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History Sheet

Rev	Reason for revision	Revised by
0	Initial issue	J Nelson
1	2004 revision required by contract MOD A033 and incorporates the changes in MOD 041. Section 1 revised to reflect revised Sections 2 and 3. Figure 1-1 updated to reflect current ICD status. Figure 1-2 updated to show new product compliance plans and WASRD as source of IHLW product specifications, and to better show document hierarchy. Section 2 rewritten to combine elements from Sections 2, 3, and 4 of Rev 0 into a description of the LAW treatment and immobilization facilities and processes and the product control strategy. Descriptions focus on only facilities and processes important to achieving ILAW product compliance. Section 3 rewritten to provide LAW waste form and container description. ILAW properties description from Section 4 of Rev 0 expanded to include container description. Information on ILAW properties and container updated to provide most recent information. Section 4 retains compliance strategy, qualification activities, and production implementation discussions for each of the ILAW specifications in the WTP contract. Changes made to incorporate specification changes in contract MOD 033 and MOD 041. Section on closure and sealing updated to reflect new ILAW container closure system. Modified ILAW production documentation discussions and Table 4-2 to follow HLW DWPF implementation. Wording changes made throughout to clarify and provide consistency in compliance strategies, qualification activities, and production implementation.	J Westsik
2	Contract Deliverable update. ORP comments requested the ILAW PCP more closely model the more concise format of the IHLW PCP. The Section 2 facility description and process overview has been moved to Appendix B. The Section 2.3 product control strategy has been revised to more concisely describe compliance control points. The data tables in Section 3 have been moved to Appendix E.	J Nelson
3	Contract Deliverable update. Incorporate Contract Mod. 114 and ORP comment letter 08-WTP-077 (CCN 176351).	J Nelson
4	Incorporate ORP comment letter 08-WTP-214 (CCN 190861) and Contract Mod M147. DHR package: 24590-LAW-DHR-RT-09-0001.	J Nelson
5	Contract Deliverable update. Incorporate 24590-LAW-PQDCN-RT-10-0001. DHR package is 24590-LAW-DHR-RT-11-0001.	J Nelson

Contents

Appendices

Tables

Figures

Acronyms and Other Abbreviations

A, D, I, T	analysis, demonstration, inspection, test
ASME	American Society of Mechanical Engineers
CAP	corrective action plan
CCC	canister centerline cooling
CCN	correspondence control number
CFR	code of federal regulations
CRV	concentrate receipt vessel
DHR	document history record
DOE	US Department of Energy
DOE-ORP	US Department of Energy, Office of River Protection
DOE/RL	US Department of Energy, Richland Operations Office
DOT	US Department of Transportation
DQO	data quality objective
DST	double shell tank
DWPF	Defense Waste Processing Facility
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
GFC	glass forming chemical
HLVIT	High-Level Vitrification (EPA Standard)
HLW	high-level waste
IHLW	immobilized high-level waste
ICD	interface control document
ILAW	immobilized low-activity waste
IP	industrial packaging
ISARD	Integrated Sampling and Analysis Requirements Document
LANL	Los Alamos National Laboratory
LAW	low-activity waste
LDR	land disposal restriction
LFP	Low Activity Waste Melter Feed Process (System)
LRH	Low Activity Waste Receipt Handling (System)
MCi	million curies
MFPV	melter feed preparation vessel
MFV	melter feed vessel
MRR	material receiving report
NRC	Nuclear Regulatory Commission
PCT	product consistency test

PQR	product qualification report
PTF	pretreatment facility
QA	quality assurance
QAM	*Quality Assurance Manual*
QAP	quality assurance program
QC	quality control
QGCR	qualified glass composition region
RCRA	Resource Conservation and Recovery Act
RPP	River Protection Project
SBS	submerged bed scrubber
SPA	special packaging authorization
Sr/TRU	strontium and transuranic
SST	single shell tank
USC	United States Congress
TCLP	toxicity characteristic leaching procedure
TFCOUP	*Tank Farm Contractor Operation and Utilization Plan*
TRU	transuranic
TSD	transportation safety document
TWINS	Tank Waste Information Network System
UHC	underlying hazardous constituent
UTI	upper tolerance interval
UTS	Universal Treatment Standards
VHT	vapor hydration test
WAC	Washington Administrative Code
WASRD	Waste Acceptance System Requirements Document
WESP	wet electrostatic precipitator
WFQ	waste form qualification
WQR	Waste Form Qualification Report
WTP	Hanford Tank Waste Treatment and Immobilization Plant

Glossary

analysis	As used in the Hanford Tank Waste Treatment and Immobilization Plant (WTP) contract specifications, an analysis is a set of engineering or scientific calculations that demonstrates that a product meets or exceeds a specification requirement. These calculations are typically based upon available data and assumptions regarding process operating conditions or materials. Analysis is required to identify conditions or assumptions, which might limit validity, and to identify specific documentation or measurements made during production to ensure validity (waste loading, container material, process additives, process measurements, etc.).
batch transfer	A quantity of waste feed transferred to the WTP at one time. In the current WTP design, there will be 200 m^3 to 600 m^3 of waste feed per batch for Envelope D (high-level waste [HLW]) and 1900 m^3 to 3800 m^3 per batch for Envelopes A, B, and C (low-activity waste [LAW]).
containerized waste form	Radioactive and dangerous waste materials in a glass matrix contained in LAW containers or HLW canisters.
certification	The endorsement or guarantee by the contractor that the waste product, intermediate waste product, or secondary waste conforms to the WTP contract requirements and specifications.
characterization	Activities conducted by the contractor to provide confidence that the actual immobilized waste products and secondary wastes produced during production operations conform to the specifications and requirements of the WTP contract.
cold commissioning	Activities conducted in the full-scale production facility before radioactive operations begin to test each processing facility individually to demonstrate that the facility performs in accordance with operation, safety, and Contract performance requirements. Cold commissioning simulants will not have any radionuclides.
compliance strategy	A concise description of the strategy for complying with one or more of the WTP contract specifications.
control strategy	A description of the process steps used to control the waste and glass former additions to the melter such that the melter feed lies within the range of compositions that will produce an ILAW product meeting WTP contract specifications.
demonstration	The proof-of-principle of a specimen, article, or process test used to verify conformance to the conditions of an analysis or product specification. Demonstrations are conducted where analysis is insufficient to provide proof-of-product acceptability or where analysis indicates the need for verification of assumptions (e.g., waste loading, explosivity, scale-up, process control).
Envelopes A, B, C, D	Waste feeds as defined in Specification 7, Low Activity Waste Envelopes Definition, and Specification 8, High Level Waste Envelope Definition, in the WTP contract.

hot commissioning	Activities conducted in the full scale production facility with initial radioactive feeds to test each processing facility individually to demonstrate that the facility performs in accordance with operation, safety, and Contract performance requirements.
inspection	A nondestructive examination or measurement of a product characteristic that confirms compliance with product specifications. Inspections are conducted when product characteristics can be easily determined by direct measurement (e.g., weight, dimensions, labeling, and external temperature) or where the results of the calculations leave some doubt as to satisfaction of the product requirements.
ILAW product	A sealed stainless steel container enclosing a poured glass waste form and an optional filler material (also referred to as the ILAW package).
manifest	Documentation that must be completed by a waste generator, collector or processor who transports or offers for transportation, radioactive waste intended for ultimate disposal at a radioactive waste disposal facility.
nameplate rate	The designed instantaneous production rate for a melter (that is, 15 metric tons of glass per day for a LAW melter and 3 metric tons of glass per day for an HLW first generation melter).
nonradioactive glass formulation	The blend of simulated wastes made from chemicals and glass forming chemicals that yield simulated nonradioactive waste glasses. Note: In cases where there are no suitable chemical surrogates, these nonradioactive glass formulations may include low concentrations of radionuclides (such as depleted uranium).
process/product control system	A set of process elements, including sampling, analysis, and measurements, required for immobilized waste product composition control to meet specification requirements.
production implementation	Activities conducted during hot commissioning and production operations to confirm that the specifications and requirements have been satisfied and to provide the basis for certification of the waste products. Includes documentation that is to be provided with the waste product (for example, production records and storage and shipping records).
production lot	As stated in WTP contract Specification 13, Waste Product Inspection and Acceptance, final acceptance of the immobilized low-activity waste (ILAW) product will be on a lot basis. For ILAW, the lot size will not exceed the amount of ILAW product that is produced in 15 days.
qualification activities	Activities conducted in advance of production operations (through hot commissioning) that provide evidence supporting waste form qualification. The detailed methods and results of these activities will be documented in product qualification reports (that is, ILAW PQR, IHLW WQR).
qualified glass composition region	A region of glass compositions that is predicted to satisfy product quality requirements after accounting for applicable variations and uncertainties. See *variation* and *uncertainty*.

target glass composition	A specific waste glass composition formulated for a specific estimate of waste composition. Target glass compositions are subject to change as information about waste composition changes. Hence, they should not be considered nominal or reference glass compositions representative of the product to be produced from a given waste type.
test	The evaluation of a product characteristic in which representative samples are destructively examined or measured to confirm compliance with product specifications. Tests are typically conducted where product characteristics cannot be readily determined by inspections, or where an inspection by itself does not provide adequate confirmation of compliance (e.g., chemical composition, radionuclide release rate).
uncertainty	Lack of knowledge about the true, fixed state of something (for example, there will be analytical *uncertainty* in the chemical analyses of any given glass sample). See also *variation*.
variation	Real changes in something over time or space (for example, there will be *variation* in waste and glass compositions between and within waste types and production lots). See also *uncertainty*.
waste envelope	Waste envelopes provide the chemical and radionuclide composition limits for the waste feed to be provided to the WTP for treatment and immobilization. Three waste envelopes for broadly categorizing the LAW feed are described in WTP contract Specification 7, Low Activity Waste Envelopes Definition.
waste form	Radioactive and dangerous waste materials in a glass matrix.
waste sodium	Waste sodium is defined in the WTP contract Facility Specification C.7(b)(3) as sodium from the LAW feed envelopes (Specification 7, Low Activity Waste Envelopes Definition) and soluble sodium from the HLW envelope (Specification 8, High Level Waste Envelope Definition). Also included is the sodium added to waste and leach solids within the limitations in Specification 12, Number of High Level Waste Canisters and Estimated Volume of ILAW Glass per Batch of Waste Envelope D.
waste type	The term *waste type* is generally defined as "the waste material fed to each vitrification plant, the composition and properties of which will remain relatively constant over an extended period during waste form production." Specifically, the waste type for LAW is the waste feed from a given LAW feed staging tank that may undergo pretreatment and possible blending before vitrification. The waste type for LAW has changed and is changing as the plan for waste pretreatment evolves. The term waste type and LAW envelope/sub-envelope in this report are interchangeable for documenting the studies related to early glass formulation and testing.
X/Y upper tolerance interval (UTI)	An X/Y UTI on the dissolution test response (of element i (r_i)) from glass produced over the course of a waste type or production lot provides X % confidence that at least Y % of the glass has r_i less than the UTI.

1 Introduction

The US Department of Energy, Office of River Protection (DOE-ORP) has responsibility for managing the safe storage, treatment, and disposal of mixed radioactive and hazardous waste in underground storage tanks at the Hanford Site in Washington State. This waste was generated primarily as a result of nuclear fuel reprocessing for defense production activities from 1943 to 1989. In 1996, DOE-ORP initiated a project to treat the waste and prepare it for disposal. Subsequently, a team of contractors was selected to design, build, and commission a facility known as the Hanford Tank Waste Treatment and Immobilization Plant (WTP) to demonstrate production scale waste treatment processes with the possibility of future expansion to treat all of the waste

Numerous interfaces exist between the tank waste treatment function and other functions at the Hanford Site. Figure 1-1 shows the interfaces necessary to accomplish waste treatment and immobilization; the inputs to, and outputs from, the WTP; and the functional responsibilities of the DOE-ORP and the WTP project. Each interface is governed by an interface description (an interface control document) that states the responsibilities of each party for all transactions occurring at the interface.

It is the objective of the WTP project to provide treated waste forms that meet or exceed contract specifications at a reasonable cost while minimizing the generation of secondary wastes. The specifications and requirements that these products and secondary wastes must meet are delineated in Section C, Statement of Work, of the WTP contract (DOE-ORP 2000).

The purpose of this *ILAW Product Compliance Plan* is to describe the immobilized low-activity waste (ILAW) product and the strategies for complying with the WTP contract requirements for the ILAW product. The outputs associated with the ILAW product (Figure 1-1) are addressed in this plan. The scope and content of this *ILAW Product Compliance Plan* are described in the WTP contract, Standard 6 (DOE-ORP 2000), and discussed in Section 1.1 below.

1.1 Content

WTP contract, Standard 6, describes the elements to be included in the *ILAW Product Compliance Plan*:

> *The Contractor shall update the IHLW Waste Form Compliance Plan (Table C.5-1.1, Deliverable 6.2), the ILAW Product Compliance Plan (Table C.5-1.1, Deliverable 6.3), and the Secondary Wastes Compliance Plan (Table C.5-1.1, Deliverable 6.1) describing the plan for qualification, characterization, and certification of each immobilized waste product and secondary wastes included under this Contract. These Plans shall provide the following information:*
>
> 1. *Identification, quantification, and description of each immobilized waste product, and secondary waste. The description shall include chemical and radiochemical composition, physical properties, and a comparison to Contract requirements.*
> 2. *Planned compliance strategies, compliance activities, and documentation to qualify each immobilized waste product and secondary waste for each requirement.*
> 3. *Planned methods and documentation to characterize and provide a basis for certifying that each immobilized waste product, and secondary waste meets Contract requirements.*

4. *Planned methods and documentation to comply with dangerous and hazardous waste regulations as required under law and in the Contract.*
5. *Identification and description of documentation to be provided with each product package submitted for acceptance, and secondary waste submitted for transfer that (a) describes the product, (b) documents characterization activities, and (c) provides a basis for certifying that the product or waste conforms to the Contract requirements.*

1.2 Organization

Sections 1, 2, and 3 of this *ILAW Product Compliance Plan* contain descriptive information. Only Section 4 contains requirements. Section 2 of this *ILAW Product Compliance Plan* provides a compliance strategy overview, Section 3 describes the ILAW waste form and container, and Section 4 discusses WTP strategies for complying with WTP contract requirements. In Section 4, each contract specification requirement is listed verbatim in italics, followed by the WTP project's method for complying with that requirement. Section 5 provides the references cited in this plan. Appendix A contains the full text of the primary ILAW product contract specifications addressed in this *ILAW Product Compliance Plan*. Appendix B provides a process overview and description of the WTP facilities. Appendix C provides summary process drawings. Appendix D contains drawings of the ILAW container. Appendix E provides tabulated examples for the chemical and physical properties of LAW and ILAW.

In Section 4, the descriptions of the planned compliance approach for the ILAW product specifications include the following elements (when applicable):

- Compliance Strategy: Statement of the WTP project strategy for compliance with each ILAW product contract specification or requirement.
- Qualification Activities: Analyses, demonstrations, inspections, and tests conducted before and during cold and hot commissioning by the WTP contractor to provide confidence, before full scale production operations, that the ILAW product will conform to the WTP contract specifications and requirements.
- Production Implementation: Analyses, demonstrations, inspections, and tests conducted to provide confidence that the ILAW produced during hot commissioning and production operations conforms to WTP contract specifications and requirements.
- Documentation: Specific documentation to be provided with the waste product (as applicable).

The WTP project will identify the items and activities that affect adherence to WTP contract requirements for waste acceptance. These items will be addressed and activities will be conducted in accordance with the appropriate quality assurance (QA) requirements and will form a basis for certification that the ILAW product complies with WTP contract requirements

The strategy for compliance with any given requirement may involve a variety of methods, from modeling and analysis to full scale radioactive demonstration. Table S6-2 in WTP contract, Standard 6 (DOE-ORP 2000), specifies requirements for analysis (A), demonstration (D), inspection (I), and test (T) activities conducted during qualification and production operations. The methods defined in Table S6-2 of the WTP contract are summarized below:

- **Analysis (A) -** Engineering or scientific calculations that demonstrate compliance with requirements
- **Demonstration (D) -** Specimen, article, or process test to demonstrate proof of acceptability
- **Inspection (I) -** Nondestructive examination or measurement of a product characteristic or comparison of results to requirements to show compliance
- **Test (T) -** Product measurement by destructive examination

As described above, this plan identifies the conduct and timing of compliance activities for ILAW. Wherever cost effective or required, actual LAW feed samples, provided by the Tank Operations Contractor, will be used to demonstrate compliance with ILAW product requirements. Wherever necessary, simulated wastes and nonradioactive samples will be used to conduct screening, small scale, and full scale demonstrations. Where testing and demonstration are not cost effective, engineering analyses and process flowsheet calculations will be used.

Waste form qualification (WFQ) documents are prepared for ILAW, as detailed in this plan, and for immobilized high-level waste (IHLW), as described in 24590-HLW-PL-RT-07-0001, Rev 0, *IHLW Waste Form Compliance Plan for the Hanford Tank Waste Treatment and Immobilization Plant*. Figure 1-2 shows the hierarchical relationship among the ILAW and IHLW WFQ documents.

Figure 1-1 WTP Inputs and Outputs

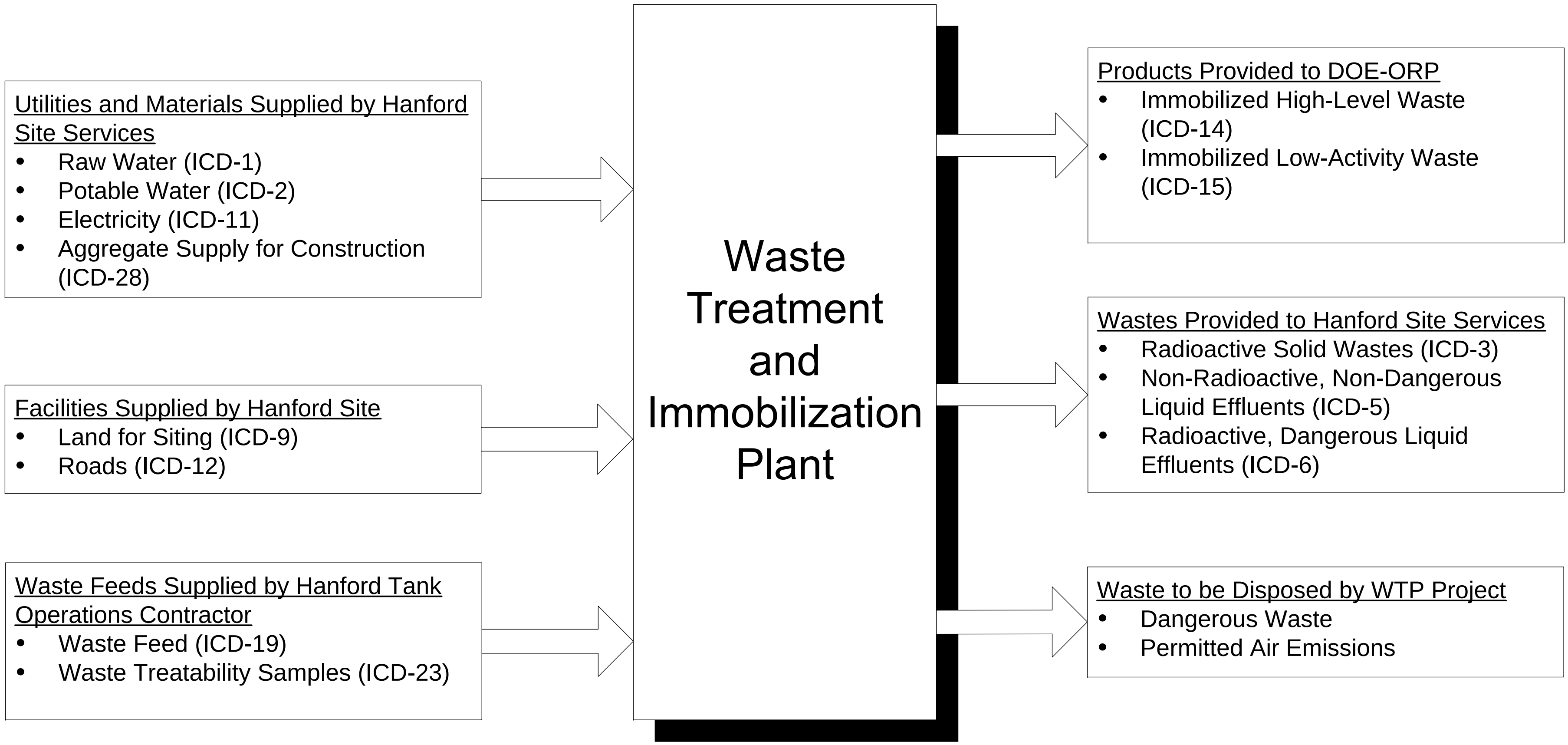
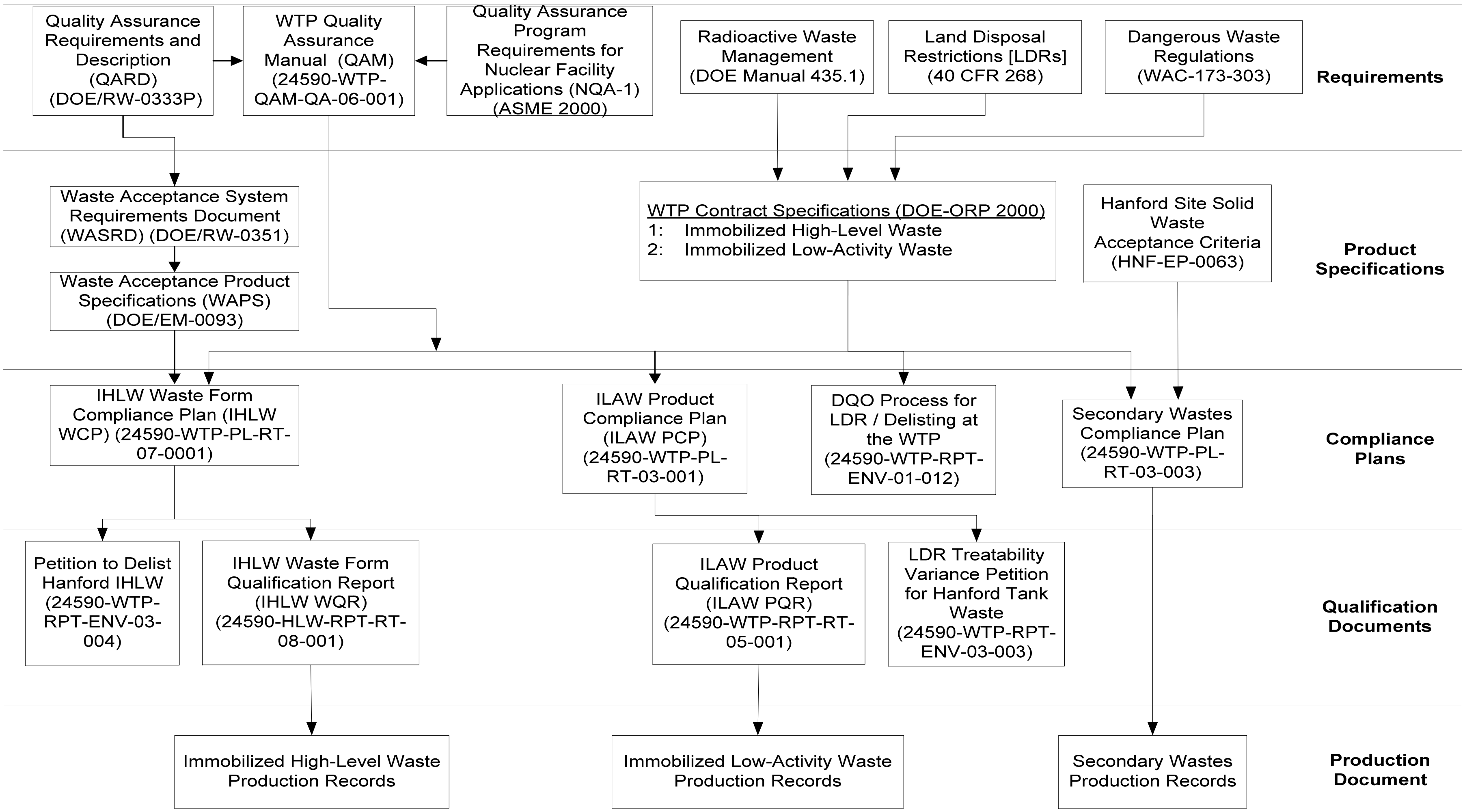


