133-02	00B	WTP-RPT-091	0	Assessment of Abnormal Process Conditions for Sr/TRU Removal Using AN-102 Tank Waste Samples				
179	Closed	1	24590-101-TSA-W000-0004-114-12	00B	WTP-RPT-088	0	AP-101 Simulant Validation for Cesium Ion Exchange Processing Using SuperLig 644	89-205			
180	Closed	0	24590-101-TSA-W000-0004-146-02	00B	WTP-RPT-082	0	Assessment of Sr/TRU Removal Mechanisms Using AN-102 and AN-107 Tank Waste Samples				
181	Closed	1	24590-101-TSA-W000-0004-114-10	00B	WTP-RPT-080	0	Mixing of WTP Process Solutions	176-202, 177-215, Attachment			
182	Closed	0	24590-101-TSA-W000-0004-03-01	00B	WTP-RPT-047	0	Chemical Degradation of SuperLig 639 Ion Exchange Resin				
183	Closed	1	24590-101-TSA-W000-0004-69-02	N/A	WTP-RPT-017	0	Evaporation of a Mixture of Tank AN-102 Low Activity Waste and C-104 Washing and Leaching Solution				
184	Closed	1	SCT-M0SRLE60-00-33-03	00B	WSRC-TR-2003-00156	0	Recycle Stream Blending for High and Low Level Waste	176-202, 177-215			
185	Closed	0	SCT-M0SRLE60-00-181-02	00B	WSRC-TR-2003-00155	0	Experimental Design for RPP Study on High Level Waste Lag Storage and Feed Blending				
186	Closed	0	SCT-M0SRLE60-00-193-01	00A	WSRC-TR-2003-00148	0	Technetium Eluate Evaporation Solubility and Precipitation Performance				
187	Closed	0	SCT-M0SRLE60-00-142-03	00D	WSRC-TR-2002-00519	0	Preliminary Study for a High Level Waste Canister Closure Weld				
188	Closed	2	24590-101-TSA-W000-0009-107-01	00D	TRR-PLT-062	1	RPP-WTP Pilot Melter Envelope A Melter Emissions Test Results Report	120-302, 121-303, 122-402, 123-403, 136-402_Rev_1, 137-403_Rev_1, 153-302, 154-303	04-0018, 04-0024, 05-0010	04-0055	
189	Closed	2	24590-101-TSA-W000-0009-120-06	00B	TRR-PLT-075	0	RPP-WTP Pilot Melter Envelope B Melter Emissions Test Results	120-302, 121-303, 122-402, 123-403, 136-402_Rev_1, 137-403_Rev_1, 153-302, 154-303	04-0018, 04-0024, 05-0010	04-0055	
190	Closed	1	SCT-M0SRLE60-00-187-03	00B	WSRC-TR-2003-00295	0	Filtration of a Hanford AN-104 Sample (U)				
191	Closed	1	24590-101-TSA-W000-0009-82-02	00B	VSL-03R3760-2	0	Glass Formulation to Support Melter Runs with HLW Simulants	126-401	03-028, 04-0037	04-0011, 04-0037	
192	Closed	1	24590-101-TSA-W000-0009-72-08	00B	VSL-03R3780-1	0	Regulatory Testing of WTP HLW Glasses for Compliance with Delisting Requirements	172-401			

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
193	Closed	0	24590-101-TSA-W000-0009-66-05	00B	VSL-02S4600-3	0	Test Matrix to Support Property-Composition Model Development for RPP-WTP LAW Glasses				
194	Closed	0	SCT-M0SRLE60-00-110-15	00B	WSRC-TR-2003-00210	0	Compositing, Homogenizing, and Characterizing Samples from Hanford Tank 241-AN-107 (U)				
195	Closed	0	SCT-M0SRLE60-00-189-01	00B	WSRC-TR-2003-00379	0	Characterization, Dilution, and Aging Study of a River Protection Project Sample from Tank 241-AW-101 (U)				
196	Closed	1	SCT-M0SRLE60-00-103-03	00B	WSRC-TR-2003-00098	0	Multiple Ion Exchange Column Runs for Cesium and Technetium Removal from AW-101 Waste Sample (U)	106-205	04-0007	04-0019	
197	Closed	1	SCT-M0SRLE60-00-187-04	00B	WSRC-TR-2003-00311	0	Cesium Ion Exchange Using Tank 241-AN-104 Supernate (U)	99-205		04-0017	
198	Closed	1	24590-101-TSA-W000-0004-97-04	00C	WTP-RPT-089	1	Analysis of SuperLig 644 Resin Used in Hanford Tank Waste Processing	101-205		04-0018	
199	Closed	1	SCT-M0SRLE60-00-110-17	00C	WSRC-TR-2003-00205	0	Compositing and Characterization of Samples from Hanford Tank 241-AY-102/C-106	124-201			
200	Closed	0	24590-101-TSA-W000-0009-69-05	00B	VSL-03R3470-3	0	LAW Glass Formulation to Support AZ-101 Actual Waste Testing				
201	Closed	1	24590-101-TSA-W000-0009-96-03	00C	TRR-PLT-073	0	Pilot Melter Sub-Envelope B2 Variation Test Results Report	96-301	03-064, 03-065		
202	Closed	0	24590-101-TSA-W000-0009-120-09	00C	REP-PLT-021	0	RPP-WTP Pilot Melter Off-Gas System Inspection Report				
203	Closed	0	SCT-M0SRLE60-00-158-01	00C	WSRC-TR-2003-00294	0	Interim Report for Crucible-Scale Active Vitrification and Product Testing of Waste Envelope B (AZ-102) Glass (U)				
204	Closed	1	24590-101-TSA-W000-0009-106-17	00B	VSL-03R3410-3	0	DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A3 and C2 Feeds in Support of the LAW Pilot Melter	249-302, 250-303	07-0029, 07-0030, 07-0037, 07-0038		
205	Closed	1	SCT-M0SRLE60-00-33-04	00B	WSRC-TR-2003-00256	0	Analysis of a Hanford Tank 241-AZ-102 Glass	240-302			
206	Closed	1	24590-101-TSA-W000-0009-144-01	00B	VSL-03R3800-1	0	Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers	136-402_Rev_1, 137-403_Rev_1, 144-402	04-0018	04-0055	
207	Closed	1	24590-101-TSA-W000-0009-106-07	00C	VSL-02R62N0-6	0	DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelopes A1 and C1 Feeds in Support of the LAW Pilot Melter	174-302			
208	Closed	1	24590-101-TSA-W000-0009-144-04	00C	VSL-03R3410-1	0	DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A2 and B1 Feeds in Support of the LAW Pilot Melter	249-302, 250-303	07-0029, 07-0030, 07-0037, 07-0038		

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
209	Closed	1	24590-101-TSA-W000-0009-106-13	00B	VSL-03S3850-2	1	Plenum Gas Sampling During LAW Sub-Envelopes A1 and C2 DM10 Tests in Support of Flammability Models	159-302, 160-402			
210	Closed	1	SCT-M0SRLE60-00-175-01	00B	WSRC-TR-2002-00282	1	Characterization of HLW and LAW Glass Formers - Final Report - (U)	148-401, 149-301	04-0020, 04-0021	03-150, 04-0057	
211	Closed	1	24590-101-TSA-W000-0009-135-04	00B	VSL-03R3410-2	0	Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope B2 Feed in Support of the LAW Pilot Melter	249-302, 250-303	07-0029, 07-0030, 07-0037, 07-0038		
212	Closed	0	SCT-M0SRLE60-00-110-18	00B	WSRC-TR-2003-00334	0	Analysis of a Hanford 241-AN-107 Supernate for Evaluation of Regulatory Analytical Methods				
213	Closed	1	24590-101-TSA-W000-0009-84-02	00B	TRR-PLT-035	0	Sub-Envelope C1-A1 Changeover Test Results Report	174-302			
214	Closed	0	SCT-M0SRLE60-00-192-01	00A	WSRC-TR-2003-00216	0	Waste Treatment Plant LAW Evaporation: Antifoam Performance (U)				
215	Closed	0	SCT-M0SRLE60-00-170-03	00B	WSRC-TR-2003-00232	0	Parameters Influencing the Formation of Post-filtration solids in the 241-AN-107 and 241-AN-102 Hanford High-level Waste Simulants				
216	Closed	1	SCT-M0SRLE60-00-191-01	00B	WSRC-TR-2003-00218	0	Evaporation of Pretreated Hanford Tank AW-101 Sample Mixed With Recycle	197-212			
217	Closed	1	24590-101-TSA-W000-0009-49-04	00B	TRR-PLT-078	0	Pilot Melter Sub-Envelope A2-B1 Changeover Test Results Report	242-302, 260-301			
218	Closed	2	24590-101-TSA-W000-0009-111-02	00B	VSL-02R8800-2	1	Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope A1 Simulants	120-302, 121-303, 122-402, 123-403, 136-402_Rev_1, 137-403_Rev_1, 153-302, 154-303	04-0018, 04-0024, 05-0010	04-0055	
219	Closed	0	24590-101-TSA-W000-0009-105-04	00C	VSL-03S3780-1	1	Augmentation Test Matrix to Support TCLP Model Development for RPP-WTP HLW Glasses				
220	Closed	0	SCT-M0SRLE60-00-88-04	00A	WSRC-TR-2003-00262	0	Evaporation of Hanford Tank Sample AN-107 Mixed with Recycles (U)				
221	Closed	1	SCT-M0SRLE60-00-133-01	00B	WSRC-TR-2001-00584	1	Results from Analysis of a Hanford Tank 241-AN-102 Melter-Scale Glass Waste Form	103-302			
222	Closed	1	24590-101-TSA-W000-0009-147-01	00B	TRR-PLT-036	1	RPP Pilot Melter Sub-Envelope C1 Production Verification Test Results Report	174-302			
223	Closed	1	SCT-M0SRLE60-00-135-02	00A	WSRC-TR-2003-00285	0	RPP-WTP LAW Melter Off-Gas Flammability Assessment	161-302			