Figure 1-2 WTP Waste Form Qualification Document Hierarchy



2 ILAW Compliance Strategy Overview

This section outlines the ILAW product compliance strategy. The ILAW product comprises the ILAW waste form, the ILAW container and any inert fill added as necessary to meet void space requirements. The overall plant process control system used to demonstrate contract compliance during production (such as sample and weigh points) are referred to as production implementation activities. Process sample, glass forming chemical (GFC) weigh points, and vessel level measurements used for contract compliance are shown in Figure 2-1. Details of the process samples and measurements supporting product composition control are provided in Table 2-1. The production implementation activities are addressed in detail in the responses to the individual contract specifications in Section 4.1 of this *ILAW Product Compliance Plan*. The discussion below summarizes the ILAW product compliance strategies, which can be broadly classified into ILAW waste form composition control and containerized waste form. Table 2-2 summarizes all production compliance strategies.

2.1 Product Composition Control Strategy

LAW feed will be transferred to one of two concentrate receipt vessels (CRV) in the LAW vitrification facility. The contents of the CRVs will be mixed, sampled, and analyzed to confirm the chemical and radionuclide composition of the material received.

The quantity of LAW feed transferred from the CRV to the MFPV will be confirmed by level detection measurements in both the CRV and MFPV. Following this transfer, GFCs will be transferred from supply silos to weigh hoppers, and then blending silos equipped with load cells to weigh the contents. Figure B-2 shows the orientation of this equipment. Transfer of each individual GFC will be terminated when the total weight of the GFCs transferred to the blending silo corresponds with the predetermined recipe weight from the glass formulation algorithm. Weight measurements from the weigh hoppers, combined with the GFC blend composition and composition of the LAW feed provide the data used for estimating the ILAW glass composition by the formulation algorithm. This ILAW waste form composition estimate is also used for ILAW waste form composition reporting.

The amounts of individual GFCs and additives required to produce an acceptable ILAW glass composition will be determined based on the analysis of the LAW feed in the CRV and the use of an ILAW glass formulation algorithm (24590-LAW-RPT-RT-04-0003). Figure B-2 in Appendix B identifies the planned GFCs and additives. The analysis of the LAW feed from the CRV is not a process hold point for transferring the waste forward to the melter feed preparation vessel (MFPV). The LAW feed may be transferred from the CRV to the MFPV before the results of the CRV sample analysis become available. The GFCs will be added to the MFPV when: 1) the results of the CRV sample analyses are available, 2) the volume of LAW feed transferred to the MFPV is confirmed, 3) the correct GFC batch recipe is determined, and 4) the GFC batch composition and mass is confirmed to match the required recipe.

The glass formulation algorithm uses glass composition models to predict glass properties over a broad range of incoming LAW feed compositions. Given the CRV sample results and the transfer volume to the MFPV, the algorithm will determine the mass of each GFC required to produce a melter feed batch that can ultimately be vitrified to a glass product meeting all contract requirements. The algorithm calculations will account for the heel of residual blended feed from the previous MFPV batch (including GFCs remaining in the heel), as well as the previous CRV sampling results.

The GFCs from the blending silos are transferred to a glass former mixer in the LAW vitrification facility for final transfer to the MFPV. For compliance purposes, the GFC weights in the weigh hoppers are controlled and used for waste form composition reporting. The total weight of GFCs in the blending silo is used to confirm the GFC addition. Weight measurements at the glass former mixer are used for process control.

The LAW feed in the MFPV will be continuously mixed by means of a mechanical agitator as the batch of GFCs is added from the LAW glass former mixer. The WTP will have the capability to obtain and analyze a sample of the MFPV batch for process control during commissioning, but this will not be a routine sample point.

The GFCs will be purchased from qualified vendors having WTP approved quality control (QC) programs. Certification of GFCs with respect to purity and composition will be required, including chemical analysis of the GFCs. The GFCs will be controlled on the WTP site to ensure that only qualified chemicals will be used in making the melter feed batches.

Once blended, the melter feed slurry will be transferred from the MFPV to the melter feed vessel (MFV). Each LAW MFV waste feed batch will feed the melter continuously for approximately 16 hours. The contents of the MFV will be stirred continuously to maintain a uniform mixture of melter feed slurry to the melter.

2.2 Running the ILAW Glass Formulation Algorithm

The following description is derived from *Preliminary ILAW Formulation Algorithm Description* (24590-LAW-RPT-RT-04-0003, Rev. 0). The sampling events (e.g. LAW 1) are as described in *Integrated Sampling and Analysis Requirements Document (ISARD)* (24590-WTP-PL-PR-04-0001, Rev. 2). LAW feed will be transferred to one of two CRVs in the LAW vitrification facility. The CRV is sampled (ISARD sample LAW 1) after completion of the waste transfer, line flush, and CRV mixing.

ISARD sample LAW 1 taken from the CRV has two sets of results reported:

- Sample report LAW 1a supports release of the process hold point for ILAW glass formulation algorithm runs and determination of the glass formulation recipe[1].
- Sample report LAW 1b supports data collection for reporting compliance in the production records for ILAW containers generated from the associated CRV batch[2].

If available, the results from the LAW 1b sample report would be used as inputs for all runs of the algorithm. If the results from LAW 1b are not available, the results from LAW 1a would be used to support:

- Definition of the transfer volume from the CRV to the MFPV
- Determination of the types and quantities of glass formers (including sucrose) and any dilution water to be added to the MFPV
- Release of waste feed for transfer from the MFPV to the MFV.

Results from the LAW 1b sample report must be used to support preparation of the ILAW production record. In all cases the sample results used by the algorithm is the average of the individual samples taken per sample event.

[1] ISARD, Page B-45.
[2] ISARD, Page B-46.

The following sections describe the algorithm runs supporting waste transfers from the CRV to the MFPV, and the subsequent sampling and process operations.

Transfer from the CRV to the MFPV
Upon completion of the LAW 1 analyses, the algorithm is run to determine the transfer volume from the CRV to the MFPV, using the following inputs:

- LAW 1 analytical results
- Actual volume of material in the CRV
- Actual volume of the MFPV heel
- Algorithm-defined volume of flush water sent to the CRV after waste transfer from the CRV to the MFPV (flush water dilution to the CRV after the LAW 1 sample), if applicable.

The algorithm-determined transfer volume is transferred to the MFPV.

Determine GFC Quantities
Upon completion of the transfer and flush from the CRV to the MFPV, the algorithm is run a second time to determine the types and quantities of glass formers (including sucrose) and dilution water to be added to the MFPV, using the following inputs:

- LAW 1 analytical results
- Actual volume of waste transferred from the CRV to the MFPV
- Algorithm-defined volume of CRV-MFPV line flush water sent to the MFPV (constant in the algorithm).

The MFPV heel volume is not used in the calculation. The algorithm-determined types and quantities of glass formers are added to the MFPV.

Release MFPV Transfer to MFV
Upon completion of the glass former addition, the algorithm is run a third time to release the transfer from the MFPV to the MFV, using the following inputs:

- LAW 1 analytical results
- Actual volume of waste transferred from the CRV to the MFPV
- Actual types and quantities of glass formers (including sucrose) added to the MFPV
- Algorithm-defined volume of dilution water added to the MFPV
- Algorithm-defined volume of CRV-MFPV line flush water sent to the MFPV (constant in the algorithm)
- Algorithm-defined volume of MFPV sampling line flush water sent to the MFPV (constant in the algorithm)
- Algorithm-defined volume of GFC dust control water added to the MFPV (constant in the algorithm).

The MFPV heel volume is not used in the calculation.

Prior to transfer from the MFPV to the MFV, ISARD sample LAW 6 is taken. The purpose of the LAW 6 sample is to verify that the correct glass former mixture has been added to MFPV[3]. The MFPV sample results are used as a check for the final, calculated composition. The confirmation analyses performed on the LAW 6 sample are not a hold point for transfer of feed to the melter[4].

[3] *System Description for Low Activity Waste Melter Feed Process System (LFP)* (24590-LAW-3YD-LFP-00001, Rev. 3), Section 6.1.
[4] ISARD, Page B-48.

If analytical results from LAW 1a were used for the third algorithm run, the algorithm will be run a fourth time using the analytical results from LAW 1b to support preparation of the production record. If the analytical results from LAW 1b are available for the third algorithm run, the results will also be used to support preparation of the production record.

Production Record

If necessary, the algorithm is run a fourth time using the following inputs:

- LAW 1b analytical results
- Actual volume of waste transferred from the CRV to the MFPV
- Actual types and quantities of glass formers (including sucrose) added to the MFPV
- Actual volume of dilution water added to the MFPV
- Algorithm-defined volume of CRV-MFPV line flush water sent to the MFPV (constant in the algorithm)
- Algorithm-defined volume of MFPV sampling line flush water sent to the MFPV (constant in the algorithm)
- Algorithm-defined volume of GFC dust control water added to the MFPV (constant in the algorithm).

The MFPV heel volume is not used in this calculation.

2.3 Containerized Waste Form Compliance Strategy

Compliance with ILAW container and ILAW containerized product specifications will be accomplished 1) during container fabrication, through the use of a container procurement specification, 2) by administrative controls on the container before filling, and 3) by direct measurements on the filled container. Table 2-2 summarizes the compliance strategies for each requirement in Specification 2 of the WTP contract. Table 2-3 shows the source of compliance documentation for each requirement in Specification 2 of the WTP contract.

The ILAW container procurement specification will identify requirements for complying with the WTP contract for the container (for example, material, dimensions, and labeling), the documentation to be submitted with each container, and the QA requirements that apply to the fabrication process. The contract requirements addressed by the procurement specification are detailed in Section 4.1 of this *ILAW Product Compliance Plan*. The fabrication vendor will be required to clean the containers before shipment and provide a shipping cover to prevent foreign materials from entering the container during transport. Upon receipt, the WTP will visually inspect the containers to confirm they have not been damaged during shipment, foreign materials have been excluded, and fabrication documentation is complete. Container handling operations and the container travel path will be reviewed to ensure foreign materials will not enter the container during processing and required waste codes and waste tracking information has been incorporated into the process record. Figure 2-2 identifies the steps in the ILAW container handling process.

Glass will be poured from the melter by means of an airlift system into 1.22 m diameter by 2.286 m tall (48 in. by 90 in. respectively) stainless steel containers. Each container will hold about 6 metric tons of ILAW product. The fill height of glass will be monitored using an infrared camera focused on the external surface of the container as the ILAW container is being filled. The camera will observe the changing thermal profile on the container wall corresponding to the glass fill level.

After cooling, the filled container will be weighed and moved to the inert fill station. At the inert fill station, the fill height will be measured by a laser level measurement system, and samples of the ILAW product can be obtained if required. Inert filler will be added if required to meet the minimum void space requirements of the WTP contract. Once the minimum void space requirement is met, the container rim is cleaned of any inert fill particles that may interfere with sealing of the container lid.

Glass shards can be collected from the top of the filled ILAW containers, but minimal sampling and analysis will be performed on the ILAW product. The glass may be sampled periodically to verify that the chemical composition meets WTP contract specifications.

The container will then be moved to the lidding station where a lid will be sealed in place. The sealed container will then be moved to a decontamination station where it a CO_2 pellet spray system will remove surface contamination. After decontamination, the container will be swabbed at various surface locations to confirm that the outside surface meets contract limits for allowable smearable contamination level. All containers will be swabbed. If a container fails to pass smearable contamination limits, it may be returned to the decontamination station up to two times for rework. If, after the third decontamination attempt, contamination limits are not met, and the container is determined to be "non-conforming", the container will be segregated and a Corrective Action Plan (CAP) prepared for DOE/ORP approval in accordance with Interface Control Document No. 15 (24590-WTP-ICD-MG-0I-015). The surface dose rate and temperature of the container will be measured in the export bay to confirm that they meet contract specification limits. ILAW products meeting WTP contract specifications will be loaded onto DOE approved shipping containers and transferred to DOE for disposal. Disposition of containers that exceed temperature or surface dose rate limits will be determined by the DOE.

Table 2-1 Samples and Measurements Supporting ILAW Product Composition Control

	GFC Supply Silo Weigh Hoppers	GFC Blending Silo	GFC Mixer	CRV	MFPV	MFV	Container
Level Measurement	NA	NA	NA	Routine	Routine	Routine	Routine
Process Sampling	NA	NA	NA	Routine	Routine	NA	Non-Routine
Weight Measurement	Routine	Routine	Routine	NA	NA	NA	Routine
Frequency	Each GFC batch.	As required for process control.	As required for process control.	• Level measurement before and after each transfer to the MFPV.[1] • One process sample set from each CRV batch.	• Level measurement before and after each transfer from the CRV.[1] • Process sampling as required for process control.	• Level measurement before and after each transfer from the CRV.[1]	• Level and weight measurement each filled container. • Process sampling as required for composition verification or as requested by ORP
Purpose	Determine GFC additions for product composition. Compliance with contract specs: 2.2.2.2 Waste Loading 2.2.2.6 Chemical Composition	Process control	Process control	Determine waste feed composition for compliance with contract specifications: 2.2.2.2 Waste Loading 2.2.2.6 Chemical Composition 2.2.2.7 Radiological Composition 2.2.2.8 Radionuclide Limits 2.2.2.9 Surface dose Rate Limits 2.2.2.17 PCT and VHT	Determine transfer volume for proper GFC addition.	Confirm transfer volume.	Report for compliance with contract specifications: 2.2.2.5 Void Space
Required Analyses	Weights of individual GFCs.	NA	NA	• Cations and anions expected to contribute greater than 0.5 wt% in the glass. • Radionuclides identified as significant in NUREG/BR-0204 and Table 2 of 49 CFR 172.101.	Fill level.	Fill level.	Fill level.
Compliance Hold Point	Yes	No	No	No	Yes[2]	No	No
Data into Production Records	Yes	No	No	Yes	No	No	Yes

1. Before and after level measurements in the CRV, MFPV, and MFV support reduction of composition reporting uncertainty.
2. GFCs will not be added to MFPV batch until analytical results from the CRV are obtained and the transfer volume into the MFPV is confirmed.

Table 2-2 Summary of Compliance Strategies during Production

Contract Specification	Topic	Production Implementation	Point of Compliance
2.2.2.1	Package Description	Control of container design, procurement, and handling	Administrative controls
2.2.2.2	Waste Loading	CRV sampling and analysis to determine glass former addition at MFPV	MFPV
2.2.2.3	Size and Configuration	Container design and procurement controls	Administrative controls
2.2.2.4	Mass Limits	Analysis of maximum container mass	Administrative controls
2.2.2.5	Void Space	Fill height measurement	Inert fill and sample station
2.2.2.6	Chemical Composition Documentation	CRV sampling and analysis to determine glass former addition at MFPV	MFPV
2.2.2.7	Radiological Composition Documentation	CRV sampling and analysis to determine glass former addition at MFPV	MFPV
2.2.2.8	Radionuclide Concentration Limits	CRV sampling and analysis to determine glass former addition at MFPV	MFPV
2.2.2.9	Surface Dose Rate Limits	Surface dose rate measurement	Load out station
2.2.2.10	Surface Contamination Limits	Surface contamination measurement	Swabbing station
2.2.2.11	Labeling	Container design and procurement controls	Administrative controls
2.2.2.12	Closure and Sealing	Lid closure	Lidding station
2.2.2.13	External Temperature	Surface temperature measurement	Buffer storage
2.2.2.14	Free Liquid	Exclusion of foreign materials	Administrative controls
2.2.2.15	Pyrophoricity or Explosivity	Exclusion of foreign materials	Administrative controls
2.2.2.16	Explosive or Toxic Gases	Exclusion of foreign materials	Administrative controls
2.2.2.17	Waste Form Testing	CRV sampling and analysis to determine glass former addition at MFPV	MFPV
2.2.2.18	Compressive Strength	N/A	Pre-production analysis
2.2.2.20	Dangerous Waste Limitations	Pre-production treatability variance	Administrative controls
2.2.2.21	Compression Testing	Control of container design, procurement, and handling	Administrative controls
2.2.2.22	Container Material Degradation	Container design and procurement controls	Administrative controls
2.2.2.23	Manifesting	Provide information for approved manifest	Administrative controls
2.2.3.1	Package Handling	Container design and procurement controls	Administrative controls
2.3	Quality Assurance	Use of approved procedures	Administrative controls
2.4	Inspection and Acceptance	Use of approved procedures	Administrative controls

Table 2-3 Source of Compliance Documentation during Production

Contract Spec	Documentation																					
	Container Number	Container MRR Number	Lid Number	Lid MRR Number	Inert Filler MRR Number	Quantity of inert filler material added	LAW feed envelope designator	ILAW Algorithm output using ISARD sample LAW 1b	ILAW production container volume, weight, and center of gravity calculation	Final verified ILAW container level	Final verified void space calculation	Statement of compliance with requirements	Surface dose measurements from Monitoring Export Station	Surface contamination measurements from Swabbing Station	Output from Buffer Store temperature transmitters	Container import inspection results	Lidding station visual inspection results	Approved LDR petition document number	Compression test calculation number	Copy of shipping manifest	QA certification	No traveler requirement
2.2.2.1	x	x	x	x	x	x																
2.2.2.2							x	x														
2.2.2.3	x	x	x	x																		
2.2.2.4									x													
2.2.2.5						x				x	x											
2.2.2.6	x	x	x	x	x	x		x														
2.2.2.7								x														
2.2.2.8								x				x										
2.2.2.9													x									
2.2.2.10														x								
2.2.2.11	x	x	x	x																		
2.2.2.12																	x					
2.2.2.13															x							
2.2.2.14																x	x					
2.2.2.15																x	x					
2.2.2.16																x	x					
2.2.2.17								x														
2.2.2.18																						x
2.2.2.20																		x				
2.2.2.21																			x			
2.2.2.22	x	x	x	x																		
2.2.2.23																				x		
2.2.3.1	x	x	x	x																		
2.3																					x	
2.4																						x