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
224	Closed	1	24590-101-TSA-W000-0009-98-07	00C	VSL-03R3800-3	0	DM1200 Tests with C-104/AY-101 HLW Simulants	136-402_Rev_1, 137-403_Rev_1, 153-302, 154-303, 185-303, 186-403	04-0018, 04-0030	04-0055, 04-0061	
225	Closed	0	SCT-M0SRLE60-00-181-03	00B	WSRC-TR-2003-00339	0	High Level Waste Lag Storage and Feed Blending				
226	Closed	0	SCT-M0SRLE60-00-184-02	00A	WSRC-TR-2003-00269	0	Modeling Treated LAW Feed Evaporation				
227	Closed	0	24590-101-TSA-W000-0004-104-05	00B	WTP-RPT-064	0	Rheological and Physical Properties of AP-101 LAW Pretreated Waste and Melter Feed				See also RTC-0101.
228	Closed	0	24590-101-TSA-W000-0004-114-13	00B	WTP-RPT-073	0	Initial Assessment of Waste, Process, and Product Variations and Uncertainties for Waste Treatment Plant IHLW and ILAW				
229	Closed	1	24590-101-TSA-W000-0004-104-08	00B	WTP-RPT-095	0	Rheological and Physical Properties of AZ-101 LAW Pretreated Waste and Melter Feed	276-301			
230	Closed	0	24590-101-TSA-W000-0009-23-09	00A	TRR-PLT-068	0	Pilot Melter Bubbler Consumable Changeout Box				
231	Closed	1	24590-101-TSA-W000-0009-102-01	00D	VSL-01R62N0-1	2	Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A3 Feed in Support of the LAW Pilot Melter	249-302, 250-303	07-0029, 07-0030, 07-0037, 07-0038		See also RTC-0014.
232	Closed	3	24590-101-TSA-W000-0009-111-01	00B	VSL-02R8800-1	1	Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope C1 Simulants	120-302, 121-303, 122-402, 123-403, 136-402_Rev_1, 137-403_Rev_1, 153-302, 154-303, 185-303, 186-403	06-0009	04-0055, 04-0061	
233	Closed	0	SCT-M0SRLE60-00-110-19	00B	WSRC-TR-2003-00335	0	Analysis of Hanford 241-AY-102/C-106 Sludge for Evaluation of Regulatory Analytical Methods				
234	Closed	0	24590-101-TSA-W000-0004-65-04	00B	WTP-RPT-045	2	Statistical Assessment of Preliminary Property-Composition Data and Models for IHLW PCT and TCLP				
235	Closed	0	24590-101-TSA-W000-0004-99-02	00C	WTP-RPT-052	1	Evaluation of Temperature and Caustic Effects on Tank Waste Solubility for Hanford Tank 241-AN-102				
236	Closed	0	24590-101-TSA-W000-0004-139-01	00B	WTP-RPT-069	0	Chemical Analysis and Physical Property Testing of 241-AP-104 Tank Waste				
237	Closed	0	24590-101-TSA-W000-0004-99-06	00A	WTP-RPT-071	1	Statistical Assessment of Preliminary Property Composition Data and Models for ILAW PCT and VHT				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
238	Closed	0	24590-101-TSA-W000-0004-114-14	00B	WTP-RPT-083	0	Thermodynamic Data Development for Modeling Sr/TRU Separations: Sr-EDTA, Sr-HEDTA, and Mn-Gluconate Complexation				
239	Closed	0	24590-101-TSA-W000-0004-99-09	00D	WTP-RPT-100	0	Technical Basis for HLW Vitrification Stream Physical and Rheological Property Bounding Conditions			06-0037	See also RTC 0349 and CCN 137198.
240	Closed	0	24590-101-TSA-W000-0004-87-09	00C	WTP-RPT-043	1	Filtration, Washing, and Caustic Leaching of Hanford Tank AZ-101 Sludge				
241	Closed	1	SCT-M0SRLE60-00-183-02	00A	WSRC-TR-2003-00267	0	Validation and Application of Concentrated Cesium Eluate Physical Property Models	292-206			
242	Closed	0	24590-101-TSA-W000-0004-133-03	00B	WTP-RPT-090	0	Assessment of Abnormal Process Conditions for SR/TRU Removal Using Waste Simulant				
243	Closed	1	24590-101-TSA-W000-0004-129-03	00B	WTP-RPT-085	0	Liquidus Temperature Testing and Model Evaluation Results	105-401, 127-401	04-0026, 04-0033	04-0011, 04-0045, 04-0046	
244	Closed	0	SCT-M0SRLE60-00-110-20	00A	WSRC-TR-2003-00390	0	Rheological and Physical Properties of Hanford Radioactive LAW AZ-102 Pretreated Waste and Melter Feed (U)				
245	Closed	0	24590-101-TSA-W000-0009-66-05	00B	VSL-02S4600-3	1	Test Matrix to Support Property-Composition Model Development for RPP-WTP LAW Glasses				
246	Closed	0	SCT-M0SRLE60-00-110-21	00A	WSRC-TR-2003-00479	0	Compositing, Homogenization, and Characterization of Samples from Hanford Tank 241-AN-104 (U)				
247	Closed	0	SCT-M0SRLE60-00-110-12	00B	WSRC-TR-2003-00084	0	LAW Radioactive Coupon CO2 Decontamination Test				See also RTC-0107.
248	Closed	0	24590-101-TSA-W000-0004-72-08	00C	WTP-RPT-078	0	Results of Small-Scale Particle Cloud Tests and Non-Newtonian Fluid Cavern Tests				
249	Closed	1	24590-101-TSA-W000-0009-144-03	00B	VSL-03R3740-2	0	Noble Metals Testing on the DM1200 Pilot Melter System with AZ-101 HLW Simulants	105-401	04-0018, 04-0030	04-0055, 04-0061	
250	Closed	0	24590-101-TSA-W000-0009-147-02	00A	TRR-PLT-067	0	RPP Pilot Melter Metallic Dam Corrosion Test Results Report				
251	Closed	1	SCT-M0SRLE60-00-193-02	00A	WSRC-TR-2003-00220	0	Development of Simulants to Support Mixing Tests for High Level Waste and Low Activity Waste	112-401			
252	Closed	1	24590-101-TSA-W000-0009-87-12	00B	VSL-03S3850-1	1	Plenum Gas Sampling During LAW DM10 and DM1200 Tests in Support of Flammability Models	192-302			
253	Closed	0	24590-101-TSA-W000-0009-147-03	00A	VSL-03R4470-1	0	LAW Glass Formulation to Support SY-101/AP-104 Actual Waste Testing				
254	Closed	0	24590-101-TSA-W000-0009-23-10	00C	TRR-PLT-061	0	RPP Pilot Melter Bubbler Life Extension Test Results Report	187-000	04-0041, 04-0056	04-0056	

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
255	Closed	0	24590-101-TSA-W000-0004-144-01	00B	WTP-RPT-096	0	Rheological and Physical Properties of AZ-101 HLW Pretreated Sludge and Melter Feed				See also RTC 0349 and CCN 137198.
256	Closed	1	24590-101-TSA-W000-0004-04-00001	00A	WTP-RPT-103	0	Comparison Testing of Multiple Resorcinol-Formaldehyde Resins for the River Protection Project-Waste Treatment Plant	248-205, 294-205			
257	Closed	0	24590-101-TSA-W000-0004-04-00003	00A	WTP-RPT-104	0	Pre-conditioning and Regeneration Requirements of Ground Gel Resorcinol Formaldehyde Ion Exchange Resin				
258	Closed	0	24590-101-TSA-W000-0004-04-00002	00A	WTP-RPT-093	0	Aging Effects of Stored SuperLig 644 Ion Exchange Resin				
259	Closed	1	24590-101-TSA-W000-0004-91-00003	00A	WTP-RPT-105	0	Elution Testing of Resorcinol-Formaldehyde Resins with AN-105 Simulant	248-205, 294-205	08-0011, 08-0012		
260	Closed	0	SCT-M0SRLE60-00-193-03	00A	WSRC-TR-2003-00433	0	Cesium Removal from Hanford Tank 241-AW-101 Supernate Using Resorcinol-Formaldehyde Resin (U)	248-205, 294-205	08-0011, 08-0012, 08-0022		
261	Closed	1	SCT-M0SRLE60-00-110-00020	00A	WSRC-TR-2003-00464	0	AN-107 Active Waste Sr/TRU Precipitation and Ultrafiltration (U)	173-203			
262	Closed	1	24590-101-TSA-W000-0009-96-02	00B	TRR-PLT-063	0	Pilot Melter Glass Pool Foaming Control Test Results	117-302			
263	Closed	0	24590-101-TSA-W000-0009-143-01	00B	VSL-03R3851-1	0	Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants	96-301	02-351, 02-352, 04-0004, 04-0018	04-0055, 04-0027, 04-0033	
264	Closed	1	24590-101-TSA-W000-0009-106-19	00B	TRR-PLT-079	0	Sub-Envelope C2-A3 Changeover Test Results Report	260-301, 276-301			
265	Closed	0	24590-101-TSA-W000-0009-148-00001	00A	REP-PLT-015	0	Refractory Corrosion Analysis for the DM-5000A M-Area and DM-3300 LAW Pilot Melters				
266	Closed	0	24590-101-TSA-W000-0009-148-00002	00A	TRR-PLT-033	1	RPP Pilot Melter ADS Pump Performance Test Results Report				
267	Closed	0	24590-101-TSA-W000-0009-40-00002	00A	TRR-PLT-065	0	RPP Pilot Melter LAW Discharge Heater Corrosion Test Results Report				
268	Closed	0	24590-101-TSA-W000-0009-148-00003	00A	TRR-PLT-066	0	RPP Pilot Melter Lid Hanger Corrosion Test Results Report				
269	Closed	0	CCN 081657	N/A	INEEL-EXT-03-00887	0	Experimental Comparison of Mott, GKN, Pall, and Graver Ultrafiltration Membranes Using Envelope A (AN-105) and Envelope D (AZ-101) Hanford Simulants				
270	Closed	1	24590-101-TSA-W000-0004-82-00004	00A	WTP-RPT-094	0	Generation of Semi-Volatile Organic Compounds Tentatively Identified from Irradiating SuperLig 639 and SuperLig 644 Ion Exchange Resins				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
271	Closed	1	24590-101-TSA-W000-0009-110-00002	00A	TRR-PLT-034	0	RPP-WTP Pilot Melter Film Cooler Performance and Cleaning Protocols Test Results	151-302, 187-000			
272	Closed	1	24590-101-TSA-W000-0004-72-13	00B	WTP-RPT-098	0	Technical Basis for LAW Vitrification Stream Physical and Rheological Property Bounding Conditions	276-301			
273	Closed	1	24590-101-TSA-W000-0009-144-00005	00A	VSL-03R3800-4	0	DM1200 Tests with AZ-101 HLW Simulants	205-401, 251-402, 252-403	07-0037, 07-0038, 07-0040, 07-0041		
274	Closed	0	24590-101-TSA-W000-0009-102-00003	00A	VSL-03R3460-2	0	LAW Glass Formulation to Support Melter Runs with Simulants				
275	Closed	0	24590-101-TSA-W000-0004-116-00002	00A	WTP-RPT-109	0	Elution Testing of SuperLig 644 with AN-105 Simulant				
276	Closed	0	SCT-M0SRLE60-00-194-00001	00A	WSRC-TR-2003-00474	0	Measuring Physical and Chemical Property Variations of SuperLig 644 and SuperLig 639 Resin (U)				
277	Closed	1	SCT-M0SRLE60-00-110-00021	00A	WSRC-TR-2003-00574	0	Determination of Cesium (Cs+) Adsorption Kinetics and Equilibrium Isotherms from Hanford Waste Simulants Using Resorcinol-Formaldehyde (RF) Resins (U)	248-205, 294-205			
278	Closed	0	SCT-M0SRLE60-00-54-0002	00A	WSRC-TR-2003-00561	0	WTP Pilot-Scale Evaporation Tests (U)				
279	Closed	0	SCT-M0SRLE60-00-110-00024	00A	WSRC-TR-2003-00064	0	Pilot-Scale Precipitation Tests of Envelope C Simulants (U)				
280	Closed	1	SCT-M0SRLE60-00-90-00002	00A	WSRC-TR-2003-00568	0	Investigation of Alternative Cleaning Solutions for Mott Porous Metal Filters	195-203			
281	Closed	1	SCT-M0SRLE60-00-110-00023	00A	WSRC-TR-2003-00547	0	Tank 241-AY-102 Simulant Development, Ultrafiltration, and Washing	173-203			
282	Closed	0	SCT-M0SRLE60-00-158-00002	00A	WSRC-TR-2003-00536	0	Crucible-Scale Radioactive Vitrification and Product Testing of Waste Envelope B (AZ-102) Low-Activity Waste Glass (U)				
283	Closed	0	24590-101-TSA-W000-0009-66-00007	00A	VSL-04R4480-1	0	Preparation and Testing of LAW Matrix Glasses to Support WTP Property-Composition Model Development				
284	Closed	1	24590-101-TSA-W000-0009-87-00019	00A	VSL-04S4850-1	0	Comparison of Off-Gas Emissions from Tests with LAW Simulants on the DM100, DM1200, and DM3300 Melters	249-302, 250-303, 255-302	07-0029, 07-0030, 07-0032, 07-0033		
285	Closed	1	24590-101-TSA-W000-0004-125-00004	00A	WTP-RPT-122	0	WTP Flowsheet Evaluation of Mercury-Containing Hanford Waste Simulant			04-0060	
286	Closed	0	24590-101-TSA-W000-0009-69-00006	00A	VSL-04R4470-1	0	LAW Glass Formulation to Support AN-104 Actual Waste Testing				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
287	Closed	1	24590-101-TSA-W000-0009-118-00009	00A	VSL-04R4800-1	0	Integrated DM1200 Melter Testing of Redox Effects Using HLW AZ-101 and C-106/ AY-102 Simulants	251-402, 252-403	07-0037, 07-0038, 07-0040, 07-0041		
288	Closed	0	SCT-M0SRLE60-00-195-00001	00A	WSRC-TR-2004-00201	0	RPP-WTP Semi-Integrated Pilot Plant-Campaign I				
289	Closed	0	24590-101-TSA-W000-0004-160-00001	00B	WTP-RPT-129	0	Technical Basis for Scaling of Air Sparging Systems for Mixing in Non-Newtonian Slurries				
290	Closed	0	24590-101-TSA-W000-0009-101-00007	00A	TRR-PLT-080	0	RPP Pilot Melter Prototypic LAW Container and HLW Canister Glass Fill Test Results				
291	Closed	0	SCT-M0SRLE60-00-05-00002	00A	WSRC-TR-2003-00555	0	Ion Exchange Modeling for Removal of Cesium from Hanford Waste Using SuperLig 644 Resin				
292	Closed	0	SCT-M0SRLE60-00-10-00004	00A	WSRC-TR-2003-00557	0	Pilot-Scale Demonstration of Methods to Remove and Replace SuperLig 644 Ion Exchange Resin in WTP Process Equipment				
293	Closed	0	24590-101-TSA-W000-0009-118-00010	00A	VSL-04R4800-2	0	ADS Pump Testing as Part of Integrated DM1200 Testing of HLW Compositions Using Bubblers				
294	VOID		VOID		VOID		VOID				
295	Closed	0	24590-101-TSA-W000-0004-150-00001	00A	WTP-RPT-092	0	Vitrification and Product Testing of AP-101 Pretreated LAW Envelope A Glass				
296	Closed	0	24590-101-TSA-W000-0004-150-00002	00A	WTP-RPT-106	0	Vitrification and Product Testing of AZ-101 Pretreated LAW Envelope B Glass				
297	Closed	1	24590-101-TSA-W000-0009-152-00001	00A	VSL-04R4500-1	0	Characterization of Simulated WTP LAW Melter Feeds	276-301			
298	Closed	1	24590-101-TSA-W000-0004-150-00003	00A	WTP-RPT-115	0	Gas Generation Testing and Support for the Hanford Waste Treatment and Immobilization Plant	208-213, 209-333, 210-433	04-0028, 06-0041		
299	Closed	1	24590-101-TSA-W000-0004-104-00011	00A	WTP-RPT-107	0	Rheological and Physical Properties of AP-104 LAW Pretreated Waste and Melter Feed	276-301			
300	Closed	1	24590-101-TSA-W000-0009-105-00006	00A	VSL-04R4851-1	0	Bubbling Rate and Foaming Tests on the DuraMelter 1200 with LAWC22 and LAWA30 Glasses	242-302			
301	Closed	0	24590-101-TSA-W000-0009-154-00001	00A	VSL-04L4440-1	1	Sampling and Analysis of Sulfate Samples from the LAW Pilot Melter				
302	Closed	1	24590-101-TSA-W000-0009-98-00008	00A	VSL-04R4410-1	0	Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope C2 Feed in Support of the LAW Pilot Melter	255-302, 260-301	07-0032, 07-0033		