Figure 2-1 LAW Vitrification with Routine and Non-Routine Sampling Points

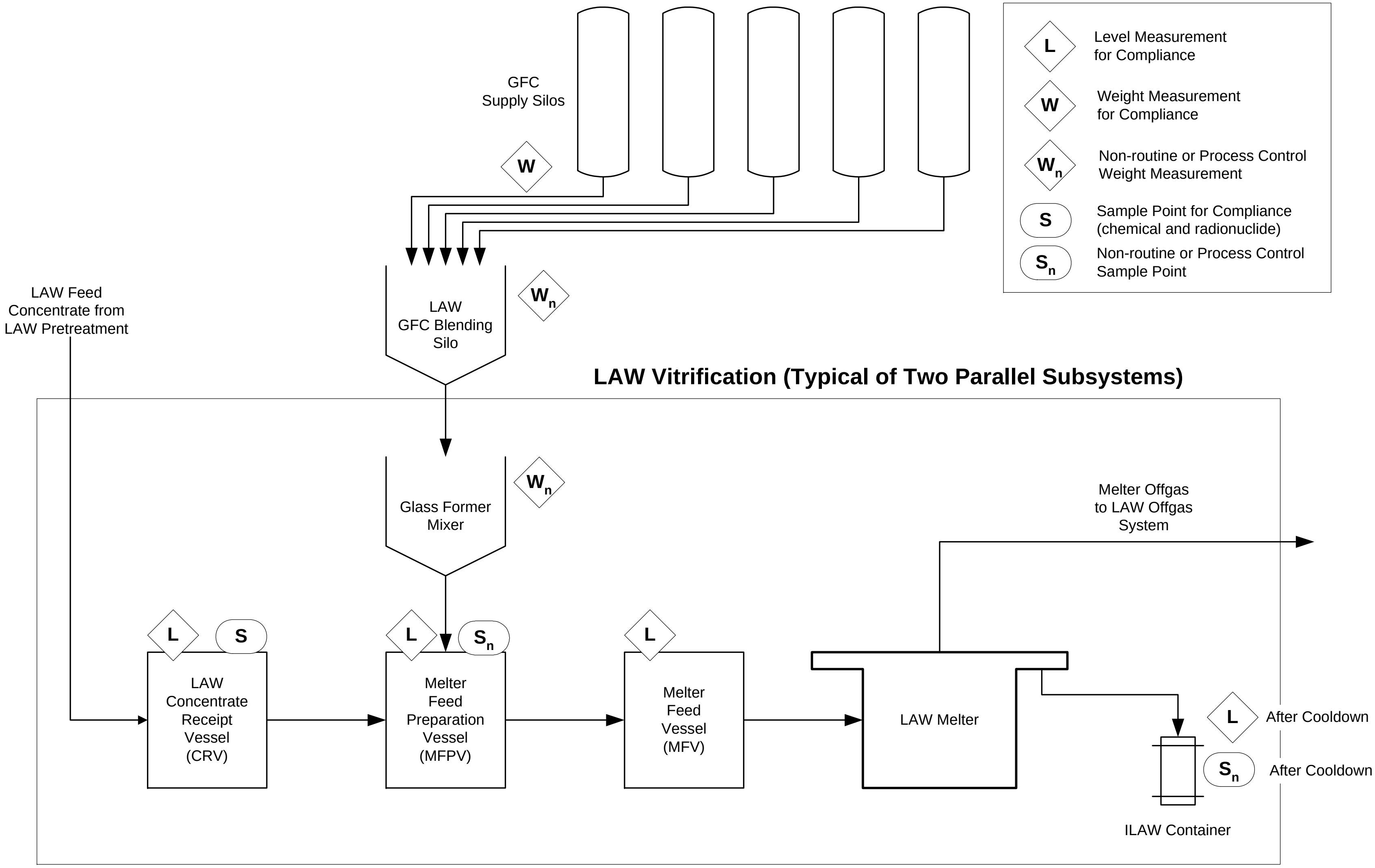
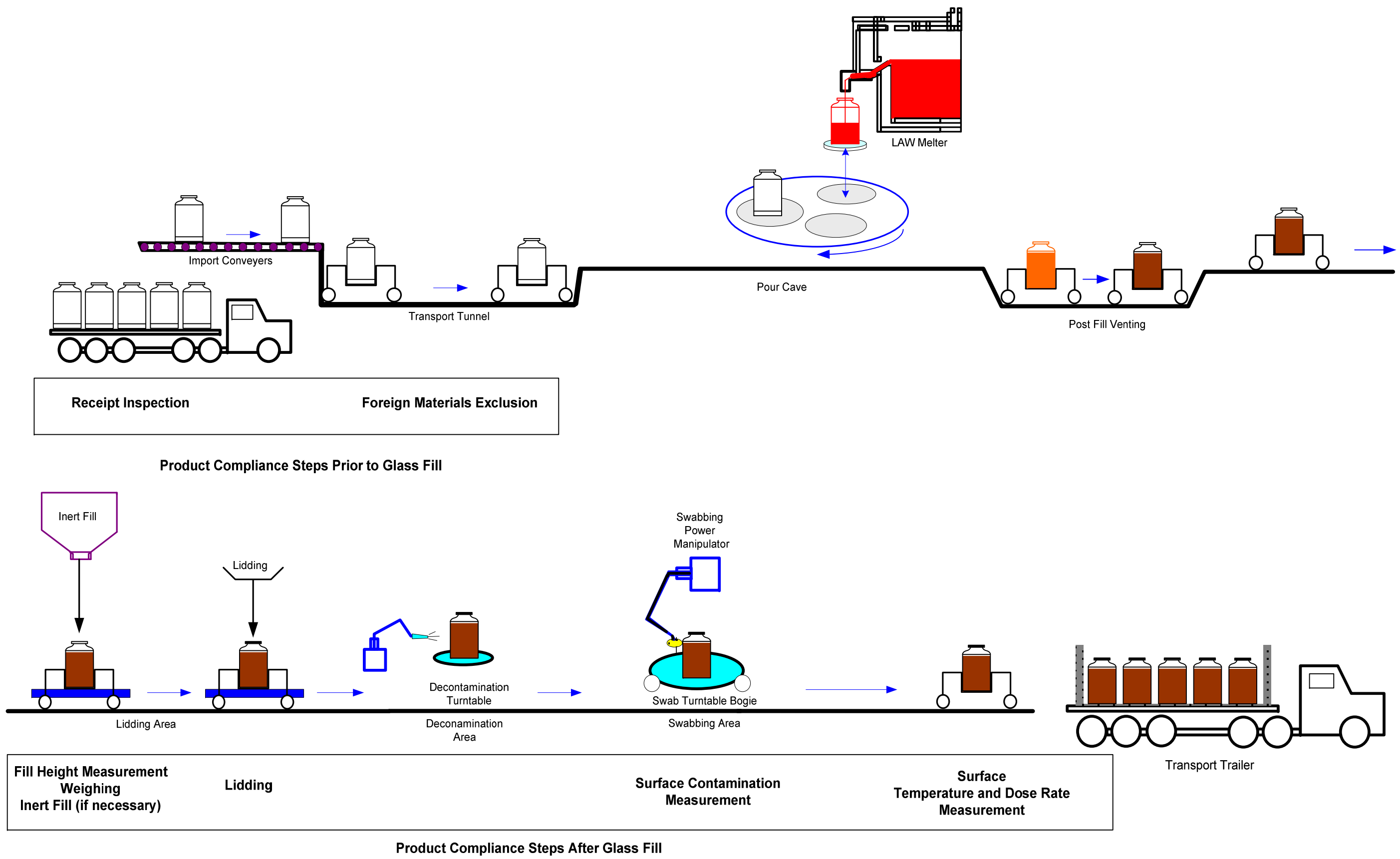


Figure 2-2 ILAW Container Handling Process



3 ILAW Waste Form and Container Description

This section summarizes the waste form and container as the final product from the treatment and immobilization of low-activity wastes in the WTP. The following discussions describe the low-activity wastes and present the characteristics of the ILAW glass waste form, the ILAW container, and the final ILAW product.

3.1 Waste Feed and Characterization

Five major separation processes were used at Hanford from 1943 until 1989, when reprocessing was terminated. The resultant wastes were blended and concentrated by evaporation to reduce volume for storage in large (up to 1,100,000 US gal) underground storage tanks. Acidic wastes were made basic with sodium hydroxide or sodium carbonate to allow storage in these carbon steel tanks. As a result, the waste consists primarily of precipitated metal hydroxides (sludge), alkaline salt solutions (supernate), and crystallized salts (saltcake). The total radioactivity in the waste is estimated to be about 128.3 million curies (MCi) in the tank solids and 70.1 MCi in the tank liquids (24590-WTP-RPT-PT-02-005). The principal activity of the waste comes from cesium-137 (^{137}Cs) and strontium-90 (^{90}Sr). Typically, ^{137}Cs is soluble and is contained primarily in supernate. Conversely, ^{90}Sr is contained largely in solids. The wastes are stored in 28 double shell tanks (DST) and some of the 149 older single shell tanks (SST). Additionally, about 124 MCi of ^{137}Cs and ^{90}Sr that were previously separated from SST waste are currently stored in stainless steel capsules in the Waste Encapsulation Storage Facility. These encapsulated wastes are not scheduled for vitrification by the WTP.

The Tank Operations Contractor will retrieve the wastes from the underground storage tanks and will provide them to the WTP. Waste feeds (characterized before delivery) will be received at the WTP by way of pipeline transfers from DSTs. Waste feeds are defined by the WTP contract (DOE-ORP 2000) as Envelopes. Envelopes A, B, and C are LAW supernatants, and Envelope D consists of the HLW solids. The chemical and radionuclide composition limits of the soluble fraction for each LAW envelope are provided in tables TS-7.1 and TS-7.2 of the WTP contract. Envelopes A, B, and C contain primarily sodium salts (such as nitrate, nitrite, aluminate, sulfate, phosphate, and hydroxide) and soluble radionuclides such as ^{137}Cs and technetium-99 (^{99}Tc). Envelope A is characterized by lower concentrations of glass limiting constituents such as sulfate (SO_4) and varying concentrations of potassium. Envelope B has higher ^{137}Cs levels and higher concentrations of sulfate. Envelope C contains organically complexed ^{90}Sr and transuranic (TRU) elements that will be removed to ensure that ILAW product specifications are met. Envelopes A, B, and C will be transferred to the WTP as concentrated solutions that contain up to 2 wt% entrained solids. Envelope D is made up primarily of insoluble metal oxides and hydroxides (such as iron, aluminum, and zirconium) and contains most of the long lived radionuclides. The Envelope D solids will be received at the WTP combined with Envelope A, B, or C supernate for pretreatment. Preliminary estimates of the composition and sequence of LAW feeds to be received in the WTP are in the *Tank Farm Contractor Operation and Utilization Plan* (TFCOUP) (CHG 2000a). In Appendix E, Table E-1 shows some example pretreated LAW compositions based on testing of actual waste samples, and Table E-2 shows the corresponding radionuclide compositions.

3.2 ILAW Product Description

The nominal waste receipt, WTP pretreatment, and LAW vitrification processes are summarized in Appendix B. The ILAW product is composed of borosilicate glass in a sealed cylindrical stainless steel container. An optional filler of silica (SiO_2) may be used to minimize the void space in the filled container. The characteristics of the glass waste form, container, and immobilized waste product are described below.

3.2.1 Glass Waste Form Description

The ILAW product is a glass waste form for disposal at the Hanford Site. GFCs will be mixed with LAW feed and the resulting slurry will be melted in a joule heated glass melter. The specific combination and quantity of glass formers will be tailored to each batch of LAW feed such that the resulting glass can be processed and the final product meets the requirements of the WTP contract Specification 2, *Immobilized Low-Activity Waste Product* (DOE-ORP 2000). Characteristics of the glass waste form are described below.

3.2.1.1 Chemical and Radiological Composition

The chemical composition of the ILAW product will be determined by the composition of the LAW feed and the additives necessary to produce acceptable ILAW glass. Preliminary estimates of the composition and sequence of LAW feeds to be received in the WTP are in the TFCOUP (CHG 2000a). Because of the variability in the compositions of the tank wastes and resulting wastes, no single glass formulation will apply to all wastes. The WTP project is using process flowsheet model calculations (24590-WTP-RPT-PT-02-005) and tests with waste treatability samples to estimate the composition of LAW that will become feed to the vitrification process. Statistically designed mixture experiments are being conducted to identify a larger glass composition region with acceptable processing and product compliance properties.

Preliminary LAW formulations that comply with the product specifications have been developed for most of the early tanks in the feed delivery sequence. The formulations have been confirmed in melter tests at various scales at the Vitreous State Laboratory, at the pilot scale melter at Duratek, and in crucible scale melts with tank waste samples at Battelle Pacific Northwest Division and Savannah River National Laboratory. These formulations were developed for the Envelope A wastes from tanks AP-101, AN-103, AN-104, AN-105, AW-101, and SY-101/AP-104; Envelope B wastes from tanks AZ-101 and AZ-102 (both as blended wastes and as individual wastes); and the Envelope C wastes from tanks AN-102 and AN-107. The formulations will also be relevant to wastes from other tanks of generally similar composition. The preliminary LAW glass formulations for waste from Envelopes A, B, and C, along with the sodium, sulfate, and potassium concentrations, are provided in Appendix E, Table E-3. The percent of waste and additive loading and the primary components that may be present in typical glass from these formulations are in Table E-4, Table E-5, and Table E-6, for Envelope A, B, and C glasses, respectively.

Table E-7 shows example radionuclide concentrations in the Envelope A, B, and C glasses, based on the analyzed compositions in WTP pretreated waste as shown in Table E-2.

The glass formulations use up to 11 added oxides: Al_2O_3, B_2O_3, CaO, Fe_2O_3, Li_2O, MgO, Na_2O, SiO_2, TiO_2, ZnO, and ZrO_2. The chemicals currently being considered to provide glass forming oxides are kyanite ($Al_2O_3 \bullet SiO_2$), boric acid (H_3BO_3), olivine (Mg_2SiO_4), sodium carbonate (Na_2CO_3), wollastonite ($CaSiO_3$), and zircon ($ZrSiO_4$), supplemented by individual oxides of the other components. These chemicals were selected to tailor the formulations to meet the many, often competing, property constraints. The ratio of sulfate to sodium was found to be the most important waste compositional factor affecting glass formulation (Muller et al. 2001). At sufficiently low ratios, the waste loadings are limited by sodium. However, as the ratio rises, sulfate becomes the dominant waste loading factor. It is not economical to adopt a single formulation for all LAW vitrification because inefficient waste loading in the glass would be required. Rather, the formulations will be tailored to cover the expected range of sulfate to sodium ratios, resulting in higher overall waste loadings.

The selected glasses are stable with respect to crystallization and the formation of secondary phases on heat treatment. Crystalline phases were not observed at concentrations greater than 0.1 vol% in the Envelopes A and C glasses under representative container centerline cooling conditions. Only trace amounts of crystals were observed for Envelope B glasses. The LAWB83 glass for AZ-101 and the LAWB88 for AZ-102 showed crystalline phases including augite, spinel, and pyroxene. Total crystalline content after container centerline cooling was less than 0.4 vol% (Muller and Pegg 2003a).

3.2.1.2 Waste Form Stability

Example LAW glasses have been characterized with respect to their chemical durability as determined through the product consistency test (PCT), the vapor hydration test (VHT), and the toxicity characteristic leaching procedure (TCLP). LAW glass formulations have been assessed with respect to thermal, radiation, biodegradation, and immersion stability (Muller et al. 2001, 2003a, and 2004; and Muller and Pegg 2004).

3.2.1.2.1 Chemical Durability

The PCT and VHT results from the sub-envelope formulations, as analyzed, and the corresponding WTP contract requirements are in Appendix E, Table E-9. In the PCT (ASTM C-1285 [ASTM 2002]), samples of 100 to 200 mesh crushed glass are exposed to deionized water at 90 °C for 7 days. The relative durability is evaluated by the quantity of sodium, boron, and silicon released into the solution, normalized to their concentration in the glass. In the VHT, coupons of glass are exposed to saturated water vapor at 200 °C for a minimum of 7 days and typically for 24 days. Performance in the VHT is based upon the amount of glass reacted. Both the PCT and the VHT indicate the relative durability of the glasses.

The TCLP is used to assess the acceptability of a hazardous waste for land disposal. The WTP is conducting TCLP tests on simulated and actual waste LAW glasses to support a land disposal restriction (LDR) treatability variance petition to the US Environmental Protection Agency (EPA). The leachate from the TCLP is analyzed for each hazardous constituent regulated by the *Resource Conservation and Recovery Act of 1976* (RCRA 1976). Table E-10 shows TCLP results for ILAW glasses prepared from actual waste samples. The results are all well below the associated Universal Treatment Standards (UTS) limits (40 CFR 268.48, Universal treatment standards).

Note that the current treatment standard identified for high-level waste (as defined by 40 CFR 268.42) is vitrification. The treatment standard applies to both HLW and LAW tank wastes at Hanford. Hence, the constituents As, Ba, Cd, Cr, Pb, Hg, Se, and Ag, when treated according to the prescribed treatment technology, vitrification, will no longer be subject to LDRs. However, the underlying hazardous constituents (UHC), Be, Tl, Ni, and Sb, will be subject to the UTS defined in 40 CFR 268.48. The leach properties of these UHCs support the development of an LDR treatability variance petition. Zinc and vanadium are exempt from regulation as UHCs under the provisions of 40 CFR 268.2(i).

Studies support the position that vitrification effectively eliminates organics from vitrified waste glasses. In a letter from the EPA to the DOE (CCN 057110), the EPA transmitted a policy document that "establishes EPA's position that vitrification units, such as that constructed as part of WTP, are expected to provide effective destruction or removal of organics from vitrified high level waste." The EPA indicates that organic waste constituents in the glass matrix are removed or destroyed through mechanisms distinct from those that result in formation of a glass matrix, and are not incorporated into, nor immobilized by, the final glass matrix. These destruction and removal efficiencies are based on chemical kinetics (pyrolysis and combustion), which are well established through basic chemical principles. The EPA notes specifically that vitrification takes place at sufficiently high temperatures to effectively destroy or remove organics from the vitrified residual. The EPA document also provides a technical justification for not sampling vitrified glass to support LDR treatability variance standards. This conclusion is consistent with the position enunciated by the EPA when establishing the high-level vitrification (HLVIT) standard, wherein the EPA indicated that "the potential hazards associated with exposure to radioactivity during analysis of this high-level waste preclude setting a concentration-based standard.

3 .2.1.2.2 Thermal, Radiation, Biodegradation, and Immersion Stability

Compressive strength was measured on simulated LAW glasses according to ASTM C39 (ASTM 1999). Multiple replicates of the samples for each of four LAW glasses were made. LAWA44 and LAWA102 were selected to represent Envelope A glasses, and LAWB45 and LAWC21 represent Envelopes B and C glasses, respectively. Table E-8 summarizes the total number of measurements as well as the minimum and maximum values for each LAW glass tested.

Based upon the results from HLW glasses and the fact that organics are destroyed in the melting process such that there is no organic material to sustain biodegradation, the LAW glasses are not readily susceptible to thermal, radiation, immersion, or biodegradation. Early LAW glass formulations have been tested to determine the effect of heat, radiation, biological activity, and immersion in water on compressive strength (Muller and Pegg 1998). The results indicated that the inherent variability in the measurements on the glasses was large enough to mask any effects of the exposures. Despite the exposures, the glasses exceeded the minimum 3.45 MPa limit.

3.2.1.3 Waste Form Physical Properties

Table E-9 presents the physical properties of the ILAW test glasses from sub-envelope formulations within Envelopes A, B, and C, including density, glass transition temperature, viscosity, and electrical conductivity. These properties are important to ensuring the glass can be processed through the glass melter and poured into the waste form container.

3.2.2 LAW Container Description

The LAW container will be 304/304L stainless steel (24590-LAW-3PS-MV00-T0002).

3.2.2.1 Size and Configuration

The LAW container will be a right circular cylinder 1.22 m diameter by 2.286 m tall (48 in. by 90 in. respectively) (Appendix D). The walls will be nominally 0.1345 in. thick. The maximum weight of the empty container is estimated to be between 1300 lb and 1600 lb. Prototypic containers used in container fill testing averaged 1230 lb. The internal volume is estimated to be approximately 84 ft^3.

3.2.2.2 Closure and Sealing

The filled ILAW container will be closed and sealed in place[5] (Appendix D). The closure lid is circular and nominally 0.99 in. thick. The lid is mechanically sealed to the container flange prepared surface by a metal E-ring held in place by a container seal spring clip welded onto the container lid. The container lid compresses the seal ring and is held in locked position by three locking bars in the lid that mate with the flange groove.

3.2.2.3 Labeling

Each LAW container will be labeled in two locations with a bead-welded five numerical digit serial number. The two labels will be located 180 º apart, on the top head of the container and on the container body below the top head to body weld. The characters will be upright, Arabic numerals with sans serif Megaron medium full width font, 2 in. high (5.08 cm) by 1.4 in. (3.56 cm) wide.

3.2.2.4 Product Handling

The top head of the LAW container includes a plate that extends slightly beyond the container neck (Appendix D). This extension provides a lifting flange that can be engaged by a three-jaw grapple. This lifting flange and grapple are of the same design as successfully demonstrated and used at the West Valley Demonstration Project for handling HLW canisters.

3.2.3 Final ILAW Product

The final ILAW product will be a closed stainless steel container filled with a glass waste form for disposal on the Hanford Site.

3.2.3.1 Mass and Void Space

The mass of the final ILAW product will depend upon the percent fill within the container and the density of the glass waste form. Under normal operations, the container will be filled to at least 90 % of the available volume. If necessary, silica sand (SiO_2) will be used to reduce the free volume within the container to less than 10 %. ILAW glass densities range from 2.5 to 2.8 g/cm^3. Over this glass density range and a maximum container weight of 727 kg, maximum ILAW product weights at 100 % fill will range from 6690 kg to 7410 kg. Five prototypic LAW containers filled to an average 94 % weighed and average 6470 kg (14,264 lb) (Duratek 2004).

3.2.3.2 Surface Dose Rate

A calculation will be performed to estimate the surface dose rate for qualification purposes. Surface dose rate and temperature will be measured before delivery for disposal.

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[5] The WTP is evaluating the impacts of Revision 1-E of the *Hanford Sitewide Transportation Safety Document* (DOE/RL-2001-36). This revision contains an ILAW Special Packaging Authorization (SPA) which identifies the Industrial Packaging (IP) design requirements of 49 CFR 173.411 as governing for transportation of the ILAW containerized waste form on the Hanford Site. An IP designation (IP-1 or IP-2) does not require ANSI 14.5 leak testing.

3.2.3.3 Surface Contamination

All external surfaces of the filled and sealed ILAW container will be cleaned using a CO_2 pellet spray decontamination system. The containers will then be swabbed and the swabs will be monitored to ensure that any removable contamination on the external surfaces does not exceed WTP limits.

3.2.3.4 Proscribed Materials

The final sealed ILAW product will not contain any free liquids, pyrophoric or explosive materials, or explosive or toxic gases. Container fabrication, inspection, and handling activities will eliminate these materials from the container before filling with glass. Any such materials in the LAW will be destroyed or volatilized during the glass melting process at 1050 °C to 1200 °C. The final container closure will prevent these materials from entering the container after filling.