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
303	Closed	1	24590-101-TSA-W000-0009-153-00001	00A	VSL-04R4800-3	0	High-Level Waste Melter Alternate Bubbler Configuration Testing	178-402			
304	Closed	0	SCT-M0SRLE60-00-110-03	00B	WSRC-TR-2002-00122	0	Pilot Scale Precipitation Test of AN-107 Simulant Without Caustic Adjustment at 50 Degrees C (U)				See also RTC-0155.
305	VOID		VOID		VOID		VOID				
306	Closed	0	SCT-M0SRLE60-00-05-00003	00A	WSRC-TR-2004-00100	0	Ion Exchange Modeling for Removal of Cesium from Hanford Waste Using Resorcinol-Formaldehyde Resin		08-0011, 08-0012, 08-0022		
307	Closed	0	24590-101-TSA-W000-0004-149-00001	00A	WTP-RPT-126	0	Statistical Assessment of Bias and Random Uncertainties in WTP HLW CRV Mixing and Sampling				
308	Closed	0	SCT-M0SRLE60-00-145-00016	00A	WSRC-TR-2004-00010	0	Physical Characterization of Florida International University Simulants (U)				
309	Closed	0	SCT-M0SRLE60-00-30-00003	00A	WSRC-TR-2003-00514	0	Ion Exchange Testing with SuperLig 644 Resin (U)				
310	Closed	1	CCN 081599	N/A	INEEL-EXT-03-00886	0	Development of an Ultrafiltration Chemical Cleaning Sequence for Hanford Simulated Tank Waste; Env. A (AN-105), Env. C (AN-102) and Env. D (AZ-101)	195-203, 238-203			
311	Closed	0	SCT-M0SRLE60-00-187-00005	00B	WSRC-TR-2003-00240	0	Filtration, Washing, and Leaching of a Hanford AY-102/C-106 Sample				
312	Closed	0	24590-101-TSA-W000-0009-64-00003	00A	VSL-044770-1	0	HLW Glass Formulation to Support C-106/AY-102 Actual Waste Testing				
313	Closed	0	24590-101-TSA-W000-0004-99-00011	00A	WTP-RPT-110	0	Test Results for Pulse Jet Mixers in Prototypic Ultrafiltration Feed Process and High-level Waste Lag Storage Vessels				
314	Closed	0	24590-101-TSA-W000-0009-134-00003	00A	VSL-04R4430-1	0	Corrosion Testing of Bubbler Materials for LAW Vitrification				
315	Closed	0	24590-101-TSA-W000-0004-99-00010	00B	WTP-RPT-111	0	Non-Newtonian Slurry Simulant Development and Selection for Pulse Jet Mixer Testing				
316	Closed	0	24590-101-TSA-W000-0004-153-00001	00B	WTP-RPT-121	0	Chemical Tracer Techniques for Assessing Mixing Performance in Non-Newtonian Slurries for WTP Pulsed Jet Mixer Systems				
317	Closed	0	SCT-M0SRLE60-00-197-00001	00A	WSRC-TR-2004-00399	0	Gas Retention and Release Tests Supporting the Concentrate Receipt Vessel (CRV-VSL-00002A/2B) Configuration (U)				
318	Closed	0	24590-101-TSA-W000-0004-150-00004	00A	WTP-RPT-116	0	Vitrification and Product Testing of AZ-101 Pretreated High-Level Waste Envelope D Glass	214-401			