4 Strategy for Meeting Immobilized Low-Activity Waste Product Requirements

This section describes the compliance strategies, activities, and documentation necessary to qualify the ILAW product. The WTP project will conduct compliance activities before ILAW production as "qualification" activities to demonstrate that the ILAW will meet specifications. During ILAW production, the treatment and immobilization process will be monitored and controlled to provide a basis for "characterizing" the final product and providing a basis for certifying that the ILAW meets specifications. Section 4.1 presents methods to be used to qualify ILAW product to meet WTP contract (DOE-ORP 2000) requirements in Specification 2, Immobilized Low Activity Waste Product. Each section presents compliance strategies for meeting each specification, describes planned qualification activities (research and technology development, cold and hot commissioning testing), and lastly, identifies the characterization activities during production operations to demonstrate compliance with ILAW requirements. The descriptions of the planned compliance approach for the ILAW product specifications include the following elements (when applicable):

- Compliance Strategy: Statement of the WTP project strategy for compliance with each ILAW product contract specification or requirement.
- Qualification Activities: Methods and documentation to be developed by the WTP contractor to provide confidence, before full scale production operations, that the ILAW product will conform to the WTP contract specifications and requirements.
- Production Implementation: Activities conducted during hot commissioning and production operations to confirm that the specifications and requirements have been satisfied and to provide the basis for certification of the waste products. This includes documentation that is to be provided with the waste product (for example, production records and storage and shipping records).
- Documentation: Specific documentation to be provided with the waste product (where applicable). ILAW production documentation will provide summaries of much more detailed production records generated during the production, inspecting, and testing of the ILAW product.

As described in Standard 6 of the WTP contract, *Product Qualification, Characterization, and Certification*, qualification activities before production and characterization activities during production will use analysis, testing, inspection, and demonstration to provide the basis for qualification and product certification. Analysis (A) is a set of engineering or scientific calculations to demonstrate that the product meets or exceeds a specific requirement. Testing (T) involves sampling and destructive examination or measurement of the material to determine a property or characteristic. Inspection (I) is a nondestructive examination or measurement of a product property or characteristic. Demonstration (D) is the proof of principle test of a specimen, article, or process used to verify conformance to the conditions of an analysis or product specification. The qualification and production implementation activities described for each requirement include an A, T, I, and/or D to show the type of activity.

Results and details of specific qualification activities and their effect on associated compliance strategies will be documented in the *ILAW Product Qualification Report* (24590-LAW-RPT-RT-05-001). Production documentation will include the manifest as required in ILAW product specification 2.2.2.23, Manifesting, and the Production Record, which provides the basis for certification that the product meets the ILAW specifications, as required in Standard 6: Product Qualification, Characterization, and

Certification. The ILAW product requirements are described in Specification 2, Immobilized Low Activity Product, of the WTP contract (DOE-ORP 2000) and are provided in Appendix A.

4.1 Compliance Strategy for Specification 2 Immobilized Low Activity Waste Product

This section describes strategies and activities the WTP project plans to use to qualify the ILAW, characterize the waste products during production operations, and document that the ILAW meets WTP contract requirements. The WTP contract identifies waste qualification and product characterization requirements for the ILAW product in Table S6-2 of the contract. Application of these requirements to the requirements of WTP contract Specification 2, Immobilized Low Activity Waste, appears in Table 4-1. This table identifies the types of activities (for example, A, D, I, and T) required to comply with contract requirements.

The WTP project will submit ILAW products for acceptance for disposal on a production lot basis. For ILAW, the WTP contract Specification 13, Waste Product Inspection and Acceptance, states that the lot size shall not exceed the amount of ILAW product that is produced in 15 days. Documentation and data demonstrating compliance with all WTP contract requirements will be provided in the production documentation for ILAW. For example, the chemical and radionuclide composition of the ILAW product will be reported based on the melter feed composition (concentrate receipt vessel [CRV] analyses and glass forming chemical [GFC] additions). Glass shard samples taken from containers may be periodically analyzed to confirm the chemical and radionuclide composition. Chemical durability (that is, leach resistance) of the waste form will be reported based on property composition models that relate durability to the chemical composition of the ILAW. Other aspects of ILAW product compliance will be documented (Table 4-2) as described in the responses to each of the WTP contract requirements that follow. Activities described below include indicators to show the type of activity: analysis (A), demonstration (D), inspection (I), or testing (T).

4.1.1 Package Description (Contract Specification 2.2.2.1)

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.

4.1.1.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to design and produce an ILAW product composed of a closed and sealed stainless steel container containing a glass waste form and a DOE approved optional filler material as needed. The ILAW product will meet the requirements identified in the WTP contract Specification 2, Immobilized Low Activity Waste.

4.1.1.2 Qualification Activities

The WTP project will conduct activities, in advance of production operations, to demonstrate compliance with this requirement, including:

- Develop ILAW container specifications and inspection criteria. (A)

- Demonstrate the design, with regard to fabrication, by fabricating prototypic containers and covers according to the established specification. Inspect the fabricated containers and covers against the established acceptance criteria. (D, I)
- Demonstrate the container design by conducting test pours of glass into prototypic containers, adding inert filler, if required, and sealing the containers. Demonstrations will be performed in pilot scale facilities and during cold commissioning. (D)
- Establish the fabrication and inspection controls necessary to verify that:
  - Procured containers and covers are acceptable
  - Characteristics of inert filler are acceptable
  - The container can be adequately sealed (I)
- Select a vendor to fabricate the containers and ensure that they are appropriately qualified through audits and inspections. (I)

The results from the qualification activities will be reported in the ILAW PQR.

4.1.1.3 Production Implementation

During production operations, the WTP project expects to perform the following activities:

- Inspect fabricated containers and covers, in accordance with inspection controls, against the established acceptance criteria. (I)
- Verify inert filler material, in accordance with the inspection controls, against the established acceptance criteria in WTP contract Specification 2.2.2.6, Chemical Composition Documentation. (I)
- Pour glass into the containers and add inert filler, if required, to comply with WTP contract Specification 2.2.2.5, Void Space. (D, I)
- Seal the container to comply with WTP contract Specification 2.2.2.12, Closure and Sealing. (D, I)

ILAW production documentation will include the container number, container Material Receiving Report (MRR) number (for container materials of construction), lid number, lid MRR number, inert filler material MRR number, and quantity of inert filler material added (if used).

4.1.2 Waste Loading (Contract Specification 2.2.2.2)

> *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 (wt%) based on Na_2O.*

4.1.2.1 Compliance Strategy

The WTP project's strategy for compliance with this requirement is to produce ILAW glass that meets or exceeds the minimum waste loading requirements while meeting other ILAW glass performance property requirements in this specification and glass processing property requirements to ensure the safe and efficient operation of the ILAW vitrification process. During qualification activities, glass composition regions that meet and exceed waste loading, glass performance, and glass processing property requirements will be identified and demonstrated through laboratory and scaled melter testing. Algorithms and models will be developed to relate the glass properties to the glass composition. During production, the LAW feed will be sampled and analyzed for chemical and radiochemical constituents. Glass formers will be added such that the resulting glass meets or exceeds the waste loading requirements and meets the other glass property requirements. The glass composition will be calculated based upon the LAW feed chemical analysis and glass former additions. The sodium waste loading will be adjusted by mass balance to account for non-waste sodium introduced during waste processing.

4.1.2.2 Qualification Activities

The WTP project will conduct activities, in advance of production operations, to demonstrate compliance with WTP contract Specification 2.2.2.2 for each waste type, including:

- Develop and test acceptable glass formulations that meet or exceed the specified minimum waste Na_2O loadings and satisfy ILAW processing and WTP contract requirements. (A, D, T)
- Optimize glass formulations to determine the maximum waste loading that can be achieved while still meeting processing constraints and WTP contract requirements. Key constraints on waste loading are expected to be limits of leachability as determined by the product consistency test (PCT) and vapor hydration test (VHT) (see responses to contract Specifications 2.2.2.17) and avoidance of salt accumulations. (A, D, T)
- Demonstrations from crucible scale to pilot scale to show that optimized glass formulations meet all constraints on waste loading. (A, D, T)
- Determine the number of process samples required to certify compliance using statistical sample size methods considering control and compliance goals. (A)
- Develop a method for determining waste Na_2O loading through sampling and analyses of LAW feed and measurements of GFCs added during processing. Mass balance methods will be used to calculate the total mass of nonvolatile oxides expected to be produced by vitrifying specific combinations of LAW feed and GFCs. Effects of heel mixing and volatilization during the vitrification process will be accounted for. The method will be demonstrated before production using simulated LAW and GFCs. (A, D, T)
- Develop a statistical interval method to summarize waste Na_2O loading determinations over a waste type. The statistical interval method will establish that the ILAW glass produced from a waste type meets the applicable envelope specific minimums. The method will be demonstrated before and during cold commissioning. (A, D, T)

The data from developing optimized glass formulations, methods for determining Na_2O loading, and further studies on sulfate and sodium loading will be reported in the ILAW PQR.

4.1.2.3 Production Implementation

During production operations, the WTP project expects to perform the following activities:

- Control the LAW vitrification process such that prepared LAW melter feed matches a target composition that is formulated to meet or exceed sodium loading while complying with specifications. (A, D, T)

- Determine the total Na_2O loading based on sampling and analysis of each LAW feed batch and measurements of the GFCs masses added. These determinations may be confirmed infrequently by chemical analysis of ILAW product samples. (A, T)
- Non-waste sodium additions (such as ultrafilter cleaning and ion exchange column regeneration) will be recorded and included in mass balance calculations. The LAW feed analysis will be adjusted by mass balance to account for average non-waste sodium introduced during feed processing. This adjustment will provide the waste sodium loading. (A)
- Report the waste Na_2O loading in the ILAW production documentation for all ILAW produced from a production lot. (D, A)

The ILAW production documentation will include identification of the LAW feed envelope, the metric tons of ILAW produced per metric ton of sodium feed, and the calculated waste Na_2O loading in the ILAW glass product.

4.1.3 Size and Configuration (Contract Specification 2.2.2.3)

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.

4.1.3.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to design and fabricate the container as a 304/304L stainless steel right circular cylinder having the contract specified dimensions, dimensional tolerance, nominal capacity, and performance requirements. The current preliminary design configuration for the ILAW container and how the dimensional aspects of this specification will be satisfied are in the Appendix D drawings.

4.1.3.2 Qualification Activities

The WTP project will conduct the following activities, before production operations, to demonstrate compliance with this specification:

- Design the container to be fabricated from 304L stainless steel, as a right circular cylinder 2.286 m tall and 1.22 m in diameter (90 in. tall and 48 in. in diameter). Design the container such that, when filled, it will stand without support on a flat, horizontal surface. (A)
- Establish fabrication specifications, acceptance criteria, and inspection controls for qualifying the container fabrication vendor. (A, I)
- Qualify the container fabrication vendor. Project personnel will inspect the vendor's fabrication control systems. Demonstrate the fabrication process and container design by having the vendor fabricate prototypic containers according to the established specification and fabrication process. Inspect the vendor's fabricated containers in accordance with the inspection requirements for qualifying the vendor. (D, I)
- Establish container receipt inspection requirements for use during production. (I)
- Demonstrate the dimensional stability of the filled container by measuring the external dimensions of prototypic containers after filling them with simulated ILAW. The variations in filled container dimensions (diameter, height, and cylindrical shape) will be quantified to demonstrate that the ILAW products will satisfy the requirements of this specification. (D, I)

Results of the design and fabrication specifications, vendor qualification, container receipt inspection requirements, and demonstrations of dimensional stability will be reported in the ILAW PQR.

4.1.3.3 Production Implementation

During production operations, the WTP project will perform the following activities:

- Inspect fabricated containers in accordance with the container receipt inspection controls against the established acceptance criteria to certify compliance with design requirements. (D, I)
- Periodically audit the container vendor to ensure that the fabrication processes and their control systems are maintained in their qualified state. (I)

ILAW production documentation will include the container number, container MRR number (provides container materials of construction and as-built measurements), lid number, and lid MRR number.

4.1.4 Mass (Contract Specification 2.2.2.4)

The mass of each package shall not exceed 10,000 kilograms.

4.1.4.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to show, by analysis during qualification, that the mass of the filled and sealed ILAW container will not exceed 10,000 kg (22,050 lb).

4.1.4.2 Qualification Activities

The WTP project will conduct the following activities, before production operations, to demonstrate compliance with this specification:

- Design the container such that its mass will not exceed 10,000 kg (22,050 lb) when filled and sealed (A). The design logic will:
  - Establish the maximum mass of the unfilled container and lid
  - Establish the maximum mass of glass and inert filler that can be poured into a container
- Establish fabrication specifications for the container design. (A)
- Show by approved calculation that the combined weight of the container, ILAW, and inert filler will be below the limit. (A)

4.1.4.3 Production Implementation

- During production operations, the WTP project will refer to the WTP calculation for the combined weight of the container, ILAW, and inert filler.

4.1.5 Void Space (Contract Specification 2.2.2.5)

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.*

4.1.5.1 Compliance Strategy

The specifications for void space will be achieved by controlling the height to which the container is filled with glass or inert filler. Typical ILAW containers will be filled with glass to a height in the container equivalent to greater than 90 % of the container inner volume. The glass height will be controlled by continuously monitoring the glass fill height with an infrared camera indicating the temperature profile on the container exterior. The glass pour will be terminated when the glass fill height exceeds the minimum fill height to meet the WTP contract specification. The glass fill height will be measured by a laser level measurement system. If necessary, an inert filler of silica or sand will be added to the container to meet the final void space requirement.

4.1.5.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations (before or during cold commissioning), to demonstrate compliance with this specification:

- Demonstrate infrared camera for control of filling the container with glass to achieve minimum fill height. (D)
- Demonstrate the glass fill height measurement system. The fill heights of full scale nonradioactive containers will be manually measured and compared to data collected through use of the laser level measurement system. (D)
- Demonstrate the inert filler addition system on full scale nonradioactive containers. (D)

The results from qualification activities on the glass fill height measurement systems and filler addition systems will be documented in the ILAW PQR.

4.1.5.3 Production Implementation

During production operations, the WTP project expects to perform the following activities:

- Control and measure the fill height in the container according to the same methods, logic, operating parameters, and control strategies established during qualification. (D)
- Measure the fill height of glass in the container after cooling and before addition of any required inert filler. (I)
- Calculate the final void space from the glass fill height measurement and any inert filler addition. (D)

The glass fill level (before and after addition of inert filler), amount of fill material added, and the calculated void space (after any inert filler is added) will be recorded in the ILAW production documentation.

4.1.6 Chemical Composition Documentation (Contract Specification 2.2.2.6)

The chemical composition of the waste form, filler, and package shall be identified.

The WTP project will comply with this specification for each LAW waste type as described below. LAW waste types are discussed in Section 3.1 of this *ILAW Product Compliance Plan*.

4.1.6.1 Deleted (Contract Specification 2.2.2.6.1)

4.1.6.2 Chemical Composition During Production (Contract Specification 2.2.2.6.2)

> *The production documentation (Table C.5-1.1, Deliverable 6.7) shall provide the chemical composition of each waste form, optional filler, and package. The reported composition shall include elements (excluding oxygen) present in concentrations greater than 0.5 percent by weight and elements and compounds required to meet regulatory or Contract requirements.*

4.1.6.2.1 Compliance Strategy

The WTP project compliance strategy for reporting the ILAW glass composition is to identify glass compositions that meet WTP contract requirements and processing requirements, control the composition of the ILAW glass product by sampling and analyzing the treated LAW for chemical and radiochemical constituents and adding glass forming chemicals to achieve a compliant glass composition, and report the final ILAW glass composition based upon mass balance calculations using the LAW quantity and composition and the measured amount of GFCs added.

During qualification activities, regions of qualified ILAW glass compositions will be identified based upon crucible scale and melter scale tests with simulants and crucible scale tests with actual wastes. Glass property composition models will be developed to relate the glass composition to PCT and VHT product properties (Specification 2.2.2.17) and glass processing properties. Qualified glass composition regions (QGCR) will be developed based upon the PCT and VHT glass property composition models. A glass composition control algorithm will be developed to determine the amount of GFCs to add to a batch of treated waste such that the resulting glass meets contract and processing requirements.

During production, the LAW waste will be sampled in the CRV and analyzed for chemical and radiochemical constituents. The glass composition control algorithm will be used to determine the quantity of GFCs to add to the waste. The glass composition will be calculated and reported using a mass balance model that uses the CRV volumes and chemical analyses and the compositions and masses of GFCs. If a filler is added to achieve the void space requirements (Specification 2.2.2.5), its composition will be reported based upon the material certification.

4.1.6.2.2 Qualification Activities

The WTP project will conduct the following qualification activities, in advance of production operations, to demonstrate compliance with this specification. The results from qualification activities will be presented and discussed in the ILAW PQR.

1. Estimate the composition of each waste type to be processed in the WTP using the best available data on LAW feeds.
    - The chemical composition projections for each waste type to be received at the WTP will be developed based on characterization of waste treatability samples and data from other sources such as the latest project approved revisions of the Best Basis Inventory (CHG 2000b), the Tank

Waste Information Network System (TWINS) database (CHG 2000c), and the TFCOUP (CHG 2000a). (A)

- Process flowsheet calculations will be used to predict the composition of LAW feed to be received in the LAW vitrification facility. (A)

2. Develop and test glass formulations appropriate for a range of possible LAW feed compositions.
   - ILAW glass compositions will be developed based on possible LAW feed compositions for each waste type. Glass formulation knowledge, experience, and statistical experimental design methods will be used to select glass formulations that adequately cover the composition region of glasses that may be produced by the WTP. (A, D, I, T)
   - Nonradioactive versions of these glass compositions will be prepared and tested for the key processing properties of density, viscosity, electrical conductivity, and sulfate solubility, and for the WTP contract compliance requirements (Table 4-1) for chemical composition, dangerous and hazardous waste, waste loading, leaching, and durability. The results of the testing will be used to develop a property composition database, property composition models, and model uncertainty expressions. (A, D, I, T)
3. Develop a QGCR that describes a region of ILAW glass compositions that meets glass contract specifications.
   - The PCT and VHT product compliance property composition models and uncertainty expressions will be used to derive a QGCR for ILAW. The QGCR will contain glass compositions projected to satisfy WTP contract specifications for PCT and VHT. (A)
4. Within the QGCR, develop a range of target glass compositions corresponding to the range of waste types to be processed in the WTP.
   - Example, representative target compositions will be developed for vitrifying the waste. It may be necessary to identify separate target composition for each LAW feed batch or a single target may be sufficient to process multiple waste feeds. Nonradioactive versions of glass formulations will be tested for the key processing properties of density, viscosity, electrical conductivity, and sulfate solubility and for the WTP contract compliance requirements (Table 4-1) for chemical composition, dangerous and hazardous waste, waste loading, and waste form leaching and durability. (A, D, I, T)
   - The WTP project will also prepare radioactive ILAW glasses using waste treatability samples provided by the Tank Farm Contractor per *ICD 23 - Interface Control Document for Waste Treatability Samples* (24590-WTP-ICD-MG-01-023). The waste treatability samples will be subjected to pretreatment processes that are prototypic of the full scale WTP production process. The pretreated radioactive samples will then be combined with GFCs and melted in crucibles to produce ILAW glasses. Samples of the ILAW glasses will be analyzed to determine the chemical composition. Various analyses and tests will be performed to confirm compliance with WTP contract requirements. (D, I, T)
   - The results from testing both radioactive and nonradioactive versions of ILAW glass formulations will be compared. Radioactive formulations will be prepared to address features of actual waste: chemical compounds present, speciation, combinations of major constituents, and the effects of minor constituents. These features that affect glass properties will be reflected in nonradioactive simulants. The test results of primary interest are chemical composition (primary phase and any secondary phases), PCT, VHT, and the toxicity characteristic leaching procedure (TCLP). For processability concerns, test results on properties such as viscosity, electrical conductivity, and sulfate solubility will be obtained. (A, D, I, T)

- As new information about the composition of waste types becomes available, or changes occur that affect the composition of the LAW feed for a given waste type, the target compositions for the ILAW glass may be changed to new compositions within the QGCR without further development to qualify the new target compositions. (A)
- The target glass compositions for each waste type will be used to project the expected chemical composition of ILAW to be produced at the WTP. These projections will include estimates of variations in ILAW composition that may result from process variations, including variations in waste feed composition. (A)

5. Estimate uncertainties in ILAW glass composition based on variations and uncertainties in LAW feed composition and vitrification process sampling, chemical analyses, and process measurements.
   - Tests will be conducted to validate the design basis weighing and transferring capabilities for delivering GFCs to the melter feed preparation vessel (MFPV) and to quantify uncertainties. Uncertainties in weighing and transferring GFCs will be estimated in advance of this demonstration activity and updated during cold commissioning, if required. The effects of hygroscopic GFCs on batch formulation will be evaluated. (A, D, T)
   - Tests with prototypic vessels will be conducted to quantify the uncertainty due to mixing and representative sampling, and to demonstrate level and volume measurement and uniform and accurate transfer in process vessels. The estimated uncertainties will be compared to the variability estimates in the design basis. These activities will be conducted using simulated (nonradioactive) wastes and actual GFCs. During cold commissioning, process data will be evaluated to confirm variability and uncertainty estimates. (A, D, I, T)
   - Analyses will be performed to quantify the variation in glass composition for each waste type based on estimated variations in waste composition and the ability to accommodate variations by adjusting GFC additions. Glass composition uncertainties (due to sampling and analysis) will be quantified based on data collected during qualification testing. Analyses will be conducted to show that variations and uncertainties in glass composition for each waste type will be within the corresponding QGCR (see response to WTP contract Specification 2.2.2.6.1). (A, T)
   - Tests and analyses will be conducted to determine uncertainties and sample sizes for the sampling and measurement points associated with the strategy for controlling the ILAW composition. Sampling, analytical, measurement (for example, weighing GFCs or determining volumes or levels in process vessels), and transfer uncertainties will be estimated using available data. Based on the initial uncertainty estimates, the number of samples or measurements required and the number of chemical analyses per sample will be determined. Sampling requirements will be determined before cold commissioning and confirmed or updated during cold commissioning. (A, T)
   - The ability to predict the ILAW composition within a reasonable margin of error from LAW feed and GFC compositions will be demonstrated during cold commissioning through sampling and analyses of CRV, MFPV, and final glass product. (A, D, T)
6. Develop an ILAW glass composition algorithm to determine quantity of GFCs to add to a LAW feed batch and to confirm resulting ILAW glass will meet product and process specifications.
   - A product control system will be developed and qualified. Given the estimates and uncertainties of the LAW composition in the CRV, the volume of LAW, and the GFC compositions; the algorithm will calculate which GFCs and the quantity of each to add to the MFPV to provide a compliant glass. As part of the calculation, the algorithm will use glass property composition models for PCT, VHT, glass melt viscosity, and electrical conductivity to predict the glass properties and confirm they will meet requirements. The algorithm will consider the uncertainties

in the models, sampling and analyses, and process measurements in quantifying the GFCs and confirming compliance. (A, D)

- The chemical compositions of the container and optional filler material(s) will also be projected as part of qualification activities, as discussed in the responses to WTP contract Specifications 2.2.2.3 and 2.2.2.5. The chemical composition of the container will be projected from industry standard material specifications for series 304/304L stainless steel. The composition of the inert filler material will be projected from vendor specifications for the selected filler material. (A, I)

4.1.6.2.3 Production Implementation

During production operations, the WTP project expects to perform the following characterization and reporting activities:

- Qualified sampling, test methods, analytical techniques, and models will be used to demonstrate compliance with this requirement during production. As new methods become available, they may be evaluated for development and qualification for use in ILAW production. (A, D, T)
- The WTP project's *Quality Assurance Manual* (QAM), 24590-WTP-QAM-QA-06-001, requires the GFC supplier facility to follow a WTP project approved QA program (QAP) and perform audit and surveillance activities at the WTP vitrification facility to ensure that quality materials are used in GFC addition. GFC suppliers will be required to certify the compositions and uncertainties of GFCs (major components as well as impurities) and to provide chemical analysis data. (A, I)
- The impurities in GFCs will be kept to a minimum by requiring the vendor to supply the material at a specific purity level and certify it with material test reports. If the glass forming chemical (for example, Fe_2O_3) contains Al_2O_3 as a impurity, it will be accounted for in the calculation of the amount of GFC to be added to the waste batch. (A, I)
- ILAW chemical composition will be controlled during production operations by sampling and chemically analyzing LAW feed, and calculating required additions of GFCs necessary to yield ILAW satisfying all WTP contract and processing requirements. In addition, volume transfers of CRV batches and mass of GFCs transferred to the MFPV will be verified within measurement uncertainties. (A, D, I, T)
- The product control aspects of the strategy for compliance with this requirement will be implemented as part of a larger process control system for LAW vitrification. Aspects of the product control system that are part of the compliance strategy will be conducted according to NQA-1 (ASME 2000) requirements and documented in the ILAW production documentation. The process will be operated within control limits based on parameters and results from qualification activities. (A, D, T)
- The means and standard deviations of reportable glass components will be calculated over the chemical composition determinations of ILAW produced as a given production lot is being processed. Standard deviations will be computed to account for multiple sources of variation and uncertainty. (A, I)

The following information will be reported in the ILAW production documentation: container number, container MRR number (for container materials of construction), lid number, lid MRR number, inert filler material MRR number (for chemical composition of inert filler material), quantity of inert filler material added (if used), and the estimated composition of the ILAW glass based on output from the ILAW glass formulation algorithm.