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
319	Closed	1	SCT-M0SRLE60-00-199-00001	00C	WSRC-TR-2004-00387	0	Evaluation of Foaming/Antifoaming in WTP Tanks Equipped with Pulse Jet Mixers and Air Spargers	212-204, 234-203			See also RTC-0362.
320	Closed	0	24590-101-TSA-W000-0004-114-11	00C	WTP-RPT-053	1	Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Hanford Waste Tank 241-AZ-101 (Envelope B)				
321	Closed	0	24590-101-TSA-W000-0004-114-04	00C	WTP-RPT-031	1	Small Column Testing of SuperLig 639 for Removing 99Tc from Hanford Tank 241-AN-102 Supernate (Envelope C) Mixed with Tank 241-C-104 Solids (Envelope D) Wash and Permeate Solutions				
322	Closed	0	24590-101-TSA-W000-0004-114-02	00C	WTP-RPT-033	1	Small Column Ion Exchange Testing of SuperLig 644 for Removing 137Cs from Hanford Waste Tank 241-AN-102 Supernate (Envelope C) Mixed with Tank 241-C-104 Solids and Permeate Solutions				
323	Closed	0	24590-101-TSA-W000-0004-114-08	00B	WTP-RPT-058	1	Small Column Testing of SuperLig 639 for Removing 99Tc from Hanford Tank Waste Envelope B (Tank 241-AZ-101)				
324	Closed	0	24590-101-TSA-W000-0009-54-00001	00C	VSL-01R2200-1	1	Submerged Bed Scrubber (SBS): Off-line Component Testing of DM1200 SBS Unit				
325	Closed	0	SCT-M0SRLE60-00-198-00001	00A	WSRC-TR-2004-00398	0	Hybrid-mixing Tests Supporting the Concentrate Receipt Vessel (CRV-VSL-00002A/2B) Configuration (U)				
326	Closed	1	24590-101-TSA-W000-0009-156-00001	00A	VSL-04R4780-1	0	Regulatory Testing of RPP-WTP HLW Glasses to Support Delisting Compliance	198-402	06-0001, 06-0002		
327	VOID		VOID		VOID		VOID				
328	Closed	1	24590-101-TSA-W000-0009-157-00001	00A	VSL-04R4710-1	0	DM100 HLW and LAW Tests of the Influence of Technetium on Cesium Volatility Using Rhenium as a Technetium Surrogate	194-402		04-0012, 04-0013, 04-0022, 04-0023	
329	Closed	1	24590-101-TSA-W000-0009-158-00001	00A	VSL-04R4800-4	0	Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW-AZ-101 Simulants				
330	Closed	0	24590-101-TSA-W000-0004-99-00012	00A	WTP-RPT-117	0	Oxidative-Alkaline Leaching of Washed 241-SY-102 and 241-SX-101 Tank Sludges				
331	Closed	1	SCT-M0SRLE60-00-203-00001	00A	WSRC-TR-2004-00232	0	Evaporation, Rheology, and Vitrification of a Pretreated Radioactive Hanford Tank 241-AN-104 Sample Mixed with Simulated LAW SBS Recycle	237-212			
332	Closed	0	24590-101-TSA-W000-0009-162-00001	00A	REP-RPP-069	0	Investigation of Glass Bubbling and Increased Production Rate				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
333	Closed	0	24590-101-TSA-W000-0009-72-00014	00A	VSL-04L4780-1	0	Summary and Recommendations on Viscosity and Electrical Conductivity Model Forms to Support HLW Vitrification	105-401		04-0046	
334	Closed	0	24590-101-TSA-W000-0009-66-00008	00A	VSL-04R4480-2	0	Final Report - Phase 1 ILAW PCT and VHT Model Development				
335	Closed	0	24590-101-TSA-W000-0009-119-00003	00A	VSL-04R5730-1	0	High-Level Waste Melter System Materials of Construction Testing				
336	Closed	0	SCT-M0SRLE60-00-141-00004	00A	WSRC-TR-2005-00009	0	Immobilized High Level Waste Test Canister Closure Welding				
337	Closed	1	24590-101-TSA-W000-0009-155-00003	00A	VSL-05R5410-1	0	DuraMelter 100 Tests with LAW AP-101/AY-102 Blended Feed from the Semi-Integrated Pilot Plant	255-302, 260-301	07-0032, 07-0033, 07-0037, 07-0038		
338	Closed	0	SCT-M0SRLE60-00-211-00001	00A	WSRC-TR-2005-00035	0	Physical Characterization of Vitreous State Laboratory AY102/C106 and AZ102 High Level Waster Melter Feed Simulants				See also RTC 0349 and CCN 137198.
339	Closed	0	24590-101-TSA-W000-0004-114-00017	00C	WTP-RPT-072	0	Statistical Methods and Results for WTP IHLW and ILAW Compliance				
340	Closed	0	24590-101-TSA-W000-0004-165-00001	0	WTP-RPT-128	0	Hybrid Mixing System Test Results For Prototype Ultrafiltration Feed Process and High-Level Waste Lag Storage Vessels				
341	Closed	0	24590-101-TSA-W000-0009-121-00006	00A	VSL-05R5740-1	0	Modeling the Behavior of Noble Metals During HLW Vitrification in the DM 1200 Melter				
342	Closed	1	24590-101-TSA-W000-0009-98-00009	00A	VSL-05R5780-1	0	Development of Phase 1 HLW Models for PCT Response and One-Percent Crystal Fraction Temperature	296-401			
343	Closed	1	24590-101-TSA-W000-0004-168-00002	00B	WTP-RPT-137	0	Oxidative Alkaline Leaching of SX-101 and SY-102 and its Impact on Immobilized High-Level Waste	196-203, 235-203	07-0025		
344	Closed	0	24590-PTF-RPT-RT-04-0005	0	24590-PTF-RPT-RT-04-0005	0	Gas Retention and Release Tests in Non-Newtonian Simulants at the Florida International University in Support of the WTP Project				
345	Closed	1	24590-101-TSA-W000-0009-157-00002	00A	VSL-05R5460-1	0	Comparison of LAW Simulant, Actual Waste, and Melter Glasses	240-302			
346	Closed	1	24590-101-TSA-W000-0009-144-00006	00B	VSL-05R5800-1	0	Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification	205-401, 251-402, 252-403	07-0037, 07-0038, 07-0040, 07-0041		
347	Closed	0	24590-101-TSA-W000-0009-165-00001	00A	VSL-05R5780-2	0	Preparation and Testing of HLW Matrix Glasses to Support WTP Property-Composition Model Development				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
348	Closed	1	SCT-M0SRLE60-00-199-00002	00B	WSRC-TR-2005-00263	0	Evaluation of Foaming and Antifoam Effectiveness During the WTP Oxidative Leaching Process	213-203			
349	Closed	1	24590-101-TSA-W000-0004-172-00001	00A	WTP-RPT-112	0	Technical Basis for HLW Vitrification Stream Physical and Rheological Property Bounding Conditions	205-401, 207-206	06-0019, 06-0034, 06-0035, 06-0036, 06-0037	06-0037	
350	Closed	0	24590-101-TSA-W000-0009-23-09	00D	TRR-PLT-068	1	Pilot Melter Bubbler Consumable Changeout Box Test Results Report				See also RTC-0136.
351	Closed	0	24590-101-TSA-W000-0004-89-01	00D	WTP-RPT-020	1	Chemical Analysis and Physical Property Testing of 241-AN-102 Tank Waste - Supernatant and Centrifuged Solids				
352	Closed	1	SCT-M0SRLE60-00-110-06	00A	WSRC-TR-2002-00459	0	Pilot Scale Precipitation Test of AN-107 Simulant with Caustic Adjustment at 20 Degrees C (U)	224-203			
353	Closed	0	24590-101-TSA-W000-0009-72-05	00D	VSL-03R3760-1	0	Regulatory Spike Testing for RPP-WTP LAW and HLW Glasses for Compliance with Land Disposal Restrictions				
354	VOID		VOID		VOID		VOID- per RAB duplicate of RTC 350				
355	Closed	0	24590-101-TSA-W000-0004-101-03	00C	WTP-RPT-044	1	Combined Entrained Solids and Sr/TRU Removal from AN-102/C-104 Waste Blend				
356	VOID		VOID		VOID		VOID				
357	Closed	0	24590-101-TSA-W000-0004-87-08	00C	WTP-RPT-048	1	Chemical Analysis and Physical Property Testing of 241-AZ-101 Tank Waste - Supernatant and Centrifuged Solids				
358	VOID		VOID		VOID		VOID				
359	Closed	0	24590-101-TSA-W000-0004-114-01	00D	WTP-RPT-016	1	Small Column Ion Exchange Testing of SuperLig 644 for Removal of 137Cs from Hanford Waste Tank 241-AP-101 Diluted Feed (Envelope A)				
360	Closed	0	SCT-M0SRLE60-00-196-00001	00A	WSRC-TR-2004-00298	0	Foaming - Antifoaming in WTP Tanks Equipped with Pulse Jet Mixers and Air Spargers - Interim Report				
361	Closed	0	24590-101-TSA-W000-0004-153-00002	00B	WTP-RPT-114	1	Gas Retention and Release in Hybrid Pulse Jet Mixed Tanks Containing Non-Newtonian Waste Simulants				
362	Closed	0	SCT-M0SRLE60-00-199-00001	00C	WSRC-TR-2004-00387	0	Evaluation of Foaming/Antifoaming in WTP Tanks Equipped with Pulse Jet Mixers and Air Spargers				See also RTC-0319.
363	Closed	0	SCT-M0SRLE60-00-220-00001	00A	WSRC-TR-2004-00381	0	Task Technical and Quality Assurance Plan for Radiolytic, Thermal, and Physical Degradation Testing with Resorcinol-Formaldehyde (RF) Resin (U)				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
364	Closed	1	SCT-M0SRLE60-00-32-02	00D	WSRC-TR-2001-00594	0	Cesium Eluate Analytical Data Evaluation	262-206			
365	Closed	0	24590-101-TSA-W000-0009-72-00011	00B	VSL-03L4480-2	1	Summary and Recommendations on Viscosity and Electrical Conductivity Model Forms to Support LAW Vitrification				
366	Closed	0	SCT-M0SRLE60-00-205-00001	00A	WSRC-TR-2004-00488	0	UFP Restart and Sparger Testing				
367	Closed	0	SCT-M0SRLE60-00-208-00001	00B	WSRC-TR-2004-00478	0	RPP-WTP Semi-Integrated Pilot Plant Campaign II				
368	Closed	0	SCT-M0SRLE60-00-208-00002	00B	WSRC-TR-2004-00565	0	RPP-WTP Semi-Integrated Pilot Plant Campaign III				
369	Closed	0	24590-101-TSA-W000-0004-114-00016	00A	WTP-RPT-113	0	Technical Basis for Testing Scaled Pulse Jet Mixing Systems for Non-Newtonian Slurries				
370	Closed	0	SCT-M0SRLE60-00-193-00004	00B	WSRC-TR-2004-00394	0	Hanford HLW AY-102/C106 Pretreated Sludge Physical and Chemical Properties Prior to Melter Feed Processing (U)				
371	Closed	0	24590-101-TSA-W000-0009-106-00021	00A	VSL-05R5710-1	0	DuraMelter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds				
372	Closed	1	SCT-M0SRLE60-00-208-00003	00B	WSRC-TR-2005-00105	0	RPP-WTP Semi-Integrated Pilot Plant	219-202, 220-203, 222-212	07-0016, 07-0018, 07-0019		
373	Closed	0	24590-101-TSA-W000-0009-74-01	00E	VSL-01R0100-2	0	Start-up and Commissioning Tests on the DuraMelter 1200 HLW Pilot Melter System Using AZ-101 HLW Simulants				
374	Closed	0	24590-101-TSA-W000-0004-169-00001	00A	WTP-RPT-138	0	Progress Report on Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins				
375	Closed	1	SCT-M0SRLE60-00-217-00001	00B	WSRC-TR-2005-00281	0	Hydrogen Generation Rate Scoping Study of DOW Corning Antifoam Agent	234-203			
376	Closed	0	24590-101-TSA-W000-0009-164-00001	00A	REP-PLT-069	0	Modeling the HLW Melter with Revised Bubbler Design and Noble Metals				
377	Closed	0	24590-101-TSA-W000-0004-170-00001	00B	WTP-RPT-120	0	Hanford Immobilized High-level Waste Canister Drop Testing				
378	Closed	1	24590-101-TSA-W000-0009-166-00001	00B	VSL-05R5830-1	0	Regulatory Off-Gas Emissions Testing on the DM1200 Melter System Using HLW and LAW Simulants	215-303, 216-403			
379	Closed	0	SCT-M0SRLE60-00-218-00001	00A	WSRC-TR-2005-00410	0	Vitrification and Product Testing of AY-102/C-106 HLW (Env D)	214-401			
380	Closed	1	24590-101-TSA-W000-0009-168-00001	00B	VSL-05R5760-1	0	Comparison of HLW Simulant, Actual Waste, and Melter Glasses	214-401			
381	Closed	0	24590-101-TSA-W000-0004-114-00019	00B	WTP-RPT-127	0	Overview of the Pulse Jet Mixer Non-Newtonian Scaled Test Program				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
382	Closed	0	24590-101-TSA-W000-0004-114-00018	00B	WTP-RPT-13	0	Technical Basis for Predicting Mixing and Flammable Gas Behavior in the Ultrafiltration Feed Process and High-Level Waste Lag Storage Vessels with Non-Newtonian Slurries				
383	Closed	1	SCT-M0SRLE60-00-99-12	00A	WSRC-TR-2005-00561	0	Ultra Filtration Process Vessel Suction Line Control Testing Final Report (U)	233-203			
384	Closed	0	24590-101-TSA-W000-0004-173-00001	00A	WTP-RPT-141	0	Waste, Process, and Product Variations and Uncertainties for Waste Treatment Plant IHLW and ILAW				
385	Closed	1	24590-101-TSA-W000-0004-174-00001	00A	WTP-RPT-134	0	Spherical Resorcinol-Formaldehyde Resin Testing for CS-137 Removal from Simulated and Actual Hanford Waste Tank 241-AP-101 Diluted Feed (Envelope A) Using Small Column Ion Exchange	248-205, 294-205	08-0011, 08-0012		
386	Closed	1	SCT-M0SRLE60-00-99-00009	00A	WSRC-TR-2005-00564	0	Ultrafiltration Process (UFP) Caustic Leaching Antifoam Performance	234-203			
387	Closed	1	24590-101-TSA-W000-0009-169-00001	00A	VSL-06R6480-1	0	DuraMelter 100 Tests to Support LAW Glass Formulation Correlation Development	249-302	07-0037, 07-0038		
388	Closed	1	24590-101-TSA-W000-0004-72-00017	00C	WTP-RPT-135	1	Small Column Ion Exchange Testing of Spherical Resorcinol Formaldehyde Resin for 137Cs Removal from Pre-Treated Hanford Tank 241-AN-102 Waste (Envelope C)	248-205, 294-205	08-0011, 08-0012		
389	Closed	0	SCT-M0SRLE60-00-110-00028	00A	WSRC-TR-2005-00570	0	Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin				
390	Closed	1	24590-101-TSA-W000-0004-114-00020	00B	WTP-RPT-144	0	Spherical Resorcinol-Formaldehyde Resin Analysis Following Actual Hanford Tank Waste Processing	248-205, 294-205			
391	Closed	0	24590-101-TSA-W000-0009-119-00003	00B	VSL-04R5730-1	1	High-Level Waste Melter System Materials of Construction Testing				
392	Closed	0	24590-101-TSA-W000-0009-170-00001	00A	VSL-06R6780-1	0	Sulfate Solubility in RPP-WTP HLW Glasses				
393	Closed	1	SCT-M0SRLE60-00-10-00005	00A	WSRC-TR-2005-00075	0	Radiolytic, Thermal, and Physical Degradation Testing of Spherical Resorcinol-Formaldehyde (RF) Resin (U)	248-205, 294-205	08-0011, 08-0012		
394	Closed	0	24590-101-TSA-W000-0009-169-00002	00A	VSL-06R6480-2	0	Preparation and Testing of LAW High Phosphorus and High Chromium Glasses				
395	Closed	1	24590-101-TSA-W000-0009-174-00001	00A	VSL-06R6710-1	0	Summary of DM1200 WESP History and Performance	250-303, 252-403	07-0029, 07-0030, 07-0040, 07-0041		
396	Closed	1	24590-101-TSA-W000-0009-172-00001	00A	VSL-06R6410-1	0	Review of Properties of Simulated Feeds Used for Melter Testing	205-401, 276-301			

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
397	Closed	0	24590-101-TSA-W000-0004-99-00013	00A	WTP-RPT-143	0	Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project - Waste Treatment Plant				
398	Closed	1	24590-101-TSA-W000-0004-174-00002	00B	WTP-RPT-142	0	Laboratory Scale Hydraulic Testing of Spherical Resorcinol Formaldehyde Ion Exchange Resins	248-205, 294-205	08-0011, 08-0012		
399	Closed	1	24590-101-TSA-W000-0009-177-00001	00A	VSL-06R6410-2	0	Summary of DM1200 SBS History and Performance	250-303, 252-403	07-0029, 07-0030, 07-0040, 07-0041		
400	Closed	1	24590-101-TSA-W000-0009-171-00001	00A	VSL-06R6710-2	0	Summary of DM1200 Operation at VSL	249-302, 250-303, 251-402, 252-403	07-0029, 07-0030, 07-0037, 07-0038, 07-0040, 07-0041		
401	Closed	0	24590-101-TSA-W000-0009-173-00001	00A	VSL-06R6480-3	0	Preparation and Testing of LAW High -Alkali Correlation and Augmentation Matrix Glasses				
402	Closed	0	24590-101-TSA-W000-0004-176-00001	00A	WTP-RPT-149	0	Literature Review of Plutonium (IV) Hydrous Oxide Solubility in Dilute Sodium Hydroxide and in Dilute Nitric Acid Solutions				
403	Closed	0	24590-101-TSA-W000-0009-98-00011	00A	VSL-06R6780-2	0	Preparation and Testing of HLW Matrix Glasses to Support Development of WTP Phase 2 Property-Composition Models				
404	Closed	1	24590-101-TSA-W000-0004-99-00013	00C	WTP-RPT-143	1	Comparison Testing of Multiple Spherical Resorcinol-Formaldehyde Resins for the River Protection Project - Waste Treatment Plant	248-205, 294-205	08-0011, 08-0012		
405	Closed	1	SCT-M0SRLE60-00-110-00028	00B	WSRC-TR-2005-00570	1	Pilot-Scale Hydraulic Testing of Resorcinol Formaldehyde Ion Exchange Resin	248-205, 294-205	08-0011, 08-0012		
406	Closed	0	24590-101-TSA-W000-0004-150-00005	00B	WTP-RPT-147	0	Effect of Anti-Foam Agent on Gas Retention and Release Behavior in Simulated High-Level Waste				
407	Closed	1	SCT-M0SRLE60-00-221-00001	00B	WSRC-TR-2005-00228	0	Spherical Resorcinol-Formaldehyde Resin Reactivity with Nitric Acid and Other Hanford RPP-WTP Process Solutions	294-205			
408	Closed	0	24590-101-TSA-W000-0009-98-00012	00A	VSL-06R1240-1	0	Preparation and Testing of HLW Glasses to Support Development of WTP IHLW Formulation Algorithm				
409	Closed	1	SCT-M0SRLE60-00-110-00029	00B	WSRC-STI-2006-00071	0	Batch, Kinetics, and Column Data from Spherical Resorcinol-Formaldehyde Resin	248-205, 294-205	08-0011, 08-0012		
410	Closed	0	24590-101-TSA-W000-0004-114-00021	00B	WTP-RPT-153	0	Estimate of Hanford Waste Insoluble Solid Particle Size and Density Distribution				
412	Closed	0	24590-101-TSA-W000-0004-181-00001	00B	WTP-RPT-155	0	Assessment of Pulse Tube Mixing for Vessels Containing Non-Newtonian Slurries				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
413	Closed	0	24590-101-TSA-W000-0004-180-00001	00C	WTP-RPT-146	0	Pulse Jet Mixer Controller and Instrumentation Testing				
414	Closed	0	24590-101-TSA-W000-0009-178-00001	00A	VSL-07R1230-1	0	ILAW PCT, VHT, Viscosity, and Electrical Conductivity Model Development	304-301			
415	Closed	1	SCT-M0SRLE60-00-05-00004	00A	WSRC-STI-2007-00030	0	Ion Exchange Modeling of Cesium Removal from Hanford Waste Using Spherical Resorcinol-Formaldehyde Resin	248-205, 294-205			
416	Closed	0	24590-101-TSA-W000-0009-02-00001	00B	VSL-07R1240-2	0	Baseline HLW Glass Formulations for Bismuth Phosphate	301-401	09-0010, 09-0011, 09-0012		
417	VOID		VOID		VOID		VOID per RAB- duplicates 419				
418	Closed	0	24590-101-TSA-W000-0009-179-00001	00A	VSL-07R1240-3	0	Time-Temperature-Transformation Diagrams for AY-102 HLW Glass				
419	Closed	1	SCT-M0SRLE60-00-110-00030	00B	WSRC-STI-2007-00213	0	Characterization of Spent Spherical Resorcinol-Formaldehyde Resin	294-205			
420	VOID		VOID		VOID		VOID per RAB- same as 416				
421	Closed	0	24590-QL-HC9-WA49-00001-03-00001	00A	WTP-RPT-148	0	Storage and Aging Effects on Spherical Resorcinol-Formaldehyde Resin Ion Exchange Performance	248-205, 294-205	08-0011, 08-0012, 08-0022		
422	Closed	0	SCT-M0SRLE60-00-224-00001	00A	WSRC-STI-2007-00537	0	Effects of Alternate Antifoam Agents, Noble Metals, Mixing Systems and Mass Transfer on Gas Holdup and Release from Non-Newtonian Slurries				
423	Closed	0	24590-101-TSA-W000-0009-98-00014	00A	VSL-07R1240-1	0	Preparation and Testing of HLW Algorithm Glasses to Support Small Scale Melter Testing				
424	Closed	0	24590-101-TSA-W000-0009-180-00002	00A	VSL-07R1220-1	0	Small Scale Testing of HLW Algorithm Glass: Matrix 1 Tests				
425	Closed	0	24590-101-TSA-W000-0004-178-00001	00A	WTP-RPT-151	0	Review of Caustic Leaching Testing With Hanford Tank Waste Sludges				
426	Closed	0	24590-QL-HC9-WA49-00001-03-00007	00A	WTP-RPT-154	0	Estimate of Hanford Waste Rheology and Settling Behavior				
430	Closed	0	24590-101-TSA-W000-0009-69-00007	00A	VSL-08R1410-1	0	LAW Glass Testing and VHT Model Assessment				
431	Closed	0	24590-101-TSA-W000-0009-195-00001	00B	VSL-08R1430-1	0	Pretreated Waste and Melter Feed Composition Variability Testing Using LAW Simulants				
432	Closed	0	24590-HLW-RPT-RT-05-001	0	24590-HLW-RPT-RT-05-001	0	Preliminary IHLW Formulation Algorithm Description.				
433	Closed	0	24590-QL-HC9-WA49-00001-03-00013	00A	WTP-RPT-176	0	Development and Characterization of Gibbsite Component Simulant				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
434	Closed	0	24590-QL-HC9-WA49-00001-03-00014	00A	WTP-RPT-171	0	Laboratory Demonstration of the Pretreatment Process with Caustic and Oxidative Leaching Using Actual Hanford Tank Waste				
435	Closed	0	24590-QL-HC9-WA49-00001-03-00015	00A	WTP-RPT-167	0	Characterization and Leach Testing for PUREX Cladding Waste Sludge (Group 3) and Redox Cladding Waste Sludge (Group 4) Actual Waste Composites				
437	Closed	0	24590-QL-HC9-WA49-00001-03-00003	00A	WTP-RPT-165	0	Plutonium Speciation in Support of Oxidative-Leaching Demonstration Test				
438	Closed	0	24590-QL-HC9-WA49-00001-03-00004	00A	WTP-RPT-162	0	A Scaling Approach for Full-Scale Sparger Operations in the UFP-2 Vessel				
439	Closed	0	24590-QL-HC9-WA49-00001-03-00005	00A	WTP-RPT-152	0	Ultrafiltration Process Vessel-1 (UFP-1) Heat Transfer Analysis				
440	Closed	0	24590-QL-HC9-WA49-00001-03-00006	00A	WTP-RPT-174	0	Ultrafilter Drain Flush Project Simulant Rheology Report				
441	Closed	0	24590-QL-HC9-WA49-00001-03-00008	00A	WTP-RPT-173	0	Mechanism of Phosphorus Removal from Hanford Tank Sludge by Caustic Leaching				
442	Closed	0	24590-QL-HC9-WA49-00001-03-00009	00A	WTP-RPT-160	0	Technical Basis for Scaling Relationships for the Pretreatment Engineering Platform				
443	Closed	0	24590-QL-HC9-WA49-00001-03-00011	00A	WTP-RPT-180	0	Preparation AD Characterization of Chemical Plugs Based on Selected Hanford Waste Simulants				
444	Closed	0	24590-QL-HC9-WA49-00001-03-00012	00A	WTP-RPT-159	0	Analysis of Transient Heat Transfer in the Waste Treatment Plant (WTP) Ultrafiltration Feed Preparation and Process (UFP) Vessels - Modeling Approach, Assumptions, and Results				
445	Closed	0	24590-QL-HC9-WA49-00001-05-00001	00A	WTP-RPT-156	0	Results of Large-Scale Testing on Effects of Antifoam Agent on Gas Retention and Release				
446	Closed	0	24590-QL-HC9-WA49-00001-05-00002	00B	WTP-RPT-150	0	Pulse Jet Mixer Overblow Testing for Assessment of Loadings During Multiple Overblows				
447	Closed	0	24590-QL-HC9-WA49-00001-03-00018	00A	WTP-RPT-172	0	Filtration and Leach Testing for Redox Sludge and S-Saltcake Actual Waste Sample Composites				
448	Closed	0	24590-QL-HC9-WA49-00001-03-00019	00A	WTP-RPT-183	0	Development and Demonstration of Ultrafiltration Simulants				
449	Closed	0	24590-QL-HC9-WA49-00001-03-00020	00A	WTP-RPT-181	0	Filtration and Leach Testing for PUREX Cladding Sludge (Group 3) and Redox Cladding Sludge (Group 4) Actual Waste Sample Composites				