The estimated composition will be calculated using a mass balance based upon the analyses of LAW feed samples, the volume of waste transferred from the CRV to the MFPV, the composition of the GFCs as provided in the vendor certifications, and the masses of GFCs added (as measured in the glass former batching facility), as well as the estimated volume and composition of the tank heels in the MFPV. The reported compositions will span several ILAW containers corresponding to a production lot. Reportable glass components will include those at concentrations greater than 0.5 wt% in the glass plus those necessary to meet regulatory or contract requirements.

4.1.6.3 Deleted (Contract Specification 2.2.2.6.3)

4.1.7 Radiological Composition Documentation (Contract Specification 2.2.2.7)

The radionuclide composition of the waste form shall be documented. Radionuclides shall be identified that are significant as defined in NUREG/BR-0204 and 49 CFR 172.101 (Table 2). Technetium-99 (^{99}Tc) shall be considered to be significant at concentrations greater than 0.003 Ci/m^3 in the ILAW form. The inventories shall be indexed to December 31, 2002. The documentation shall be consistent with the radiological description format described in NUREG/BR-0204.

Radionuclide Composition Qualification (Contract Specification 2.2.2.7.1)

The ILAW Product Qualification Report (Table C.5-1.1, Deliverable 6.6) shall identify the estimated radionuclide concentration in the waste form.

Radionuclide Composition During Production (Contract Specification 2.2.2.7.2)

The ILAW production documentation (Table C.5-1.1, Deliverable 6.7) shall identify the radionuclide inventory in each ILAW package produced. The actual inventory indexed at the month of product transfer and the inventory indexed to December 31, 2002, shall be reported.

4.1.7.1 Compliance Strategy

The WTP project's compliance strategy for reporting the ILAW radionuclide composition is to determine the radionuclide content of the LAW feed in the CRV and then report the final ILAW glass radionuclide composition based upon mass balance calculations using the LAW feed chemical and radiochemical analysis and the measured amount of GFCs added. During qualification activities, both maximum and expected radionuclide concentrations for ILAW products from wastes in Envelopes A, B, and C will be estimated. The estimates will account for the expected removal of ^{137}Cs, ^{90}Sr, and TRU constituents during pretreatment at WTP as required to meet the limits in WTP contract Specification 2.2.2.8. Results from flowsheet calculations and from pretreatment and vitrification process testing on LAW treatability samples will be used to estimate the radionuclide composition of the ILAW glass product.

During production operations, the radionuclide inventories in the ILAW glass product produced from a given production lot (Section 4.1) will be determined based on radiochemical analysis of CRV process samples of LAW feed , mass measurements of GFCs added into the MFPV, and estimated masses of glass in filled ILAW containers. The WTP project will use chemical and radiochemical analysis to identify concentrations of all significant radionuclides. Analyses for key radionuclides will be conducted for each CRV batch. Detailed radionuclide analyses will be conducted less frequently and the resulting ratios may be used to estimate the inventory for each CRV batch.

Interim inventories on a production lot basis will be reported as ILAW containers are submitted for acceptance to comply with this requirement and WTP contract Specification 2.2.2.8. Final average inventories for each production lot will be computed and reported in the production documentation.

Radionuclide inventories in the ILAW product will be indexed to the month of transfer to DOE and to 31 December 2002 by performing decay calculations from a known reference date. Radionuclide content for ILAW versus time relationships will be generated for each production lot from which the activity in any given month of transfer to DOE can be derived.

The concentration of the following radionuclides will be estimated:

- Radionuclides that are significant as defined in NUREG/BR-0204 (NRC 1998) and are present at greater than 1 % of the smallest concentrations listed in Table 1 and Table 2 of 10 CFR 61.55
- Radionuclides other than ones listed in 10 CFR 61.55 if they are contained in the waste in concentrations greater than 0.26 megabecquerels/cm^3 (7 Ci/m^3)
- Any radionuclide whose activity represents a reportable quantity under US Department of Transportation (DOT) regulations (49 CFR 172.101, Table 2) or is 1 % or more of the total activity within the disposal container
- ^{99}Tc at concentrations greater than 0.003 Ci/m^3

4.1.7.2 Qualification Activities

The WTP project will perform the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

1. Estimate the radionuclide composition of each waste type to be processed in the WTP using the best available data on LAW feeds.
   - The radionuclide composition projections for each waste type to be received at the WTP will be developed based on characterization of waste treatability samples and data from other sources such as the latest project approved revisions of the Best Basis Inventory (CHG 2000b), the TWINS database (CHG 2000c), and the TFCOUP (CHG 2000a). Maximum radionuclide inventories will be based upon Specification 7, Low Activity Waste Envelopes Definition (Table TS-7.2). (A)
   - Process flowsheet calculations will be used to predict the composition of LAW feed to be received in the LAW vitrification facility. The flowsheet calculations will account for radionuclide removal processes including cesium removal using ion exchange and strontium and TRU precipitation. (A)
2. Estimate the radionuclide concentration in representative ILAW glasses.
   - Flowsheet calculations using the Aspen Custom Modeler™ and the WTP Tank Utilization Assessment model will also be used to estimate the volume of glass to be produced from the LAW feed. ILAW volumes will be based on waste loading (that is, wt% sodium oxide) in the glass for each waste type to be processed in the WTP. (A)
   - Produce samples of ILAW glass from pretreated waste treatability samples. The waste will be pretreated using conditions that are prototypic of the production process, to the extent possible under laboratory conditions. Perform radiochemical analysis and compare the results to estimates. (D, I, T)

3. Develop tools for determining and reporting radionuclide composition during production.
   - Assess the performance of identified methods for obtaining and analyzing process and product samples (for example, alpha, beta, and gamma analyses in conjunction with inductively coupled plasma mass spectrometry) for radionuclides that are significant as defined in NUREG/BR-0204 (NRC 1998) and 49 CFR 172.101, Table 2. If the methods are not sufficient for obtaining and analyzing samples, redesign, modify, or change the procedure. (A, I)
   - Establish and confirm ratios that may be used for estimating concentrations of radionuclides that will not be determined by direct measurement. Ratios between radionuclides or ratios between radionuclides and nonradioactive components will be established, if necessary, based on similar chemical behavior during the treatment process and confirmed through analysis of glass made from waste treatability samples. (A, I)
   - Conduct demonstrations using small scale and pilot scale melter tests to determine partitioning of radionuclides during the vitrification process (for example, volatilization to offgas or deposition in the melter). Demonstrations will use nonradioactive surrogates. (D)
   - Estimate variations in radionuclide inventories over the course of a waste type, as well as uncertainties due to sampling, radiochemical analysis, ratios, decay calculations, and any other sources using statistical error propagation methods. Variations in radionuclide inventory are expected due to variations in the LAW feed composition (as discussed in Section 4.1.1). (A)

Significant radionuclides in ILAW glass by envelope will be documented in the ILAW PQR. Estimates of maximum radionuclide concentrations will be reported for ILAW products corresponding to flowsheet assessments of pretreated Envelope A, B, and C feeds. Estimates of expected radionuclide concentrations will be reported for representative LAW waste types to be treated in the WTP. The documentation will be consistent with the radiological description format described in NUREG/BR-0204 (NRC 1998). The details of the sampling and analytical methods for process and ILAW product samples developed during qualification activities will be documented. Variations and uncertainties associated with the radionuclide inventory estimates will also be quantified in advance of production and reported in the ILAW PQR.

4.1.7.3 Production Implementation

During production operations, the WTP project expects to conduct the following activities to comply with this requirement:

- Collect and perform radiochemical analysis on process samples to determine the concentrations of significant radionuclides as defined in NUREG/BR-0204 (NRC 1998) and 49 CFR 172.101, Table 2. (D, T)
- Apply the ratio method to estimate radionuclide concentrations for those radionuclides not directly measured, if necessary. (A)
- Calculate the means and standard deviations of the radionuclide inventory determinations for ILAW containers produced from a given LAW production lot for each significant radionuclide. (A)
- Calculate radionuclide inventories indexed to the month of product transfer and to 31 December 2002 using a computer code (for example, MicroShield™ [Grove 1996]) for each significant radionuclide. (A)

Concentrations and inventories (in Ci per container) of reported radionuclides based on glass formulation algorithm output will be included in the ILAW production documentation for each significant radionuclide. The documentation will be consistent with the radiological description format described in NUREG/BR-0204 (NRC 1998).

4.1.8 Radionuclide Concentration Limitations (Contract Specification 2.2.2.8)

> *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.*

4.1.8.1 Compliance Strategy

The WTP project's compliance strategy for the requirement is to develop and demonstrate WTP LAW pretreatment processes that will remove ^{137}Cs and ^{90}Sr/TRU when necessary to meet WTP contract requirements. When necessary, ^{90}Sr/TRU will be removed through pretreatment precipitation and ultrafiltration, and ^{137}Cs will be removed through pretreatment ion exchange.

During production, controls will be implemented and the radionuclide concentrations in the ILAW will be calculated from analysis of LAW feed samples and process flowsheet calculations. The means, standard deviations, and the number of radionuclide concentration estimates upon which these statistics are based will be provided in the ILAW production documentation. Periodic ILAW product samples may be analyzed to confirm compliance with this requirement.

4.1.8.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Demonstrate the ability to remove Cs from LAW feeds using ion exchange materials. Small scale tests will be conducted with candidate LAW samples using ion exchange to demonstrate sufficient radionuclide removal to comply with this requirement. (D)
- Demonstrate removal of ^{90}Sr and TRU radionuclides from Envelope C feeds by adding nonradioactive strontium nitrate and sodium permanganate solutions to precipitate ^{90}Sr and TRU components that are held in solution by organic complexants. Tests will be conducted with waste treatability samples to demonstrate sufficient removal of radionuclides to comply with this requirement. (D)
- Perform radiochemical analyses of glass made from waste treatability samples to determine the concentration of the radionuclides listed, as well as TRU components. (D, T)
- Compare the concentrations of the radionuclides in the test glass to the Class C limits to ensure that the limits are met. Concentrations of other fission products that may be important by the "sum of fractions" rule described in 10 CFR 61.55 will also be determined. (A)
- Determine number of process samples using statistical sample size methods considering process control and compliance goals. (A)
- Estimate variations in radionuclide concentrations that will occur over all ILAW containers, as well as uncertainties due to sampling, radiochemical analysis, ratios, decay calculations, and any other sources. (A)

4.1.8.3 Production Implementation

During production, the WTP project expects to perform the following activities:

- Determine the radionuclide concentrations in the ILAW product through analysis of a combination of process samples, flowsheet calculations, or periodic confirmatory product samples. Radionuclide concentrations will be determined routinely based upon samples taken from the ILAW CRVs. (A, T)
- Verify that radionuclide concentrations are less than Class C limits as defined in 10 CFR 61.55 and as described in the Nuclear Regulatory Commission's *Branch Technical Position on Concentration Averaging and Encapsulation* (NRC 1995). (A, I, T)
- Verify that the average concentrations for the following radionuclides are below their respective concentration limits: $^{137}Cs < 3$ Ci/m^3, $^{90}Sr < 20$ Ci/m^3, and TRU<100 nCi/g. The average concentrations will be determined by calculating the means of radionuclide concentrations, measured in process or confirmatory product samples, for all containers submitted for acceptance. (A, I, T)
- Calculate a running average of radionuclide concentrations by summing the actual inventories of each radionuclide in the ILAW product presented to date and dividing by the total volume of waste in these containers. (A)

Inventories of reported radionuclides in Ci per container based on glass formulation algorithm output will be included in the ILAW production documentation for each significant radionuclide. The WTP project will also report running averages of radionuclide concentrations over all ILAW product containers presented to date for acceptance on a waste type basis in the ILAW production documentation.

4.1.9 Surface Dose Rate Limitations (Contract Specification 2.2.2.9)

The dose rate at any point on the external surface of the package shall not exceed 500 mrem/hr.

4.1.9.1 Compliance Strategy

The WTP project will use a combination of engineering analysis during qualification and actual measurements during production operations to demonstrate compliance with this requirement. The radionuclide compositions of each of the ILAW waste forms to be produced will be determined in order to demonstrate compliance with WTP contract Specifications 2.2.2.7 and 2.2.2.8. The data, along with information on the geometry of the container and thickness and density of shielding materials (for example, container wall), will be used to calculate a surface dose rate for the ILAW product.

4.1.9.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Evaluate the maximum and expected concentrations of radionuclides in the ILAW glass as described in response to WTP contract Specification 2.2.2.7.1 for LAW waste envelopes (based on WTP contract maximum concentrations) and candidate LAW feeds (based on expected concentrations). These projections will account for removal of radionuclides to meet WTP contract Specification 2.2.2.8. (A)

- Demonstrate the ability to effectively remove radionuclides as described in response to WTP contract Specification 2.2.2.8. (D)
- Calculate projected maximum and expected surface dose rates for the ILAW product based on maximum and expected radionuclide concentrations in ILAW glass. (A)
- Calculate projected dose rates based on waste type specific radionuclide inventories generated by flowsheet model runs. These data will be reported in a future revision of this *ILAW Product Compliance Plan*, as the results become available. (A)
- Use dose rate models such as MicroShield™ (Grove 1996) or the Monte Carlo N-Particle transport code (LANL 1998) to project dose rates from the ILAW product based on maximum and expected radionuclide concentrations in the ILAW glass. Confirm that the dose rate models are verified and validated for WTP conditions. (A)

4.1.9.3 Production Implementation

During production, the WTP project expects to perform the following activities:

- Check radionuclide concentrations projected for compliance with WTP contract Specification 2.2.2.7, Radiological Composition Documentation, to verify that they will be lower in the ILAW product than the maximum used to demonstrate compliance with this specification. (A)
- Confirm compliance with this requirement by monitoring the surface dose rate of each ILAW container using handheld instrumentation or automated monitoring equipment prior to transfer for disposal. (I)

Surface dose rates measured for each container will be reported in the ILAW production documentation.

4.1.10 Surface Contamination Limitations (Contract Specification 2.2.2.10)

> *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).*

4.1.10.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to clean all external surfaces of the filled ILAW containers using a CO_2 pellet spray decontamination system. The containers will then be swabbed to determine the level of removable contamination using the method in 49 CFR 173.443(a). The swabs will be monitored to ensure that removable contamination does not exceed specified limits.[6]

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[6] Revision 1E to the *Hanford Sitewide Transportation Safety Document* (TSD) (DOE/RL-2001-0036) issued May 2011 modified the ILAW Special Packaging Authorization (SPA) Entry Bounding Requirements to read:

> *Compliance with removable surface contamination requirements for ILAW product containers does not require container decontamination because of the process and form of the molten glass product. Off-normal conditions can be addressed using a DOE/RL-approved fixative.*

The WTP will continue to evaluate the impacts of this revision.

4.1.10.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Conduct small scale demonstrations of the CO_2 pellet spray decontamination process using stainless steel coupons with baked on ^{137}Cs contamination. Use the results of these tests to determine what effect, if any, the decontamination process would have on the structural integrity of the ILAW container. (D, I, T)
- Conduct an analysis to determine which areas of the container should be swabbed to yield a representative assessment of removable contamination levels consistent with 49 CFR 173.443 requirements. (A)
- Develop a container swabbing procedure, and any remote equipment required, to obtain and count the swabs. (A)
- Demonstrate operability of the decontamination and container swabbing systems during cold commissioning. (D)
- Demonstrate in nonradioactive tests that the decontamination method will not compromise the ILAW container integrity. (D)
- Demonstrate the decontamination, swabbing, and contamination control procedures during hot commissioning. (D, I)
- Design and test an ILAW container overpacks. (D, T)

4.1.10.3 Production Implementation

During production, the WTP project expects to perform the following activities:

- Decontaminate each container using the CO_2 pellet spray decontamination system selected and qualified during qualification activities. (D)
- Swab each container to verify that it meets limits for removable contamination. (I)

During production operations, results of swab testing for removable contamination will be reported for each container in the ILAW production documentation.

4.1.11 Labeling (Contract Specification 2.2.2.11)

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.

4.1.11.1 Compliance Strategy

The WTP project compliance strategy for this requirement is to label each ILAW container with a unique alphanumeric identification number on the shoulder and side of each ILAW container. Each ILAW container will be labeled in two locations with a bead-welded five numerical digit serial number. The two labels will be 180 degrees apart, on the top head of the container and on the container body below the top head to body weld. The characters will be upright, Arabic numerals with sans serif Megaron medium full width font, 2 in. high (5.08 cm) by 1.4 in. (3.56 cm) wide. The preliminary design configuration for the ILAW container and labeling is in Appendix D. The label will meet all WTP contract specifications for lettering and durability, and have a predicted service life of 50 years assuming that the container is stored in a ventilated enclosure at ambient temperatures. The unique alphanumeric number will be transcribed onto all production record documentation associated with the ILAW product.

4.1.11.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Develop fabrication specifications for the size, format, location, and unique alphanumeric identification system and method of labeling the ILAW container. (D)
- Establish acceptance criteria and inspection controls for qualifying the container fabrication vendor. (A, I)
- Qualify the container fabrication vendor. Project personnel will inspect the vendor's fabrication control systems. Demonstrate the fabrication process and container design by having the vendor fabricate prototypic containers according to the established specification and fabrication process. Inspect the vendor's fabricated containers in accordance with the inspection requirements for qualifying the vendor. (D, I)
- Establish container receipt inspection requirements for use during production. (I)
- Analyze label service life by referring to published data (e.g., West Valley Demonstration Project and the Defense Waste Processing Facility, as appropriate). The estimated corrosion rate of the selected material will be such that the label is expected to remain readable for 50 years. Legibility of the label after 50 years will be demonstrated by showing that the label sized to account for the corrosion expected after 50 years can be read. (A, I)
- Demonstrate the selected label integrity and readability during container filling, decontamination, and handling activities of cold commissioning. (D, I)

4.1.11.3 Production Implementation

During production operations, the following activities will be conducted in order to comply with this requirement:

- Fabricate ILAW production containers in accordance with the fabrication specifications and with the unique alphanumeric identification applied. (D, I)
- Inspect the delivered containers upon receipt to confirm that each container is uniquely labeled and that the identifier is transcribed onto the accompanying documentation. (I)

- Inspect labels visually to ensure compliance with labeling requirements before the container enters the vitrification caves for filling and during temporary storage at the WTP. (I)

The production documentation accompanying each container will include the container number, container MRR number (provides container labeling specification), lid number, and lid MRR number (provides lid labeling specification)..

4.1.12 Closure and Sealing (Contract Specification 2.2.2.12)

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.

4.1.12.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to provide a mechanical lid closure for the ILAW container.[7] The seal will be designed to maintain its integrity for 50 years in a ventilated enclosure at ambient temperature.