Table E-1 Closed or Voided Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
451	Closed	0	24590-QL-HC9-WA49-00001-03-00022	00A	WTP-RPT-168	0	Characterization of Filtration Scale-Up Performance				
452	Closed	0	24590-QL-HC9-WA49-00001-03-00023	00A	WTP-RPT-170	0	Characterization, Leaching and Filtration Testing of Ferrocyanide Waste Tank Sludge (Group 8) Actual Waste Composite				
453	Closed	0	24590-QL-HC9-WA49-00001-03-00024	00B	WTP-RPT-184	0	Development and Characterization of Boehmite Component Simulant				
454	Closed	0	24590-QL-HC9-WA49-00001-03-00027	00A	WTP-RPT-178	0	A Qualitative Investigation of Deposition Velocities of a Non-Newtonian Slurry in Complex Pipeline Geometries				
455	Closed	0	24590-QL-HC9-WA49-00001-03-00034	00A	WTP-RPT-204	0	Scale-Up, Production and Procurement of PEP Simulants				
456	Closed	0	24590-QL-HC9-WA49-00001-03-00035	00A	WTP-RPT-201	0	Simulated Waste for Leaching and Filtration Studies - Laboratory Preparation Procedure				
457	Closed	0	24590-QL-HC9-WA49-00001-03-00036	00A	WTP-RPT-205	0	Laboratory Tests on Post-Filtration Precipitation in the WTP Pretreatment Process				
459	Closed	0	24590-QL-HC9-WA49-00001-03-00030	00B	WTP-RPT-188	1	EFRT M-12 Issue Resolution: Comparison of PEP and Bench-Scale Oxidative Leaching Results				
460	Closed	0	24590-QL-HC9-WA49-00001-03-00037	00A	WTP-RPT-191	0	PEP Run Report for Integrated Test A, Caustic Leaching in UFP-VSL-T01A, Oxidative Leaching in UFP-VSL-T02A				

Table E-2 Open Review Tracking Coversheets (RTCs)

RTC No	RTC Status	RTC Rev	WTP (PDC) Document Number	WTP Doc Rev	Originator Document Number	Orig Doc Rev	Document Title	BARD Change #	Model Change Request #	Model Run Request #	RTC Comments
411	Open	0	SCT-M0SRLE60-00-145-00020	00B	WSRC-STI-2006-00313	0	Transport of Waste Simulants in PJM Vent Lines	295-214			To be closed with BARD Rev 6 release.
427	Open	0	24590-101-TSA-W000-0009-190-00001	00A	VSL-08R1220-1	0	Final Report Small Scale Melter Testing of HLW Algorithm Glasses: Matrix 2 Test	450-401			To be closed with BARD Rev 6 release.
428	Open	0	24590-QL-HC9-WA49-00001-03-00016	00A	WTP-RPT-166	0	Characterization, Leaching and Filtration Testing for Bismuth Phosphate Sludge (Group 1) and Bismuth Phosphate Saltcake (Group 2) Actual Waste Sample Composites	403-103	11-0023		To be closed with BARD Rev 6 release and Dynamic (G2) Flowsheet Version 7.0 release.
429	Open	0	24590-QL-HC9-WA49-00001-03-00010	00B	WTP-RPT-157	0	Characterization and Leach Testing for Redox Sludge and S-Saltcake Actual Waste Sample Composites	420-103	11-0023		To be closed with BARD Rev 6 release and Dynamic (G2) Flowsheet Version 7.0 release.
436	Open	0	24590-QL-HC9-WA49-00001-03-00002	00A	WTP-RPT-164	0	Process Development for Permanganate Addition During Oxidative Leaching of Hanford Tank Sludge Simulants	399-203			To be closed with BARD Rev 6 release.
450	Open	0	24590-QL-HC9-WA49-00001-03-00021	00A	WTP-RPT-169	0	Characterization, Leaching and Filtration Testing of Tri-Butyl Phosphate (TBP, Group 7) Actual Waste Sample Composites	403-103	11-0023		To be closed with BARD Rev 6 release and Dynamic (G2) Flowsheet Version 7.0 release.
458	Open	0	24590-QL-HC9-WA49-00001-03-00042	00A	WTP-RPT-206	0	Effect of Antifoam Agent on Oxidative Leaching of Hanford Tank Sludge Simulant	402-203			To be closed with BARD Rev 6 release.

Appendix F

Line Flush Locations and Volumes

Appendix F
Line Flush Locations and Volumes

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
CXP-43	CXP-PMP-00002A to ASK-SMPLR-00017 to CXP-VSL-00026A	CXP-VSL-00026A	73.89		yes	192.86
		TLP-SEP-00001	15.37			
		CXP-VSL-00001	47.29			
		TCP-VSL-00001	56.31			
CXP-44	CXP-PMP-00002A to ASK-SMPLR-00017 to CXP-VSL-00026B	CXP-VSL-00026B	84.66		yes	203.63
		TLP-SEP-00001	15.37			
		CXP-VSL-00001	47.29			
		TCP-VSL-00001	56.31			
CXP-45	CXP-PMP-00002A to ASK-SMPLR-00017 to CXP-VSL-00026C	CXP-VSL-00026C	65.18		yes	184.15
		TLP-SEP-00001	15.37			
		CXP-VSL-00001	47.29			
		TCP-VSL-00001	56.31			
FEP-02	FEP-VSL-00017A to ASX-SMPLR-00025 Nozzle 13 via FEP-PMP-00007B	FEP-VSL-00017A	64.25		yes	64.25
FEP-04	FEP-VSL-00017A to FEP-SEP-00001A Circ. Loop via FEP-PMP-00007B	FEP-SEP-00001A	39.99		yes	147.78
	FEP-VSL-00017A to ASX via PMP-7B	FEP-VSL-00017A	33.77			
	FEP-VSL-00017A to FRP-VSL-00002A	FRP-VSL-00002A	55.79			
	FEP-VSL-00017A to FEP-SEP-00001B	FEP-SEP-00001B	18.23			
FEP-07	FEP-VSL-00017A to FEP-SEP-00001B Circ. Loop via FEP-PMP-00007A	FEP-SEP-00001B	40.64		yes	137.68
	FEP-VSL-00017A to ASX via PMP-7A	FEP-VSL-00017A	30.63			
	FEP-VSL-00017A to FEP-SEP-00001A	FEP-SEP-00001A	11.44			

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
	FEP-VSL-00017A to FRP-VSL-00002A	FRP-VSL-00002A	54.97			
FEP-10	FEP-VSL-00017B to ASX-SMPLR-00025 via FEP-PMP-00007B	FEP-VSL-00017B	65.36		yes	65.36
FEP-12	FEP-VSL-00017B to FEP-SEP-00001A via FEP-PMP-00007B	FEP-SEP-00001A	39.06		yes	143.37
	FEP-VSL-00017B to ASX via PMP-7B	FEP-VSL-00017B	35.4			
	FEP-VSL-00017B to FEP-SEP-00001B	FEP-SEP-00001B	15.51			
	FEP-VSL-00017B to FRP-VSL-00002A	FRP-VSL-00002A	53.4			
FEP-15	FEP-VSL-00017B to FEP-SEP-00001B via FEP-PMP-00007A	FEP-SEP-00001B	47.68		yes	144.72
	FEP-VSL-00017B to ASX via PMP-7A	FEP-VSL-00017B	30.63			
	FEP-VSL-00017B to FEP-SEP-00001A	FEP-SEP-00001A	11.44			
	FEP-VSL-00017B to FRP-VSL-00002A	FRP-VSL-00002A	54.97			
FEP-17	FEP-SEP-00001A Circ. Loop to UFP-VSL-00001A via FEP-PMP-00008A	UFP-VSL-00001A	34.93	450		102.99
		UFP-VSL-00001B	14.96			
		FRP-VSL-00002A	53.1			
FEP-18	FEP-SEP-00001A Circ. Loop to UFP-VSL-00001B via FEP-PMP-00008A	UFP-VSL-00001B	38.85	450		103.78
		UFP-VSL-00001B	11.83			
		FRP-VSL-00002A	53.1			
FEP-20	FEP-SEP-00001B Circ. Loop to UFP-VSL-00001A	UFP-VSL-00001A	37.99	450		99.4
		UFP-VSL-00001B	10.84			
		FRP-VSL-00002A	50.57			
FEP-21	FEP-SEP-00001B Circ. Loop to UFP-VSL-00001B	UFP-VSL-00001B	42.04	450		100.2
		UFP-VSL-00001A	7.59			
		FRP-VSL-00002A	50.57			
FRP-01	FRP-VSL-00002A to FEP-VSL-00017A	FEP-VSL-00017A	228.79		yes	756.09

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001A	156.12			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002B	73.45			
FRP-02	FRP-VSL-00002A to FEP-VSL-00017B	FEP-VSL-00017B	255.27		yes	761.39
		FEP-VSL-00017A	118.36			
		UFP-VSL-00001A	156.12			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002B	73.45			
FRP-03	FRP-VSL-00002A to UFP-VSL-00001A	UFP-VSL-00001A	276		yes	765.54
		FEP-VSL-00017A	118.36			
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002B	73.45			
FRP-04	FRP-VSL-00002A to UFP-VSL-00001B	UFP-VSL-00001B	278.59		yes	766.06
		FEP-VSL-00017A	118.36			
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001A	156.12			
		FRP-VSL-00002B	73.45			
FRP-05	FRP-VSL-00002B to FEP-VSL-00017A	FEP-VSL-00017A	261.26		yes	789.25
		FEP-VSL-00017B	139.77			
		UFP-VSL-00001A	156.35			
		UFP-VSL-00001B	158.42			
		FRP-VSL-00002B	73.45			
FRP-06	FRP-VSL-00002B to FEP-VSL-00017B	FEP-VSL-00017B	259.53		yes	788.9
		FEP-VSL-00017A	141.15			
		UFP-VSL-00001A	156.35			
		UFP-VSL-00001B	158.42			
		FRP-VSL-00002B	73.45			
FRP-07	FRP-VSL-00002B to UFP-VSL-00001A	UFP-VSL-00001A	280.25		yes	793.04
		FEP-VSL-00017A	141.15			

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
		FEP-VSL-00017B	139.77			
		UFP-VSL-00001B	158.42			
		FRP-VSL-00002B	73.45			
FRP-08	FRP-VSL-00002B to UFP-VSL-00001B	UFP-VSL-00001B	282.84		yes	793.56
		FEP-VSL-00017A	141.15			
		FEP-VSL-00017B	139.77			
		UFP-VSL-00001A	156.35			
		FRP-VSL-00002C	73.45			
FRP-09	FRP-VSL-00002C to FEP-VSL-00017A	FEP-VSL-00017A	245.1		yes	772.4
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001A	156.12			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002C	73.45			
FRP-10	FRP-VSL-00002C to FEP-VSL-00017B	FEP-VSL-00017B	243.37		yes	772.05
		FEP-VSL-00017A	140.92			
		UFP-VSL-00001A	156.12			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002C	73.45			
FRP-11	FRP-VSL-00002C to UFP-VSL-00001A	UFP-VSL-00001A	264.09		yes	776.19
		FEP-VSL-00017A	140.92			
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002C	73.45			
FRP-12	FRP-VSL-00002C to UFP-VSL-00001B	UFP-VSL-00001B	266.68		yes	776.71
		FEP-VSL-00017A	140.92			
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001A	156.12			
		FRP-VSL-00002C	73.45			
FRP-13	FRP-VSL-00002D to FEP-VSL-00017A	FEP-VSL-00017A	296.68		yes	823.98
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001A	156.12			

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002C	73.45			
FRP-14	FRP-VSL-00002D to FEP-VSL-00017B	FEP-VSL-00017B	294.95		yes	823.63
		FEP-VSL-00017A	140.92			
		UFP-VSL-00001A	156.12			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002C	73.45			
FRP-15	FRP-VSL-00002D to UFP-VSL-00001A	UFP-VSL-00001A	315.68		yes	827.78
		FEP-VSL-00017A	140.92			
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001B	158.19			
		FRP-VSL-00002C	73.45			
FRP-16	FRP-VSL-00002D to UFP-VSL-00001B	UFP-VSL-00001B	318.27		yes	828.3
		FEP-VSL-00017A	140.92			
		FEP-VSL-00017B	139.54			
		UFP-VSL-00001A	156.12			
		FRP-VSL-00002C	73.45			
FRP-17	FRP-VSL-00002A to ASX-SMPLR-00025	FRP-VSL-00002B	172.66		yes	172.66
FRP-19	FRP-VSL-00002B to ASX-SMPLR-00025	FRP-VSL-00002B	155.8		yes	155.8
FRP-21	FRP-VSL-00002C to ASX-SMPLR-00025	FRP-VSL-00002C	158.28		yes	158.28
FRP-23	FRP-VSL-00002D to ASX-SMPLR-00025	FRP-VSL-00002C	208.87		yes	208.87
FRP-41	Tank Farm Waste Feed to HLP-VSL-00022	HLP-VSL-00022	254.33		yes	542.4
		FRP-VSL-00002D	138.18			
		FRP-VSL-00002C	40.77			
		FRP-VSL-00002B	52.71			
		FRP-VSL-00002A	56.41			
FRP-44	Tank Farm Waste Feed to FRP-VSL-00002A	FRP-VSL-00002A	283.7		yes	509.15
		HLP-VSL-00022	96.56			

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
		FRP-VSL-00002D	53.53			
		FRP-VSL-00002C	31.71			
		FRP-VSL-00002B	43.65			
FRP-45	Tank Farm Waste Feed to FRP-VSL-00002B	FRP-VSL-00002B	279.06		yes	508.22
		HLP-VSL-00022	96.56			
		FRP-VSL-00002D	53.53			
		FRP-VSL-00002C	31.71			
		FRP-VSL-00002A	47.36			
FRP-46	Tank Farm Waste Feed to FRP-VSL-00002C	FRP-VSL-00002C	264.14		yes	505.24
		HLP-VSL-00022	96.56			
		FRP-VSL-00002D	53.53			
		FRP-VSL-00002B	43.65			
		FRP-VSL-00002A	47.36			
FRP-47	Tank Farm Waste Feed to FRP-VSL-00002D	FRP-VSL-00002D	291.42		yes	510.7
		HLP-VSL-00022	96.56			
		FRP-VSL-00002C	31.71			
		FRP-VSL-00002B	43.65			
		FRP-VSL-00002A	47.36			
FRP-48	FEP-SEP-00001A	FRP-VSL-00002A	130.00			130.00
HLP-02	HLP-VSL-00022 to ASX-SMPLR-00020	HLP-VSL-00022	262.79		yes	262.79
HLP-03	HLP-VSL-00022 to UFP-VSL-00001A	UFP-VSL-00001A	211.27		yes	1086.08
		HLP-VSL-00022	67.7			
		HLP-VSL-00022	72.53			
		UFP-VSL-00001B	133.32			
		FEP-VSL-00017A	159.11			
		FEP-VSL-00017B	127.11			
		FRP-VSL-00002A	315.04			
HLP-04	HLP-VSL-00022 to UFP-VSL-00001B	UFP-VSL-00001B	210.4		yes	1085.9
		HLP-VSL-00022	67.7			
		HLP-VSL-00022	72.53			
		UFP-VSL-00001A	134.01			

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
		FEP-VSL-00017A	159.11			
		FEP-VSL-00017B	127.11			
		FRP-VSL-00002A	315.04			
HLP-05	HLP-VSL-00022 to FEP-VSL-00017A	FEP-VSL-00017A	242.64		yes	1092.35
		HLP-VSL-00022	67.7			
		HLP-VSL-00022	72.53			
		UFP-VSL-00001A	134.01			
		UFP-VSL-00001B	133.32			
		FEP-VSL-00017B	127.11			
		FRP-VSL-00002A	315.04			
HLP-06	HLP-VSL-00022 to FEP-VSL-00017B	FEP-VSL-00017B	202.63		yes	1084.34
		HLP-VSL-00022	67.7			
		HLP-VSL-00022	72.53			
		UFP-VSL-00001A	134.01			
		UFP-VSL-00001B	133.32			
		FEP-VSL-00017A	159.11			
		FRP-VSL-00002A	315.04			
HLP-11	HLP-VSL-00028 to ASX-SMPLR-00020 Nozzle 21 via HLP-PMP-00019B	HLP-VSL-00028	326.91		yes	326.91
HLP-13	HLP-VSL-00028 to HFP-VSL-00005 via HLW transfer line #HLP-PC-00009 and HLP-PMP-00019B	HFP-VSL-00005	450		yes	1490
		HLP-VSL-00028	52			
		HLP-VSL-00028	88			
		PWD-VSL-00043	900			
HLP-15	HLP-VSL-00028 to HFP-VSL-00001 via HLW transfer line #HLP-PC-00011 via HLP-PMP-00019B	HFP-VSL-00001	440		yes	1460
		HLP-VSL-00028	52			
		HLP-VSL-00028	88			
		PWD-VSL-00043	880			
HLP-20	HLP-VSL-00027A to ASX-SMPLR-00020 Nozzle 19	HLP-VSL-00027A	300.61		yes	300.61

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
HLP-22	HLP-VSL-00027A to HLP-VSL-00028 via 24590-PTF-PP-HLP-PX-00329	HLP-VSL-00028	144.43		yes	341.03
		HLP-VSL-00027A	93.55			
		HLP-VSL-00027A	48.64			
		HLP-VSL-00027B	23.7			
		PWD-VSL-00033	30.71			
HLP-24	HLP-VSL-00027B to ASX-SMPLR-00020 Nozzle 17	HLP-VSL-00027B	245.31		yes	245.31
HLP-26	HLP-VSL-00027B to HLP-VSL-00028 via 24590-PTF-PP-HLP-PX-00329	HLP-VSL-00028	119.72		yes	327.79
		HLP-VSL-00027B	91.05			
		HLP-VSL-00027B	40.66			
		HLP-VSL-00027A	45.65			
		PWD-VSL-00033	30.71			
HLP-27	FEP-SEP-00001A	HLP-VSL-00027A	130.00		yes	130.00
LCP-01	LCP-VSL-00001	LCP-VSL-00001	28.00		yes	28.00
LCP-02	LCP-VSL-00002	LCP-VSL-00002	43.00		yes	43.00
LFP-01	LCP-VSL-00001	LFP-VSL-00001	15.00		yes	25.00
		LCP-VSL-00001	10.00			
LFP-02	LCP-VSL-00001	LFP-VSL-00003	26.00		yes	36.00
		LCP-VSL-00001	10.00			
LFP-03	LCP-VSL-00002	LFP-VSL-00001	11.00		yes	21.00
		LCP-VSL-00002	10.00			
LFP-04	LCP-VSL-00002	LFP-VSL-00003	16.00		yes	26.00
		LCP-VSL-00002	10.00			
LFP-05	LFP-VSL-00001	LFP-VSL-00001	79.00		yes	79.00
LFP-06	LFP-VSL-00003	LFP-VSL-00003	111.00		yes	111.00
LFP-07	LFP-VSL-00001	LFP-VSL-00002	18.00		yes	45.00
		LFP-VSL-00001	27.00			
LFP-08	LFP-VSL-00003	LFP-VSL-00004	18.00		yes	46.00
		LFP-VSL-00001	28.00			
LFP-09	LFP-VSL-00002	LMP-MLTR-00001	6.00		yes	18.00
		LFP-VSL-00002	12.00			
LFP-10	LFP-VSL-00004	LMP-MLTR-00002	6.00		yes	18.00
		LFP-VSL-00004	12.00			