4.1.12.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Demonstrate and qualify the closure process by performing lid closures during acceptance testing using production equipment or the equivalent. (D)
- Demonstrate the integrity of the seal by conducting an evaluation of the closure to meet the requirements that the seal remains intact for the most severe conditions encountered during normal use and handling and a storage period of 50 years in an ambient temperature, ventilated enclosure. (A)
- Confirm the integrity of the seal by inspecting the final closure during cold commissioning. (I)

4.1.12.3 Production Implementation

During production operations, the following activities will be conducted in order to comply with this requirement:

- Train and qualify the staff to install the lid using the same equipment and procedures demonstrated during qualification. (D)

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[7] The WTP is evaluating the impacts of Revision 1-E of the *Hanford Sitewide Transportation Safety Document* (DOE/RL-2001-36). This revision contains an ILAW Special Packaging Authorization (SPA) which identifies the Industrial Packaging (IP) design requirements of 49 CFR 173.411 as governing for transportation of the ILAW containerized waste form on the Hanford Site. An IP designation (IP-1 or IP-2) does not require ANSI 14.5 leak testing.

- Prior to closure, inspect the container top flange by remote video camera or by visual inspection through the cell window to verify condition and cleanliness of the closure surfaces. (I)
- Visual inspection of the closure process and final closure will be used as a means of assessing closure quality during production operations. (I)

Certification of the visual inspection for the final closure will be provided in the ILAW production documentation.

4.1.13 External Temperature (Contract Specification 2.2.2.13)

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.

4.1.13.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to hold the filled ILAW containers for sufficient time to cool to meet the external temperature requirements. The external temperature of the filled ILAW container will be measured to confirm that the temperature is below the maximum temperature before the ILAW product is picked up for transport to the disposal facility.

4.1.13.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Design and construct the LAW vitrification facility to ensure that the external temperatures of ILAW containers are less than the contract required temperature at time of shipment to the disposal facility. (A)
- Fill prototypic containers with simulated LAW glass and measure their external surface temperatures to generate cooling profiles and a recommended time interval for adequate cooling. (D, I)
- Measure container external surface temperatures during cold commissioning. (I)

4.1.13.3 Production Implementation

During production operations, the WTP project will hold the ILAW containers to ensure that they have cooled for sufficient time before shipment to the disposal facility. The surface temperature of the container will be measured before shipment. (I)

The production documentation for each container will include the measured surface temperature.

4.1.14 Free Liquids (Contract Specification 2.2.2.14)

The package shall contain no detectable free liquids as defined in ANSI/ANS-55.1 or SW-846 Method 9095.

4.1.14.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to show by analysis that the vitrification process itself does not introduce free liquids. Procurement specifications will be established to ensure that inert filler and containers are received at the WTP without liquids. Administrative and processing controls will be implemented to ensure that liquids are not added to containers during WTP storage and process handling.

4.1.14.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Estimate the temperature and relative humidity conditions in the cell to evaluate the likelihood of condensation of liquids inside the filled container after initial cooling and before closure. Analysis is expected to show that condensation will not occur in the filled containers, because under normal operations the filled containers will not cool to a temperature below the ambient cell dew point prior to closure. (A)
- Develop the container fabrication specification to require that containers be delivered to the waste treatment facility with no free liquids present. (D)
- Review the container handling system and the vitrification system to ensure that addition or formation of free liquids in the ILAW product is highly unlikely during routine operations. The molten glass will be poured into the container at 800 °C or higher; this will prevent the introduction of materials that could form liquids at ambient conditions. Limited quantities of non-drainable liquids that may be in the container prior to filling would also be destroyed or volatilized during the container filling process. (A)
- Review filler addition system to ensure that the addition or formation of free liquids in the ILAW container is unlikely. (A, T, I)
- During commissioning of the full scale plant, inspect containers and the inert filler materials upon receipt and at selected points in the process to verify the absence of free liquids. (D, I)

4.1.14.3 Production Implementation

During production operations, the following activities will be conducted in order to comply with this requirement:

- Require that the fabricator clean and dry ILAW containers prior to shipping them to the WTP. Require that the containers be packaged for shipping to prevent proscribed materials from entering the container. (D)
- Store and handle empty ILAW containers in a manner that prevents proscribed materials from entering the containers. (I)
- Visually inspect all ILAW containers prior to entry into the LAW vitrification facility to ensure that they contain no drainable liquids and that no liquid adheres to the container surfaces. (I)
- Operate the vitrification process such that any water or other materials that exist as free liquids at ambient conditions within the melter feed slurry will be volatilized. (A, I)

- Implement administrative controls and closure of the container lid to ensure that free liquids do not enter or condense inside the filled container. (D)
- Confirm the absence of foreign materials in the filled ILAW container through visual inspection, just prior to addition of any inert filler and container closure. (I)
- Specify during procurement of inert filler materials that they do not contain free liquids and verify by inspection that the procurement specifications are met. (I)
- Perform permanent closure after filling the container to ensure against introduction of prohibited materials into the container. (D)

The ILAW production documentation will include certification that the container passed all in-process inspections for foreign materials.

4.1.15 Pyrophoricity or Explosivity (Contract Specification 2.2.2.15)

> *The package contents shall not be pyrophoric, readily capable of detonation, or readily capable of explosive decomposition or reaction (including reaction with water) at normal pressure and temperature. The waste form and any optional filler materials shall not be ignitable or reactive as defined in WAC 173-303-090(5) and WAC 173-303-090(7).*

4.1.15.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to develop the ILAW as a glass waste form and to use inert material (such as silica sand) as optional filler. The WTP project will show, through testing and analysis, that the ILAW glass and inert material are not ignitable per WAC 173-303-090(5), reactive per WAC 173-303-090(7), or an oxidizer per 49 CFR 173.151. Procurement specifications will be established to ensure that containers are received at the WTP without pyrophoric or explosive materials. Administrative and processing controls will be implemented to ensure that pyrophoric or explosive materials are not added to the ILAW containers during WTP storage and process handling.

4.1.15.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Ensure through analysis that the waste form and inert filler are not ignitable or reactive. Tests such as EPA SW-846 Method 1030, *Ignitability of Solids* (EPA 1997), will be evaluated. Evaluations to determine whether the waste form and filler meet the eight points of reactivity in Chapter 7 of SW-846 will also be conducted. (A, T)
- Develop the ILAW container fabrication specification to require the manufacturer to clean and degrease the container and to prevent the introduction of prohibited materials after fabrication through delivery to the WTP. (D)
- Review the container handling system and the vitrification system to ensure that addition of foreign material in the ILAW product is highly unlikely during routine operations. (A)
- During commissioning of the full scale plant, inspect containers and the inert filler materials upon receipt and at selected points in the process to verify the absence of foreign materials. (D, I)

4.1.15.3 Production Implementation

During production operations, the WTP project expects to perform the following activities:

- Require that the fabricator clean and degrease ILAW containers prior to shipping them to the WTP. Require that the containers be packaged for shipping to prevent proscribed materials from entering the container. (D)
- Store and handle empty ILAW containers in a manner that prevents proscribed materials from entering the containers. (I)
- Inspect the containers prior to entry into the LAW vitrification facility to ensure that no foreign materials are present. (I)
- Control the vitrification process so it produces a mixture of oxides that are not reactive up to the glass transition temperature of between 400 °C and 500 °C and chemically stable up to the glass melting temperature (about 1150 °C). (A)
- Implement administrative controls and closure of the container lid to ensure that foreign materials do not enter or condense inside the filled container. (D)
- Confirm the absence of foreign materials in the filled ILAW container through visual inspection, just prior to addition of any inert filler and container closure. (I)
- Perform permanent closure after filling the container to ensure against introduction of prohibited materials into the container. (D)

The ILAW production documentation will include certification that the container passed all in-process inspections for foreign materials.

4.1.16 Explosive or Toxic Gases (Contract Specification 2.2.2.16)

> *The package shall not contain or be capable of generating quantities of explosive (e.g., hydrogen) or toxic gases, vapors, or fumes harmful to persons handling the waste.*

4.1.16.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to fill the ILAW container with glass and optional filler and seal the container. The waste product will be borosilicate glass and the optional filler material will be an inert material known to not generate harmful quantities of explosive or toxic gases, vapors, or fumes at ambient temperatures. The ILAW container filling process will be controlled to prevent any foreign material from entering that could in turn generate explosive or toxic gases.

4.1.16.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Demonstrate the ability of the vitrification process to destroy or remove toxic organics in the LAW feed. This will be demonstrated through sampling and analysis conducted to demonstrate compliance with WTP contract Specification 2.2.2.20, Dangerous Waste Limitations. Preliminary data show that toxic organic materials present in the feed will not persist in the glass product. (A, D, T)

- Review the available technical literature to determine the composition and quantities of gases that could volatilize from the ILAW glass near the glass transition temperature (up to 500 °C [932 °F]). (A)

4.1.16.3 Production Implementation

During production operations, the WTP project expects to control the container handling and closure processes to ensure that prohibited gases are not introduced into the container. (A, D)

The ILAW production documentation will include certification that the container passed all in-process inspections for foreign materials.

4.1.17 Waste Form Testing (Contract Specification 2.2.2.17)

Deleted (Contract Specification 2.2.2.17.1)

Product Consistency Test (PCT) (Contract Specification 2.2.2.17.2)

> *The normalized mass loss of sodium, silicon, and boron shall be measured using a seven day product consistency test run at 90 °C as defined in ASTM C1285-98. The test shall be conducted with a glass to water ratio of 1 gram of glass (-100 +200 mesh) per 10 milliliters of water. The normalized mass loss shall be less than 2.0 grams/m^2. Qualification testing shall include glass samples subjected to representative waste form cooling curves. The product consistency test shall be conducted on waste form samples that are statistically representative of the production glass.*

Vapor Hydration Test (VHT) (Contract Specification 2.2.2.17.3)

> *The glass corrosion rate shall be measured using at least a seven (7)-day vapor hydration test run at 200°C as defined in the DOE-concurred upon ILAW Product Compliance Plan. The measured glass alteration rate shall be less than 50 grams/(m^2 day). Qualification testing shall include glass samples subjected to representative waste form cooling curves. The vapor hydration test shall be conducted on waste form samples that are representative of the production glass.*

4.1.17.1 Compliance Strategy

The WTP project's strategy for compliance with these requirements is to produce ILAW glasses that have predicted PCT and VHT properties below the maximum levels specified while meeting waste loading requirements and glass processing property requirements. During qualification activities, glass composition regions that meet and exceed PCT, VHT, waste loading, and glass processing property requirements will be identified and demonstrated through laboratory scale and melter scale testing. Algorithms and glass property composition models will be developed to relate the glass PCT and VHT properties to the glass composition. During production, controlling the ILAW glass composition will control PCT and VHT performance. The LAW feed will be sampled at the CRV and analyzed for chemical and radiochemical constituents. GFCs will be added such that the resulting glass will meet PCT and VHT requirements and the other glass property requirements. PCT and VHT property composition models will be used to calculate the expected PCT and VHT performance of the glass produced.

4.1.17.2 Qualification Activities

The WTP project will conduct the following qualification activities to demonstrate compliance with WTP contract PCT and VHT specifications. The results from the qualification activities will be presented and discussed in the ILAW PQR.

Identify a region (or regions) of glass compositions that meets PCT and VHT requirements.

- Using statistically designed test matrices, conduct PCT and VHT on simulated ILAW glasses spanning the glass composition region(s) of interest for LAW vitrification. Develop target glass compositions for expected waste types and conduct PCT and VHT on simulated and radioactive glasses. (A, T)
- Assess the potential effects of heat treatment on PCT and VHT performance via literature review, analyses, and testing. Selected simulated ILAW compositions will be subjected to quick cooling (air quenched) and ILAW container centerline cooling (CCC) heat treatments and then tested by the PCT and VHT. Quenched and CCC heat treatments will be used because they are expected to bound the range of temperature conditions that the glass will experience as it cools. The test results will be compared to assess whether different heat treatments affect PCT and VHT performance. Any secondary phases (crystalline or amorphous) in the quenched or CCC glass samples will be determined so that differences in PCT and VHT performance can be related to the types and fractions of secondary phases in the heat treated glass samples. (A, T)
- Assess the potential effects of redox state on PCT and VHT performance via literature review and analyses. The redox state of selected glass formulations will be evaluated and related to changes, if any, in PCT performance. (A)
- Perform literature reviews, analyses, and tests to demonstrate that radionuclides do not significantly affect PCT and VHT performance. Radioactive and nonradioactive versions of glasses otherwise having the same chemical composition will be tested using the PCT and VHT. The results will be used to demonstrate that radionuclides, which are typically present at very low chemical concentrations, do not significantly affect performance, and to confirm that effects of minor constituents in the waste (such as noble metals) have been accounted for. (A, T)
- Conduct PCT and VHT on glasses spread over the region of glass compositions that may be produced from a range of LAW waste types using glass formulation knowledge, experience, and statistical experimental design methods. Data will be generated for nonradioactive and radioactive glasses to develop and validate the PCT and VHT property composition models. These data may be augmented by relevant existing data produced by others, provided the data satisfy QA requirements or can be qualified to meet such requirements and will be documented in the ILAW PQR. (A, T)

Develop glass property composition models to relate PCT and VHT performance to the ILAW glass composition.

- Develop and validate property composition models and corresponding uncertainty equations for predicting PCT normalized boron and sodium releases (r_B^{PCT} and r_{Na}^{PCT}) as functions of glass composition. Because PCT results for silicon are always less than for boron and sodium, a PCT model for silicon release will not be developed. The models and uncertainty equations will be statistically developed and validated using property composition data from nonradioactive and radioactive tests. The resulting models and uncertainty equations will be used to help define a QGCR for ILAW as described in the response to WTP contract Specification 2.2.2.6. (A)

- Develop and validate property composition models and corresponding uncertainty equations for predicting VHT performance as a function of glass composition. The model and uncertainty equations will be statistically developed and validated using property composition data from nonradioactive and radioactive tests. The resulting models and uncertainty equations will be used to help define a QGCR for ILAW as described in the response to WTP contract Specification 2.2.2.6. (A)

Assess the uncertainty in predicted PCT and VHT properties based on uncertainties in the PCT and VHT property composition models and variations and uncertainties in sampling, chemical analyses, and process measurements to predict the ILAW compositions as described in the compliance strategy for Specification 2.2.2.6, Chemical Composition Documentation. Verify that the ranges of PCT and VHT values corresponding to the region of glass compositions expected to be produced from each waste type (after accounting for variations and uncertainties) will be below their respective limits.

- Equations for predicting uncertainties will be developed and validated. Statistical methods will be applied to develop and validate models and corresponding uncertainty equations as functions of glass composition. The resulting PCT and VHT property composition models and the corresponding uncertainty equations will be used to help define the QGCR for ILAW as described in the response to WTP contract Specification 2.2.2.6. (A)
- Statistical analyses will be performed to quantify variations and uncertainties affecting glass composition. These variations and uncertainties will be combined to estimate the region of glass compositions expected to be produced from each waste type. The glass property composition models will be applied to determine the ranges of PCT and VHT values in the expected composition region. These values will be verified to be below the corresponding limits. (A, D, T)
- A statistical interval method will be developed to demonstrate that ILAW glass produced over a waste type complies with the PCT and VHT specifications. The method will account for the source of variation of interest (i.e., variation in PCT performance due to variation in ILAW composition over the course of a waste type). The method will also account for nuisance uncertainties (e.g., sampling, analytical, other measurements, and property composition model uncertainties). Statistical X/Y upper tolerance intervals may be used for this purpose. (A)
- Develop a statistical method to determine the number of process samples and the number of chemical analyses per sample required to demonstrate that the PCT and VHT values will satisfy their respective limits. Calculate the number of process samples per production lot and the number of chemical composition analyses per sample that are required to demonstrate compliance with PCT and VHT specifications according to the statistical method selected. The calculations will require estimates of glass composition variation as well as sampling, analytical, and property composition model uncertainties. The estimates of variations and uncertainties will be developed as part of qualification activities described above and in the responses to WTP contract Specification 2.2.2.6. (A)
- A product control system will be developed and tested as described in the qualification activities under WTP contract Specification 2.2.2.6. Simulant testing during qualification and actual testing during cold commissioning will demonstrate the ability of the process and product control system to control chemical composition and PCT and VHT performance of the ILAW product through sampling and analyses of the CRV, MFPV, and glass product and PCT and VHT testing of the glass product. (A, T)

4.1.17.3 Production Implementation

During production operations, the WTP project expects to perform the following characterization and reporting activities:

- The chemical composition of the ILAW product will be determined and controlled as described in the response to WTP contract Specification 2.2.2.6. (A, I, T)
- The PCT and VHT property composition models will be applied using the ILAW glass chemical composition determinations for each MFPV batch. The outcomes will be predicted PCT and VHT values, and calculated uncertainties of the predictions for each chemical composition determination. (A)
- The predicted PCT and VHT values for glasses produced over a production lot will be used to calculate means, standard deviations, and statistical intervals. The calculations will account for variations and uncertainties in the predicted property values due to variations in glass composition, as well as uncertainties due to glass sampling, glass chemical analyses, other measurement uncertainties and the PCT and VHT property composition models. Statistical variance and error propagation methods will be used, and will be discussed in detail in the ILAW PQR after they are developed and applied. (A)

The ILAW production documentation will include the chemical composition of ILAW glass as oxides and masses of GFCs added and the predicted PCT and VHT calculated from PCT and VHT glass property composition models.

4.1.18 Compressive Strength (Contract Specification 2.2.2.18)

The mean compressive strength of the waste form shall be determined by testing representative non-radioactive samples. The compressive strength shall be at least 3.45E6 Pa when tested in accordance with ASTM C39/C39M-99 or an equivalent testing method.

4.1.18.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to conduct experiments to measure the compressive strength of nonradioactive ILAW glasses to demonstrate that the LAW glass will satisfy this requirement.

4.1.18.2 Qualification Activities

The WTP project will conduct the following activity, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Conduct experiments to provide compressive strength data on typical simulated ILAW glasses to demonstrate that ILAW produced will have mean compressive strengths that satisfy the requirement. (A, I)

4.1.18.3 Production Implementation

During production operations, the WTP project will control the vitrification process to produce glass that meets other (waste loading, radionuclide inventory, PCT, and VHT) requirements. Glasses meeting these requirements will also meet the compressive strength requirement. No activities are planned to demonstrate compliance with compressive strength requirements during production operations. The production documentation will include reference to the glass compressive strength testing reported in the ILAW Product Qualification Report.

4.1.19 Deleted (Contract Specification 2.2.2.19)

4.1.20 Dangerous Waste Limitations (Contract Specification 2.2.2.20)

> *The ILAW product shall be acceptable for land disposal under the State of Washington Dangerous Waste Regulations, WAC 173-303, and RCRA LDR in 40 CFR 268.*

4.1.20.1 Compliance Strategy

The WTP will comply with applicable LDR treatment standards and applicable Dangerous Waste Permit Conditions. The WTP project's strategy for compliance with this requirement is to petition EPA and Washington State Department of Ecology (Ecology) for a variance from existing performance based treatment standards, if necessary. Under normal circumstances, treated waste (ILAW) would typically be sampled and analyzed for comparison to those standards to demonstrate compliance. The WTP project has determined that, because of the radiological exposures associated with sampling and analysis of the ILAW during production, a performance based standard is inappropriate. Sampling and analysis would entail TCLP testing of the ILAW product and comparison to numerical standards for leachate concentrations. The treatability variance will exempt treated Hanford tank wastes for all waste codes and hazardous constituents not otherwise covered under the HLVIT standard (defined in 40 CFR 268.42).

A data quality objective (DQO) process was conducted to establish criteria for developing adequate data with acceptable quality to support the petition for a treatability variance for ILAW (24590-WTP-RPT-ENV-01-012). As a result, the WTP project will perform testing with nonradioactive versions of the ILAW product that simulate the treated waste. Data from those tests will be statistically analyzed and the results presented as part of the petition for the treatability variance. A treatability variance petition will be developed and submitted to regulatory agencies (24590-WTP-RPT-ENV-03-003). During production, the WTP project will control the vitrification process to adequately treat the waste in accordance with any conditions established as part of the treatability variance.

4.1.20.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Conduct a DQO process to identify the testing required to support the strategy for obtaining a petition for a treatability variance for compliance with LDRs for ILAW. (A)
- Conduct testing as delineated in the *Data Quality Objectives Process in Support of LDR/Delisting at the WTP* (24590-WTP-RPT-ENV-01-012), as agreed upon by DOE, EPA, and Ecology. The proper

QA controls will be applied, including compliance with the WTP *Quality Assurance Manual* (24590-WTP-QAM-QA-06-001) and the *EPA Requirements for Quality Assurance Project Plans* (EPA 2001). (A, D, I, T)

- Use results of prior tests with simulated ILAW glasses spiked with hazardous constituents to demonstrate proof of principle that vitrification is an appropriate treatment for Hanford tank waste. (A)
- Prepare nonradioactive samples of ILAW glasses for testing per EPA Method 1311 (TCLP). The glasses will be spiked with elevated concentrations of constituents of potential concern identified through the DQO process. (D, T)
- Conduct statistical analysis of the TCLP test results and prepare a test report in support of the petition for a treatability variance. Data from TCLP testing of ILAW glasses made from waste treatability samples may be used to support the petition, although this is not a requirement of the DQO. (A, D, T)
- Prepare a petition for treatability variance from LDR treatment standards for Hanford tank waste, obtain DOE concurrence, and submit the petition to Ecology and EPA. (D)

The ILAW PQR will document the progress toward meeting the schedule proposed for obtaining the LDR treatability variance provided in Table 6 of the *Approach to Immobilized Hanford Tank Waste Land Disposal Restrictions Compliance* (CHG 2000d).

4.1.20.3 Production Implementation

The WTP has petitioned for an unconditional treatability variance. Once the variance is approved, the ILAW will no longer be subject to regulation as a land disposal prohibited waste. The ILAW production documentation will reference the approved ILAW LDR petition.

4.1.21 Compression Testing (Contract Specification 2.2.2.21)

> *Each fully loaded package shall be able to withstand a compression load of five (5) times the weight of the container. Compliance with this specification shall be established by using the compression (stacking) test described in 49 CFR 173.465(d) or evaluated against this test by any of the methods authorized by 49CFR173.461(a). The integrity of the package shall be demonstrated by showing that the seal remains intact in accordance with Specification 2.2.2.12, Closure and Sealing.*

4.1.21.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to design the constituent parts of the ILAW container such that the dimensions of the filled container remain within the tolerance range dictated by disposal requirements and the closure remains intact after it is subjected to the compressive load specified in this requirement. As allowed in 49 CFR 173.461(a), calculations will be used to demonstrate compliance with the compression test design requirements in 49 CFR 173.465(d).