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
LFP-11	LFP-VSL-00002	LMP-MLTR-00001	6.00		yes	6.00
LFP-12	LFP-VSL-00004	LMP-MLTR-00002	6.00		yes	6.00
RDP-21	RDP-VSL-00002C to RDP-CASK-00001 via RDP-PMP-00008B	RDP-VSL-00002B	431.74		yes	431.74
TCP-03 (CCN 139031) (24590-LAW-M0C-20-00006)	TCP-VSL-00001 to LCP-VSL-0001 via TCP-PMP-00001A	PWD-VSL-00033	1280		yes	2153
		LCP-VSL-00001	643			
		TLP-VSL-00009A	50			
		TLP-VSL-00009B	58			
		TCP-VSL-00001	122			
TCP-04 (CCN 139031) (24590-LAW-M0C-20-00006)	TCP-VSL-00001 to LCP-VSL-0002 via TCP-PMP-00001B	PWD-VSL-00033	1320		yes	2191
		LCP-VSL-00002	664			
		TLP-VSL-00009A	44			
		TLP-VSL-00009B	51			
		TCP-VSL-00001	112			
TLP-07	TLP-VSL-00009A to ASX-SMPLR-00017 via TLP-PMP-00005B	TLP-VSL-00009A	74.76		yes	74.76
TLP-08	TLP-VSL-00009B to ASX-SMPLR-00017 via TLP-PMP-00005B	TLP-VSL-00009B	77.87		yes	77.87
TLP-10	TLP-SEP-00001 to TCP-VSL-00001 via TLP-PMP-00011B	TCP-VSL-00001	86.36	164		86.36
UFP-01	HLP-VSL-00027A	UFP-VSL-00001A	200.00		yes	400.00
		UFP-VSL-00001B	200.00			
UFP-02	UFP-VSL-00001A to ASX Sampler	UFP-VSL-00001A	139.21	1965		139.21
UFP-05	UFP-VSL-00001A to UFP-VSL-00002B	UFP-VSL-00002B	285.54	524		562.61
		UFP-VSL-00001A	37.44			
		UFP-VSL-00001A	39.17			
		FEP-VSL-00017B	59.91			
		FEP-VSL-00017A	73.73			
		UFP-VSL-00002A	66.82			

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
UFP-06	UFP-VSL-00001A to UFP-VSL-00002A	UFP-VSL-00002A	274.02	524		560.3
		UFP-VSL-00001A	37.44			
		UFP-VSL-00001A	39.17			
		FEP-VSL-00017B	59.91			
		FEP-VSL-00017A	73.73			
		UFP-VSL-00002B	76.03			
UFP-08	UFP-VSL-00001B to ASX Sampler	UFP-VSL-00001B	220.72	1965		220.72
UFP-11	UFP-VSL-00001B to UFP-VSL-00002B	UFP-VSL-00002B	343.14	524		757.79
		UFP-VSL-00001B	46.08			
		UFP-VSL-00001B	46.08			
		FEP-VSL-00017B	103.68			
		FEP-VSL-00017A	105.99			
		UFP-VSL-00002A	112.90			
UFP-12	UFP-VSL-00001B to UFP-VSL-00002A	UFP-VSL-00002A	331.62	524		755.56
		UFP-VSL-00001B	46.08			
		UFP-VSL-00001B	46.08			
		FEP-VSL-00017B	105.99			
		FEP-VSL-00017A	103.68			
		UFP-VSL-00002B	122.11			
HLW-04	HFP-VSL-00001 to HFP-VSL-00002 (via HFP-PMP-00005A)	HFP-VSL-00002	7.72		yes	7.72
HLW-06	HFP-VSL-00001 to ASX-SMPLR-00029 (includes return line to HFP-VSL-00001) (via HFP-PMP-00005A)	HFP-VSL-00001	29.7		yes	29.7
HLW-17	HFP-VSL-00005 to HFP-VSL-00006 (via HFP-PMP-00018A)	HFP-VSL-00006	6.62		yes	6.62
HLW-19	HFP-VSL-00005 to ASX-SMPLR-00042 (includes return line to HFP-VSL-00005) (via HFP-PMP-00018A)	HFP-VSL-00005	13.43		yes	13.43
HLW-29	HOP-SCB-00001 to RLD-VSL-00007 (via HOP-EJCTR-00053A)	RLD-VSL-00007	36.35		yes	36.35

Sequential Transfer Route Number (CCN 141492)	Transfer Route, Blank Denotes a Dead Leg Route	Destination of Flush	Volume per Flush (gallons)	Hours to Form Bubble of Concern (BOC)	Flush After Every Transfer	Total Flush Volume Including All Dead Legs (gallons)
HLW-35	HOP-VSL-00903 to RLD-VSL-00007 (spare HOP-EJCTR-00003B)	RLD-VSL-00007	64.76		yes	64.76
HLW-37	HOP-HEME-00001A drain to HOP-VSL-00903	HOP-VSL-00903	26.77	4380		26.77
HLW-39	HOP-SCB-00002 to RLD-VSL-00007 (via HOP-EJCTR-00918A)	RLD-VSL-00007	35.94		yes	35.94
HLW-44	HOP-VSL-00904 to RLD-VSL-00007 (spare HOP-EJCTR-00929A)	RLD-VSL-00007	79.85		yes	79.85
HLW-47	HOP-HEME-00002A drain to HOP-VSL-00904	HOP-VSL-00904	12.55	4380		12.55
HLW-51	RLD-VSL-00007 to RLD-BRKPT-00009 to PWD-VSL-00043 (PTF) (via RLD-EJCTR-00050)	PWD-VSL-00043	119.09		yes	119.09
HLW-55	RLD-VSL-00007 to ASX-SMPLR-00028; includes return line to RLD-VSL-00007 (via RLD-RFD-00162A)	RLD-VSL-00007	29.46		yes	29.46
HLW-81	HDH-VSL-00003 to RLD-VSL-00007 via HDH-EJCTR-00002B	RLD-VSL-00007	94.55		yes	94.55
HLW-85	HDH-VSL-00001 to HDH-VSL-0003 via line HDH-ZE-00034	HDH-VSL-00003	34.94		yes	34.94

Note: The minimum flush water volume per transfer may be greater than some values indicated in this table due to operational requirements and flow measurement constraints.

References

24590-LAW-M0C-20-00006, *LAW Concentrate Receipt and Melter Feed Line Volumes.*

24590-PTF-M6C-UFP-00014, *Line Sizing and Pressure Drop Calculations for UFP-PMP-00041A/B.*

24590-PTF-MEC-UFP-00001, *Spiral Heat Exchanger UFP-HX-00041A/B Sizing for Vessels UFP-VSL-00001A/B.*

24590-PTF-3YD-HLP-00001, Rev 2, *System Description for HLW Lag Storage and Feed Blending Process System (HLP).*

24590-PTF-3YD-TCP-00001, Rev 3, *System Description for the Treated LAW Concentrate Storage Process (TCP).*

CNN 139031, J Hall to N Wilkens, *Flushing and Draining of LAW Transfer Lines.* 25 April 2006.

CCN 141492, E Strieper to Distribution, *Transmittal of Flush Requirements Following Transfers.* 1 August 2006.

CCN 142760, E Strieper to Distribution, *Changes to Flush Requirements - Transfers from UFP to HLP.* 26 September 2006.

Memorandum

To:	Roger Landon – MS16-A	Date:	June 18, 2015
From:	Bob Voke – MS5-G	CCN:	280210
Phone:	(509)-371-8191		

Subject: **LAW MISCELLANEOUS TREATMENT UNIT HYDROGEN ACCUMULATION DOCUMENTATION FOR THE DWP ADMINISTRATIVE RECORD – ADDITIONAL CLARIFICATION – SUPERSEDES CCN 277655**

References:
1) 24590-WTP-PER-PR-03-001, Report, *Prevention of Hydrogen Accumulation in WTP Tank Systems and Miscellaneous Treatment Unit Systems*, August 2003.
2) 24590-WTP-DB-ENG-01-001, *Basis of Design*, October 2014.
3) WA7890008967, Permit, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste, Part III, Operating Unit Group JO (Waste Treatment and Immobilization Plant)*,Washington State Department of Ecology, January 2012.

The memorandum provides information relating to the potential accumulation of hydrogen in the Low-Activity Waste (LAW) Vitrification Facility miscellaneous treatment units. This memorandum should be referenced instead of the *Prevention of Hydrogen Accumulation in WTP Tank Systems and Miscellaneous Treatment Unit Systems* report (Ref. 1).

The WTP *Basis of Design* (Ref. 2) Section 14.13 states that "*the WTP vitrification melters and their associated offgas systems, as well as other facility elements, have been determined to be miscellaneous units*". This includes equipment items in the LAW Melter Process System (LMP), the LAW Primary Offgas Process System (LOP), and the LAW Secondary Offgas/Vessel Vent Process System (LVP) that are listed in Table III.10.H.A of the Dangerous Waste Permit (Ref. 3). As such, these equipment items do not pose a hydrogen accumulation hazard under normal operating conditions as they will have continual gas flow while in operation which will preclude the accumulation of gases.

RVoke

Bob Voke
Process Manager
Process Engineering

RV/ejs

Distribution

Copy Coverage	MSIN
Barry Curn	MS16-A
Stuart Kretzschmar	MS4-E2
Chris Musick	MS4-D2
Scott Neubauer	MS4-A2
Michael O'Neill	MS4-E2
Prabhu Rajagopalan	MS4-E2
Dan Robertson	MS16-A
Eric Slaathaug	MS5-G
Phil Townsend	MS5-L
David Wagner	MS12-2A
PADC	MS19-A

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA) are regulated at the U. S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts that pursuant to AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

Attachment 2
15-ECD-0038
(2 Pages)

U.S. Department of Energy, Office of River Protection
and Bechtel National, Inc.'s Certifications
for the
Submittal of Dangerous Waste Permit Package LAW-025, Rev. 0,
Thermal Catalytic Oxidizer/Selective Catalytic Reducer

U.S. Department of Energy, Office of River Protection Certification

The following certification statement is provided for the submittal of Dangerous Waste Permit Package LAW-025, Rev 0, *Thermal Catalytic Oxidizer/Selective Catalytic Reducer.*

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

K. W. Smith, Manager
U.S. Department of Energy,
Office of River Protection

8/13/2015
Date

Bechtel National, Inc. Certification

The following certification statement is provided consistent with Contract No. DE-AC27-01RV14136, Section H.26, Environmental Permits, paragraph (g) for the submittal of the Hanford Facility Resource Conservation and Recovery Act Permit Modification Notification Form LAW-25, Rev 0, *Thermal Catalytic Oxidizer/Selective Catalytic Reducer.*

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Margaret G. McCullough — July 16, 2015

M. G. McCullough
Project Director

Date