4.1.21.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Design the container such that the closure remains intact after it is subjected to the compressive load of this requirement. (A)
- Establish fabrication specifications, acceptance criteria, and inspection controls for qualifying the ILAW container vendor. (A)
- Demonstrate the container design by conducting numerical analyses to evaluate the effect of a 50,000 kg (110,231 lb) load applied to the top flange of an upright empty ILAW container. The calculations will assume that the container is empty, which is conservative. Show that the container retains its integrity and that the seal remains intact after the test load is removed per WTP contract Specification 2.2.2.12. (A)
- Establish container receipt inspection requirements for use during production. (I)

4.1.21.3 Production Implementation

During production, the WTP project expects to perform the following activities:

- Use containers fabricated to the same specifications as those used in the qualification activity. (D)

ILAW production documentation will include reference to the numerical analysis of container compression strength.

4.1.22 Container Material Degradation (Contract Specification 2.2.2.22)

> *The container and handling appurtenances shall be designed to allow safe lifting and movement (in accordance with Specification 2.2.3.1) after a storage period of fifty (50) years.*

4.1.22.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to fabricate the ILAW container from stainless steel of the grade, weld material, and wall thickness required to maintain container integrity over 50 years under the expected storage conditions (ambient temperature and ventilated enclosure) and during handling and disposal operations. The container handling features will be designed to enable safe lifting and handling after a storage period of 50 years in an ambient temperature, ventilated enclosure.

4.1.22.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Design the container to be fabricated from stainless steel, which is inherently resistant to degradation by the conditions of this requirement. (A)
- Design the container and its handling features such that safe lifting and movement after a storage period of 50 years is predicted. (A)
- Demonstrate the container design by conducting test pours of glass into prototypic containers, add inert filler to comply with the minimum void space requirement, and seal the containers. Sealed containers will be inspected against the established acceptance criteria. Inspections will be performed

to demonstrate container integrity during handling operations in pilot scale facilities and during cold commissioning. (D, I)

4.1.22.3 Production Implementation

During production operations, the WTP project expects to perform the following activities:

- Fabricate containers and lids according to the specification established during qualification. Only qualified materials will be used for container fabrication; this will be verified by periodically inspecting fabrication material documentation. (D, I)
- Inspect fabricated containers and lids in accordance with the receipt inspection controls to certify compliance with design requirements. (D, I)
- Visually inspect the containers and lids during production operations to check for integrity. (I)

ILAW production documentation will include the container number, container MRR number, lid number, and lid MRR number.

4.1.23 Manifesting (Contract Specification 2.2.2.23)

> *A shipping manifest shall be prepared for delivery with each shipment of ILAW product. Information on the manifest shall satisfy the requirements in DOE Manual 435.1-1, Chapter IV, section I.(2), and NUREG/BR-0204. Any package containing dangerous waste must be labeled and manifested in accordance with WAC 173-303-370 and the Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Wastes (Permit No. WA 7890008967).*

4.1.23.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to provide documentation (manifest) with each shipment of ILAW that satisfies the requirements of this specification. Manifesting will provide the basis for certification, as required in Standard 6 of the WTP Contract. Both the WTP and the ILAW disposal trench will be located in the 200 East Area of the Hanford Site. No offsite shipments of ILAW are anticipated.

DOE Manual 435.1-1, Chapter IV, Section I.(2) (DOE 2001), and NUREG/BR-0204 delineate requirements for reporting the composition and characteristics of low-level waste shipments. Much of this information will already be included in the ILAW production documentation. Permit Condition II.Q of the *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste* (Ecology 2001) describes the information required for transfer of dangerous waste to the ILAW disposal facility.

The WTP project will develop documentation that meets all of the above requirements by using information for the ILAW production records and supplementing as necessary. Radioactive Shipment Records will be used to satisfy DOE radioactive materials shipping records requirements.

4.1.23.2 Qualification Activities

The WTP project will conduct the following activities, in advance of production operations, to demonstrate compliance with this specification. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Establish and maintain the WTP project's QAM to ensure the accuracy of the ILAW characterization. (D, I)
- Support WFQ to interface with the requirements for transportation and DOE waste acceptance. (D)
- Characterize the physical, chemical, and radiological characteristics of the ILAW to meet the requirements of this specification and other requirements of WTP contract Specification 2 through demonstrations with simulated ILAW and ILAW made from samples of actual waste. (D, I, T)
- Review the information required under Permit Condition II.Q of the *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste* (Ecology 2001), the Radioactive Shipment Records, NUREG/BR-0204 (NRC 1998), and DOE Manual 435.1-1, Chapter IV, Section I.(2) (DOE 2001) with respect to the requirements for the ILAW production records, and determine an appropriate method for reporting that will meet all of these requirements. (A)
- Develop the documentation necessary to support compliance with these requirements. (D)

Documentation that will be provided with each shipment will be described in the ILAW PQR.

4.1.23.3 Production Implementation

During production operations, the WTP project expects to perform the following activities:

- Prepare the documentation necessary to transfer the ILAW from the WTP to the onsite ILAW disposal site. Information needed to complete the radioactive shipping records will be available from:
  - Sampling and analysis (T)
  - Process knowledge (I)
- Maintain and make available for inspection transportation records as required by DOE, Ecology, and DOT. (I)

During production, documentation satisfying the requirements of this specification and confirmation that the ILAW product meets radioactive shipment record requirements will be provided with each shipment of ILAW to the disposal site.

4.1.24 Package Handling (Contract Specification 2.2.3.1)

> *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.*

4.1.24.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to design the container to incorporate those features necessary to facilitate safe lifting and movement by crane, and to maintain the integrity of the container during these operations when it is fully loaded.

4.1.24.2 Qualification Activities

During qualification, the WTP project will perform the following activities. The results from the qualification activities will be presented and discussed in the ILAW PQR.

- Design the container to include those features necessary to facilitate safe lifting and movement by crane, while maintaining its integrity during those operations. (A)
- Establish fabrication specifications, acceptance criteria, and inspection controls for qualifying the ILAW container vendor. (A, I)
- Demonstrate the container design by performing the lifting and movement operations expected during operations on prototypic containers filled with simulated ILAW using the grapple designed for the ILAW container. These tests will occur during cold commissioning of the facility. Containers will be visually inspected for integrity upon receipt and during handling operations. (D, I)

4.1.24.3 Production Implementation

- During production operations, the WTP project will fabricate the containers and lids according to the specifications established during qualification, and perform inspections of the containers and lids upon receipt according to the controls also established during qualification. (D, I)

- Container handling during production operations will be limited to conditions established during qualification testing. (D)

ILAW production documentation will include the container number, container MRR number, lid number, and lid MRR number.

4.1.25 Quality Assurance (Contract Specification 2.3)

> *A QA Program (Table C.5-1.1, Deliverable 7.2) for ILAW Product development, qualification, characterization, and certification is required and shall be based upon NQA-1 (2000). The QA Plan shall address the QA/quality control requirements addressed in SW-846 and WAC 173-303-806.*

4.1.25.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to perform work in compliance with the DOE approved WTP project QAM, including NQA-1 (ASME 2000). Data obtained and measured in support of environmental regulatory activities will be collected in accordance with the requirements of the *EPA Requirements for Quality Assurance Project Plans* (EPA 2001) and applicable Washington State requirements for environmental regulatory sampling and analysis in WAC 173-303-110. The QAM provides this mechanism to address the QA and QC requirements in SW-846 (EPA 1997) and WAC 173-303-806.

QA requirements will be applicable to subcontract organizations performing services for the WTP. Contract organizations will be audited and any exceptions to the QA requirements will be approved by the WTP project prior to initiation. Results of the data validation and an assessment of "completeness" as defined by SW-846 (EPA 1997) will be included in the reports issued as the deliverable for the task.

The WTP project will ensure that subcontractor and supplier QAPs comply with the WTP project's QAM requirements. Audits and surveillances of subcontractor and supplier QAPs will be conducted and documented to assess conformance.

4.1.25.2 Qualification Activities

During qualification, the WTP project will perform the following activities. The results from the qualification activities will be presented and discussed in the ILAW PQR. The ILAW PQR will reference the QAM, EPA 2001, and the WAC.

- Perform work in accordance with the requirements of the WTP project's QAM, which implements the requirements in NQA-1 (ASME 2000). These requirements ensure that data collected during technology development and demonstration activities that may be used for WFQ are collected and controlled in accordance with QA requirements.
- Collect data in support of environmental regulatory activities, including a petition for an LDR treatability variance for the ILAW product, in accordance with the requirements of :
  - *EPA Requirements for Quality Assurance Project Plans* (EPA 2001);
  - *Test Methods for Evaluating Solid Waste Physical/Chemical Methods, SW-846* (EPA 1997);
  - *EPA Requirements for Quality Assurance Project Plans* (EPA 2001) or other approved methods.
- Ensure that subcontractor laboratories providing data for environmental regulatory requirements provide a contract laboratory program type data reporting package. The data reporting package will be validated. Once issued, the validation report will be part of the test report. Results from the validation will also be incorporated into the regulatory petition(s) to be issued as part of the product qualification activity related to WTP contract Specification 2.2.2.20 requirements. Included in this report will be an assessment of "completeness" as defined by SW-846 (EPA 1997).
- Ensure that the subcontractor and supplier QAPs comply with the WTP project's QAM requirements. For all work, subcontractors are required to develop and follow a QAP approved by the WTP project and conform to the QA requirements imposed by the WTP project QAM. The subcontractor's QAP will implement QA requirements that consider all 18 elements and supplementary requirements, as applicable, of NQA-1. All elements of NQA-1 are considered when developing the subcontractor QAP and the WTP project's QAM. Audits and surveillances of subcontractor and supplier QAPs will be conducted and documented to assess conformance. The WTP project's test specifications and test plans state the applicable QA requirements and indicate how they will be met for any given development activity. A matrix of QA requirements cross referenced to implementing procedures applicable to the work will be provided with subcontractor test plans. The matrix will include justification for QA elements not implemented to substantiate the technically defensible graded approach to the application of QA requirements. The test plans will also include a list of applicable QA implementing procedures.

4.1.25.3 Production Implementation

During production operations, the applicable elements of the WTP project's QAM will be implemented for waste qualification activities, particularly requirements for inspection, testing, sampling, analysis, and documentation. The WTP project expects to conduct audits and surveillances of subcontractor and supplier QAPs to assess conformance with the WTP project's QAM requirements.

The production documentation will include a certification that the production process for the ILAW product meets all applicable QA requirements.

4.1.26 Inspection and Acceptance (Contract Specification 2.4)

> *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).*

4.1.26.1 Compliance Strategy

The WTP project's compliance strategy for this requirement is to document in the ILAW production documentation the information required in WTP contract Standard 6 and in this *ILAW Product Compliance Plan* to demonstrate that the ILAW product conforms to WTP contract requirements. The production documentation will summarize the detailed records generated for each ILAW product container. Table 4-2 summarizes the contents of the ILAW production records. The WTP project will also conform to the contractor certification program described in DOE Manual 435.1-1, Chapter IV, Section J.(1) (DOE 2001). Specific requirements and responsibilities for accomplishing the transfer of ILAW products to DOE-ORP for disposal are identified in *ICD 15 - Interface Control Document for Immobilized Low Activity Waste* (24590-WTP-ICD-MG-01-015).

4.1.26.2 Qualification Activities

During qualification, the WTP project will perform the specific qualification activities identified in the responses to each of the WTP contract Specification 2 requirements and document all information necessary to support certification of the product to specification requirements in the ILAW PQR. (D)

- Demonstrate, during commissioning, procedures and processes for implementing ILAW product inspection and acceptance. (D)

4.1.26.3 Production Implementation

During production operations, the WTP project expects to perform the following activities:

- Retain detailed records including procurement records, container number, materials certifications, calibrations, process measurements, sampling and analyses necessary to document the ILAW product.

- Provide production documentation that summarizes the results of analyses, tests, inspections, and demonstrations along with certification that the waste meets WTP contract requirements, and complies with all requirements of *ICD 15 - Interface Control Document for Immobilized Low Activity Waste* (24590-WTP-ICD-MG-01-015) for product transfer. (D)
- Develop corrective action plans for any nonconforming product and a plan to prevent recurrence. (D)
- Dispose of nonconforming waste products in accordance with the provisions of WTP contract Specification 13 and requirements of *ICD 15 - Interface Control Document for Immobilized Low Activity Waste* (24590-WTP-ICD-MG-01-015). (D)

The minimum requirements for acceptance of nonconforming ILAW by the DOE-ORP are identified in WTP contract Specification 13. WTP contract Specification 13 (DOE-ORP 2000) states:

> *In the event the product is identified as non-conforming, the product shall be segregated and a corrective action plan shall be prepared for DOE approval for the non-conforming product along with a plan to correct and prevent recurrence of the non-conforming condition. The Contracting Officer shall be notified within 24-hours after the Contractor has determined that a non-conforming product has been produced.*
>
> *If DOE agrees that the non-conforming condition cannot be reasonably corrected based upon the analysis of the non-conforming product presented in the corrective action plan, DOE will agree to take possession of the non-conforming product.*
>
> *In the event that the Contractor produces non-conforming waste during the commissioning activity, the non-conforming product will not be credited in determining the plant production capability.*

The WTP project will also participate in periodic audits by the receiving organization in accordance with requirements for low-level waste generators as described in DOE Manual 435.1-1, Chapter IV, section J (DOE 2001) of the WTP project's ILAW product certification program.

Table 4-1 Contract Specifications for ILAW Qualification and Characterization

Requirement	Qualification	Characterization	Product Specifications
Chemical and radiochemical composition	A, D, I, T	A, D, I, T	2.2.2.6 Chemical composition documentation 2.2.2.7 Radionuclide composition documentation 2.2.2.8 Radionuclide concentration limitations
Dangerous and hazardous wastes	A, D, I, T	A, D, I, T	2.2.2.20 Dangerous waste limitations 2.2.2.23 Manifesting
Waste loading	A, D, T	A, D, T	2.2.2.2 Waste loading
Waste form leaching and durability	A, T	A, T	2.2.2.17 Waste form leach testing
Waste form stability	A, D, T	D	2.2.2.18 Compressive strength 2.2.2.19 Thermal, radiation, biodegradation, and immersion stability
Free liquids, explosivity, pyrophoricity, organic materials, and gases	A, D, I	A, D, I	2.2.2.14 Free liquids 2.2.2.15 Pyrophoricity or explosivity 2.2.2.16 Explosive or toxic gases
Heat generation and surface temperature	A	A	2.2.2.13 External temperature
Dose rate	A	A, I	2.2.2.9 Surface dose rate limitations
Container dimensions	D, I	D, I	2.2.2.3 Size and configuration
Weight and mass	A, D, I	D, I	2.2.2.4 Mass
Void space and fill height	D	D, I	2.2.2.5 Void space
Container materials	D, I	D, I	2.2.2.1 Package description
Container mechanical strength	A, D, T	D	2.2.2.21 Compression testing 2.2.2.22 Container material degradation
Labeling	D, I	I	2.2.2.11 Labeling
Container handling features	D, I	D, I	2.2.3.1 Package handling
Container closure and sealing	D, I	D, I	2.2.2.12 Closure and sealing
Surface contamination	D	D, I	2.2.2.10 Surface contamination limitations

A = Analysis D = Demonstration I = Inspection T = Testing

Table 4-2 Content of ILAW Production Documentation

ILAW Contract Specification	Production Documentation Information
2.2.2.1, Package Description	Container number Container Material Receiving Report (MRR) number (provides container materials of construction) Lid number Lid MRR number (provides lid material of construction) Inert filler material MRR number (provides physical properties and chemical composition) Quantity of inert filler material added
2.2.2.2, Waste Loading	Identification of ILAW feed envelope Glass Formulation Algorithm output for: • Identification of metric tons of ILAW produced per metric ton of sodium feed • Calculated waste Na_2O loading in ILAW product
2.2.2.3, Size and Configuration	Container number Container MRR number (provides as-built measurements) Lid number Lid MRR number (provides as-built measurements)
2.2.2.4, Mass Limit	Reference calculation for container maximum mass
2.2.2.5, Void Space	Measured fill height of glass Calculated void space fraction Amount of inert filler added (if required)
2.2.2.6.2, Chemical Composition During Production	Container number Container MRR number (provides container materials of construction) Lid number Lid MRR number (provides lid material of construction) Inert filler material MRR number (chemical composition) Quantity of inert filler material added Glass Formulation Algorithm output for the chemical composition of ILAW glass as oxides as calculated from CRV samples and masses of GFCs added (for all elements > 0.5 wt% excluding oxygen)
2.2.2.6.3, Crystalline Phase Identification	Specification Deleted
2.2.2.7.2, Radionuclide Composition During Production	Glass Formulation Algorithm output for: • Inventories of reportable radionuclides in Ci per container based on CRV analyses indexed to the month of transfer to DOE and to 31 December 2002 • Running average concentration of reportable radionuclide inventories based on CRV analyses indexed to the month of transfer to DOE and to 31 December 2002
2.2.2.8, Radionuclide Concentration Limits	Glass Formulation Algorithm output for: • Inventories of reportable radionuclides in Ci per container based on CRV analyses indexed to the month of transfer to DOE and to 31 December 2002 • Running average concentration of reportable radionuclide inventories and comparison to ^{137}Cs, ^{90}Sr, ^{99}Tc, and TRU limits • Statement of compliance with limits

Table 4-2 Content of ILAW Production Documentation

ILAW Contract Specification	Production Documentation Information
2.2.2.9, Surface Dose Limitations	Measured dose rate from ILAW container
2.2.2.10, Surface Contamination Limitation	Swabbing results from each container
2.2.2.11, Labeling	Container number Container MRR number (provides container labeling specification) Lid number Lid MRR number (provides lid labeling specification)
2.2.2.12, Closure and Sealing	Certification of visual inspection of container closure
2.2.2.13, External Temperature	External temperature of each ILAW container measured prior to transfer to DOE
2.2.2.14, Free Liquids	Certification that container passed all in-process inspections for foreign materials before use and after filling
2.2.2.15, Pyrophoricity or Explosivity	Certification that container passed all in-process inspections for foreign materials before use and after filling
2.2.2.16, Explosive or Toxic Gas	Certification that container passed all in-process inspections for foreign materials before use and after filling
2.2.2.17, Waste Form Testing (PCT, VHT)	Glass Formulation Algorithm output for: • Chemical composition of ILAW glass as oxides as calculated from CRV samples and masses of GFCs added (for all elements > 0.5 wt% excluding oxygen) • Predicted PCT and VHT calculated from PCT and VHT glass property composition models
2.2.2.18, Compressive Strength	Results of compressive strength testing are reported in the ILAW PQR (24590-LAW-RPT-RT-05-001) and not required in the production documentation.
2.2.2.19, Thermal, Radiation, Biodegradation and Immersion Stability	Specification Deleted
2.2.2.20, Dangerous Waste Limitations	Reference approved ILAW LDR petition document number
2.2.2.21, Compression Testing	Reference container compressive strength calculation number (documented in ILAW PQR)
2.2.2.22, Container Material Degradation	Container number Container MRR number (provides container materials of construction) Lid number Lid MRR number (provides lid material of construction)

Table 4-2 Content of ILAW Production Documentation

ILAW Contract Specification	Production Documentation Information
2.2.2.23, Manifesting	Shipping manifest to include ILAW characterization documentation as required by DOE Manual 435.1-1, Chapter I.(2) (DOE 2001); NUREG/BR-0204 (NRC 1998); and Permit Condition II.Q of the *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage and Disposal of Dangerous Waste* (Ecology 2001) Confirmation that ILAW meets LDR requirements
2.2.3.1, Package Handling	Container number Container MRR number (provides container specifications) Lid number Lid MRR number (provides lid specifications)
2.3, Quality Assurance	Certification that the production process for the ILAW product meets all applicable QA requirements.
2.4, Inspection and Acceptance	Certification that the production process for the ILAW product meets all applicable QA requirements Certification of conformance to the Contractor Certification Program described in DOE Manual 435.1-1, Chapter IV, Section J.(1) (DOE 2001) Documentation as described for Specification 2 of the WTP Contract Corrective Action Plan for non-conforming product

5 References

5.1 Project Documents

24590-BOF-3PS-G000-T0007, Rev 5, *Engineering Specification for the Glass Former Storage Facility*.

24590-HLW-PL-RT-07-0001, Rev 3, *IHLW Waste Form Compliance Plan for the Hanford Tank Waste Treatment and Immobilization Plant.*

24590-HLW-RPT-ENS-08-002, Rev 0, *Design Basis Event Selection for the High-Level Waste Vitrification Facility Preliminary Safety Analysis Report*.

24590-HLW-RPT-RT-08-001 Rev 0, *Waste Form Qualification Report for Immobilized High Level Waste*.

24590-LAW-3PS-MV00-T0002, Rev 0, *River Protection Project - Waste Treatment Plant Engineering Specification for LAW Production Containers*.

24590-LAW-3YD-LFP-00001, Rev 3, *System Description for Low Activity Waste Melter Feed Process System (LFP)*.

24590-LAW-RPT-RT-04-0003, Rev 0, *Preliminary ILAW Formulation Algorithm Description*.

24590-LAW-RPT-RT-05-001, Rev 0, *ILAW Product Qualification Report for the Hanford Tank Waste Treatment and Immobilization Plant*.

24590-WTP-DB-ENG-01-001, Rev 1P, *Basis of Design*.

24590-WTP-DWPA-ENV-01-001, Rev 1, *WTP Dangerous Waste Permit Application*.

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Appendix A

Specification 2: Immobilized Low-Activity Waste per WTP Contract DE-AC27-01RV14136 (Modification 215)

Appendix A
Specification 2: Immobilized Low-Activity Waste per WTP Contract DE-AC27-01RV14136 (Modification 215)

(Specification 2 of the current Contract revision.)

WTP Contract | *Section C*
Contract No. DE-AC27-01RV14136 | *Modification No. 215*

Specification 2: Immobilized Low-Activity Waste Product

2.1 Scope: This Specification defines the requirements for the ILAW product, a final waste product. The ILAW product is a glass waste form for disposal on the Hanford Site.

2.2 Requirements:

2.2.1 References:

2.2.1.1 10 CFR 61. "Licensing Requirements for Land Disposal of Radioactive Waste." *Code of Federal Regulations.* U.S. Nuclear Regulatory Commission, Washington, D.C.

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2.2.1.14 NRC. January 1995. *Branch Technical Position on Concentration Averaging and Encapsulation*. Division of Waste Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C.

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2.2.1.17 SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

2.2.1.18 WA 7890008967. Revision 2. August 1995 (as modified). *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage and Disposal of Dangerous Waste at the Hanford Facility*. Washington State Department of Ecology, Olympia, Washington.

2.2.1.19 WAC 173-303. "Dangerous Waste Regulations." *Washington Administrative Code*, as amended.

2.2.1.20 Vitreous State Laboratory, 1998. *Glass Formulation and Testing with TWRS LAW Simulants*. The Catholic University of America, Washington, D.C.

2.2.2 Product Requirements:

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.

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 (wt%) based on Na_2O.

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.

2.2.2.4 Mass: The mass of each package shall not exceed 10,000 kilograms.

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.

2.2.2.6 Chemical Composition Documentation: The chemical composition of the waste form, filler, and package shall be identified.

2.2.2.6.1 DELETED

2.2.2.6.2 Chemical Composition During Production: The production documentation (Table C.5-1.1, Deliverable 6.7) shall provide the chemical composition of each waste form, optional filler, and package. The reported composition shall include elements (excluding oxygen) present in concentrations greater than 0.5 percent by weight and elements and compounds required to meet regulatory or Contract requirements.

2.2.2.6.3 DELETED

2.2.2.7 Radiological Composition Documentation: The radionuclide composition of the waste form shall be documented. Radionuclides shall be identified that are significant as defined in NUREG/BR-0204 and 49 CFR 172.101 (Table 2). Technetium-99 (^{99}Tc) shall be considered to be significant at concentrations greater than 0.003 Ci/m^3 in the ILAW form. The inventories shall be indexed to December 31, 2002. The documentation shall be consistent with the radiological description format described in NUREG/BR-0204.

2.2.2.7.1 Radionuclide Composition Qualification: The ILAW Product Qualification Report (Table C.5-1.1, Deliverable 6.6) shall identify the estimated radionuclide concentration in the waste form.

2.2.2.7.2 Radionuclide Composition During Production: The ILAW production documentation (Table C.5-1.1, Deliverable 6.7) shall identify the radionuclide inventory in each ILAW package produced. The actual inventory indexed at the month of product transfer and the inventory indexed to December 31, 2002, shall be reported.

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.

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.

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).

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.

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.

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.

2.2.2.14 Free Liquids: The package shall contain no detectable free liquids as defined in ANSI/ANS-55.1 or SW-846 Method 9095.

2.2.2.15 Pyrophoricity or Explosivity: The package contents shall not be pyrophoric, readily capable of detonation, or readily capable of explosive decomposition or reaction (including reaction with water) at normal pressure and temperature. The waste form and any optional filler materials shall not be ignitable or reactive as defined in WAC 173-303-090(5) and WAC 173-303-090(7).

2.2.2.16 Explosive or Toxic Gases: The package shall not contain or be capable of generating quantities of explosive (e.g., hydrogen) or toxic gases, vapors, or fumes harmful to persons handling the waste.

2.2.2.17 Waste Form Testing:

2.2.2.17.1 DELETED

2.2.2.17.2 Product Consistency Test: The normalized mass loss of sodium, silicon, and boron shall be measured using a seven day product consistency test run at 90°C as defined in ASTM C1285-98. The test shall be conducted with a glass to water ratio of 1 gram of glass (-100 +200 mesh) per 10 milliliters of water. The normalized mass loss shall be less than 2.0 grams/m^2. Qualification testing shall include glass samples subjected to representative waste form cooling curves. The product consistency test shall be conducted on waste form samples that are statistically representative of the production glass.

2.2.2.17.3 Vapor Hydration Test: The glass corrosion rate shall be measured using at least a seven (7)-day vapor hydration test run at 200°C as defined in the DOE-concurred upon ILAW Product Compliance Plan. The measured glass alteration rate shall be less than 50 grams/(m^2 day). Qualification testing shall include glass samples subjected to representative waste form cooling curves. The vapor hydration test shall be conducted on waste form samples that are representative of the production glass.

2.2.2.18 Compressive Strength: The mean compressive strength of the waste form shall be determined by testing representative non-radioactive samples.
The compressive strength shall be at least 3.45E6 Pa when tested in accordance with ASTM C39/C39M-99 or an equivalent testing method.

2.2.2.19 DELETED

2.2.2.19.1 DELETED

2.2.2.19.2 DELETED

2.2.2.19.3 DELETED

2.2.2.19.4 DELETED

2.2.2.20 Dangerous Waste Limitations: The ILAW product shall be acceptable for land disposal under the State of Washington *Dangerous Waste Regulations*, WAC 173-303, and RCRA LDR in 40 CFR 268.

2.2.2.21 Compression Testing: Each fully loaded package shall be able to withstand a compression load of five (5) times the weight of the filled container. Compliance with this specification shall be established by using the compression (stacking) test described in 49 CFR 173.465(d) or evaluated against this test by any of the methods authorized by 49 CFR 173.461(a). The integrity of the package shall be demonstrated by showing that the seal remains intact in accordance with Specification 2.2.2.12, *Closure and Sealing*.

2.2.2.22 Container Material Degradation: The container and handling appurtenances shall be designed to allow safe lifting and movement (in accordance with Specification 2.2.3.1) after a storage period of fifty (50) years.

2.2.2.23 Manifesting: A shipping manifest shall be prepared for delivery with each shipment of ILAW product. Information on the manifest shall satisfy the requirements in DOE Manual 435.1-1, Chapter IV, Section I.(2), and NUREG/BR-0204. Any package containing dangerous waste must be labeled and manifested in accordance with WAC 173-303-370 and the *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Wastes* (Permit No. WA 7890008967).

2.2.3 Handling Requirements:

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.

2.3 Quality Assurance: A QA Program (Table C.5-1.1, Deliverable 7.2) for ILAW Product development, qualification, characterization, and certification is required and shall be based upon NQA-1 (2000). The QA Plan shall address the QA/quality control requirements addressed in SW-846 and WAC 173-303-806. (M066)

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).

Appendix B

Facilities Description and Process Overview

Appendix B
Facilities Description and Process Overview

This appendix describes the WTP waste treatment and immobilization process for the Hanford tank low-activity waste (LAW), using the following elements:

- Description of the WTP in terms of the individual processing facilities
- WTP pretreatment process used to produce the LAW feed
- Vitrification process to produce the ILAW glass in the ILAW container

WTP LAW Treatment and Immobilization Facilities Description

The tank waste at Hanford was generated as a result of nuclear fuel reprocessing and related chemical separation processes. Five major separation processes were used between 1943 and 1989, when reprocessing was terminated. The resultant waste was blended and concentrated by evaporation to reduce the volume for storage in large (up to 1.1 million US gal [4,164 m^3]) underground storage tanks. The waste is stored in 28 double-shell tanks and some of the 149 older single-shell tanks at the Hanford Site. Acidic wastes generated from nuclear fuel reprocessing were neutralized with sodium hydroxide to allow storage in the underground carbon steel storage tanks. As a result, the waste consists primarily of precipitated metal hydroxides (sludge), alkaline salt solutions (supernate), and crystallized salts (saltcake). The total radioactivity in the waste is estimated to be about 128.3 million curies (Ci) in the tank solids and 70.1 million Ci in the tank liquids. Most of the radioactivity of the tank waste comes from ^{137}Cs and ^{90}Sr. The ^{137}Cs is soluble in the supernate, and ^{90}Sr is largely contained in the sludge.

The WTP site is located in the 200 East Area of the Hanford Site and occupies approximately 67 acres bounded by an existing grout vault facility to the west and electrical substations to the east. The site is approximately 680 ft above mean sea level, generally sloping from the southwest to the northeast. The principal WTP processing facilities are:

- Pretreatment facility
- LAW vitrification facility
- HLW vitrification facility
- Analytical laboratory
- Glass former storage facility

The major WTP facilities are described below, based on information in the *Preliminary Safety Analysis Report to Support Construction Authorization; LAW Facility Specific Information* (24590-WTP-PSAR-ESH-01-002-03); *Design Basis Event Selection for the High-Level Waste Vitrification Facility Preliminary Safety Analysis Report* (24590-HLW-RPT-ENS-08-002); *WTP Dangerous Waste Permit Application* (24590-WTP-DWPA-ENV-01-001); *Research and Technology Plan* (24590-WTP-PL-RT-01-002); *Preliminary Safety Analysis Report to Support Construction Authorization; HLW Facility Specific Information* (24590-WTP-PSAR-ESH-01-002-04); and the *Basis of Design* (24590-WTP-DB-ENG-01-001).

The pretreatment facility (PTF), LAW vitrification facility, analytical laboratory, and glass former storage facility are key WTP facilities for the treatment and immobilization of Hanford LAW. A brief description of each facility follows.

Pretreatment Facility

The PTF will receive waste feed from the DST farms. The PTF process cells will contain equipment to support the following activities:

- LAW and HLW waste receipt and storage (including primary waste feed receipt from the DST farms and recycle streams)
- LAW feed evaporation
- Sr/TRU precipitation from LAW (currently planned for Envelope C)
- Ultrafiltration and solids washing and leaching, as required, for LAW and HLW
- Cs removal by ion exchange and adsorption for LAW
- Evaporation of pretreated LAW and transfer to the LAW vitrification facility
- HLW feed blending and transfer to the HLW vitrification facility

The PTF also contains a process vessel ventilation system and a stack. Liquid effluents are either recycled back into the process or sent to the Hanford Site Liquid Effluent Retention Facility or 200 Area Effluent Treatment Facility.

LAW Vitrification Facility

The LAW vitrification facility includes remotely operated vitrification systems. The vitrification systems are composed of feed receipt and processing vessels; joule heated melters; offgas treatment equipment; liquid effluent tanks and equipment; and waste container handling, closure, and decontamination equipment. The LAW vitrification system will include locally shielded melters for ease of access for maintenance.

The LAW vitrification facility contains remotely operated equipment to perform the following:

- Store concentrated feed
- Blend waste and GFCs into slurry
- Vitrify the waste slurry
- Sample waste and glass product
- Complete ILAW container handling activities such as inert filling, closure and sealing, decontamination, storage, and inspection
- Export ILAW containers
- Change out melters
- Treat offgas
- Package secondary solid wastes
- Return liquid secondary wastes to the PTF

The LAW vitrification facility will house the vitrification system for the production of the ILAW. Figure B-1 shows a schematic of the LAW vitrification process. Appendix C provides detailed WTP process drawings. The LAW vitrification facility contains two LAW melters and supporting MFPVs and gaseous effluent treatment systems. LAW feed may be received from the LAW concentrate storage vessel in the PTF into one of two CRVs in the LAW vitrification facility. From the CRVs, the LAW is transferred to one of two melter feed preparation vessels where the GFC are added and blended with the LAW. This LAW melter feed is transferred to one of two MFVs and from the MFV to the melters. Molten LAW glass is poured into the ILAW containers, which are then cooled, closed, and decontaminated.

An ILAW container export area and truck bay will be located adjacent to the LAW vitrification facility. Within the export area, containers will be loaded into shipping containers provided by DOE for transport and subsequent ILAW disposal.

Analytical Laboratory

The analytical laboratory will provide and coordinate radiochemical and chemical analyses and waste characterization support to the LAW vitrification process for both process control and product compliance. The analytical laboratory will be a standalone building directly east of the PTF.

Samples will be pneumatically transferred from automated sampling devices in the pretreatment and LAW and HLW vitrification facilities to the appropriate high-activity or low-activity laboratory receipt area.

The analytical laboratory will have the capability for sample preparation, pH measurement, percent solids determination, sample digestion, organics extraction, solids separation, inductively coupled plasma atomic emission spectroscopy, inductively coupled plasma mass spectrometry, gas chromatography, particle sizing wet chemistry analysis, organic analysis, ion chromatography, gamma spectroscopy, liquid scintillation counting, standard methods for radioactive counting, and other analytical techniques.

Glass Former Storage Facility

The glass former storage facility will receive, store, weigh, blend, and transport glass former materials from the WTP receipt area to the LAW and HLW vitrification facilities. The facility will handle large quantities of dry chemicals (such as silica, alumina, and boric acid) used to make borosilicate glass. The facility will consist of a materials receipt area and a storage area with storage silos, weigh hoppers, transporters, blending silos, and blended glass former transporters.

The glass former handling system will also include the transport lines from the glass former storage facility to the LAW and HLW vitrification facilities and glass former mixers in the LAW and HLW vitrification facilities. The glass former storage facility is designed to transfer LAW GFC batches of 330 ft^3 to 470 ft^3 (9.3 m^3 to 13.3 m^3) and HLW GFC batches of 170 ft^3 to 320 ft^3 (4.8 m^3 to 9.1 m^3) (24590-BOF-3PS-G000-T0007).

Treatment and Immobilization Process Overview

This section summarizes the WTP process for treating the Hanford tank waste. The WTP pretreatment process will separate the tank wastes into a large-volume but low-radioactivity waste stream ("LAW"), and a small-volume but high-radioactivity HLW stream. The vitrification processes will combine LAW feed with GFCs and melt the respective HLW or LAW mixtures into glass melts that will be poured into stainless steel IHLW canisters or ILAW containers. After the hot glass cools, each container will be sealed in preparation for external surface decontamination and onsite interim storage for IHLW product and onsite disposal for ILAW product.

Pretreatment Process

The Hanford Tank Farm Contractor transfers waste from the waste tanks to the WTP pretreatment facility. LAW Envelopes A, B, and C are transferred to the WTP as solutions that contain some undissolved solids (Envelope D type waste or undesignated LAW precipitated salts). Envelope D wastes are transferred as a slurry of HLW undissolved solids to the WTP pretreatment facility. Appendix C depicts the pretreatment process. The pretreatment process is summarized below.

Low sodium concentration (< 5 molar) waste received from the tank farms and some low sodium concentration recycle streams from pretreatment and the HLW vitrification and LAW vitrification facilities are concentrated in the waste feed evaporator. Normally, the sodium concentration exiting the waste feed evaporator is about 5 molar sodium. However, other processing constraints (such as 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 go through the following separations processes.

LAW Envelopes A or B feeds are blended with HLW feeds (Envelope D) and adjusted in pH as required in an ultrafilter preparation tank. The ratio of LAW to HLW undissolved solids is established to support both LAW and HLW glass production rates. The blended HLW and LAW feed streams go through a filtration process that separates the LAW liquid stream (permeate) from the solids in the waste slurry. The HLW concentrated solids slurry is leached (if warranted) and then washed.

Envelope C feeds contain organic complexants that cause the ^{90}Sr and some TRU to remain in solution. This waste undergoes an Sr/TRU precipitation process before filtration. In the post-precipitation filtration step, the Sr/TRU solids, manganese oxide solids (a byproduct from the precipitation process), and any entrained solids are separated from the permeate (LAW stream). The Sr/TRU precipitates are washed and blended with HLW feed before HLW vitrification. The Sr/TRU precipitates are not leached.

The Envelope A, B, and C permeate plus a sodium stream from HLW pretreatment is filtered and then undergoes ion exchange to remove Cs. The Cs eluate is concentrated by evaporation and then blended with pretreated HLW solids and solids from Sr/TRU precipitation before transfer to the HLW vitrification process.

The LAW effluent from the cesium ion exchange column is then concentrated by evaporation and is stored in the LAW concentrate storage vessel, a 93,000 gallon (352 m^3) capacity tank in the PTF, until it is transferred to the LAW vitrification facility for immobilization.

LAW Vitrification Process

Appendix C shows the LAW vitrification process. The following description and the Appendix C figures are consistent with *Flowsheet Bases, Assumptions, and Requirements* (24590-WTP-RPT-PT-02-005) plus subsequently approved changes (Trends) to the baseline configuration.

Envelope A, B, and C supernatants from pretreatment go to LAW vitrification for processing. The LAW vitrification process equipment includes two melter systems operated in parallel. Each melter system has a set of MFPVs, a joule heated ceramic melter, and a primary 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.

LAW feeds are received into one of two common LAW CRVs inside the LAW vitrification facility. A typical CRV batch is approximately 8600 gallons (32.6 m^3). Batches of concentrated LAW feed are sampled and transferred from the CRVs to MFPVs, where GFCs and sucrose are added and blended to form a uniform batch of feed to the LAW melters. There are four MFPV batches per CRV batch; a typical MFPV batch after GFC addition is approximately 3300 gallons (12.5 m^3). The slurry feed is transferred to the MFVs, where it is fed continuously to the LAW melters.

Each LAW melter is designed with a nameplate production rate of 15 metric tons per day (15,000 kg per day) of ILAW and to operate at a temperature between 1050 °C and 1200 °C. The feed enters the melter from the top and forms a cold cap above 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 and are dissolved in the glass melt. Bubblers agitate the mixture to increase the glass production rate. An airlift system pours the molten glass through an overflow from the melter into stainless steel containers. Each container holds about 6 metric tons (6,000 kg) 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 and recycled to the treated LAW evaporator in the PTF. 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, destroys organics, reduces NO_x, and removes halides and mercury to meet offgas discharge requirements. This is done by using high efficiency particulate air filters, activated carbon beds, a catalytic oxidizer, a selective catalytic reducer, and a caustic scrubber.

After the ILAW container is filled and removed from the pour cave, a lid is sealed to the top of the container, and the container is allowed to cool. Before sealing, the product glass in the container can be sampled and inert filler added. Use of inert filler may be required to ensure that WTP contract requirements for less than 10 % void space are achieved. External contamination is removed by a CO_2 pellet spray decontamination process to comply with the radioactive surface decontamination requirement.

Each container will have a permanently affixed unique alphanumeric identifier, which will be referenced in all of the documentation associated with the container and the containerized waste form. Each container will be fabricated according to a container fabrication specification and will be inspected to confirm that the requirements of the specification have been met. Appendix D presents drawings of the current ILAW container design.

Figure B-1 Simplified Diagram of the LAW Treatment Process

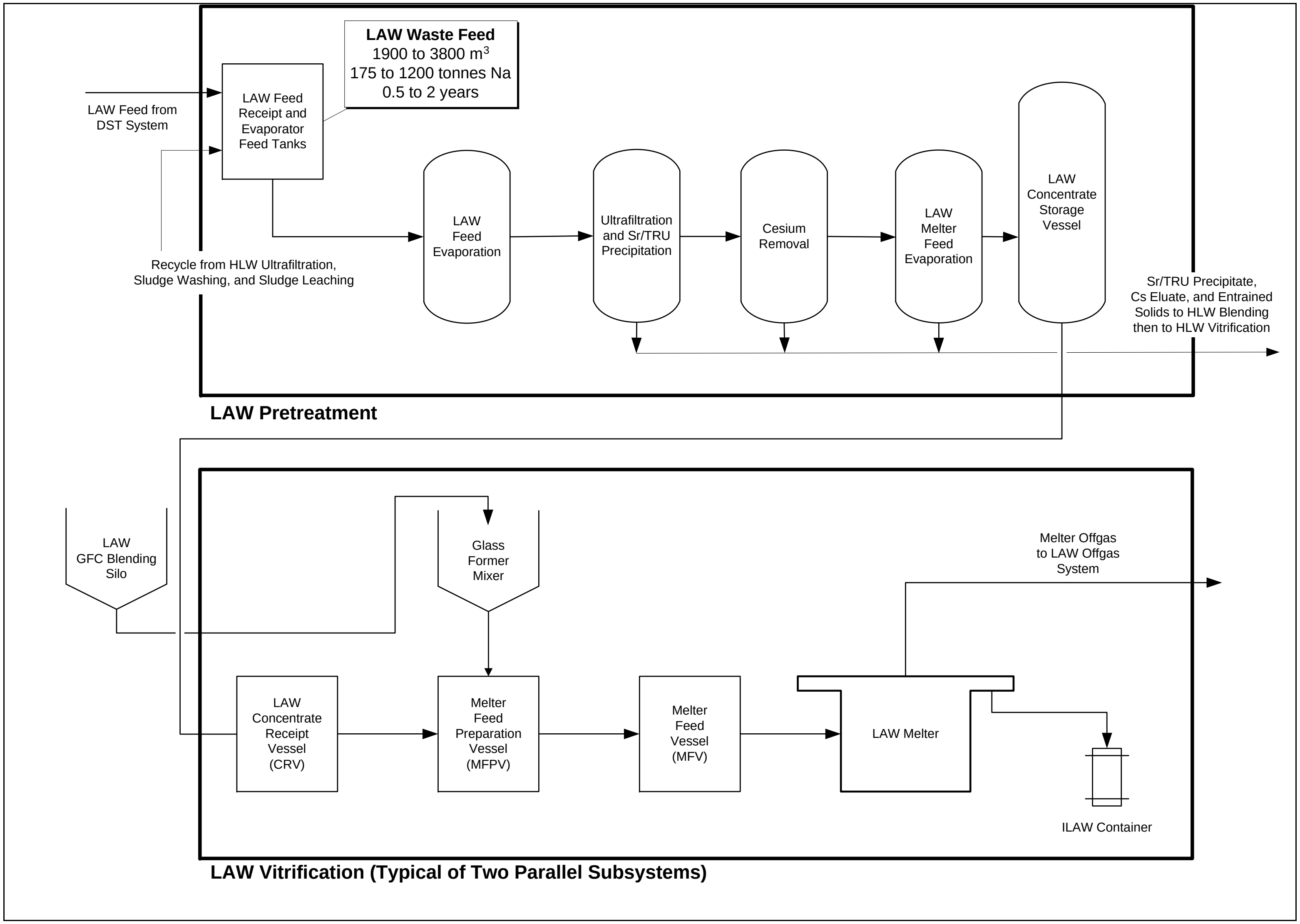
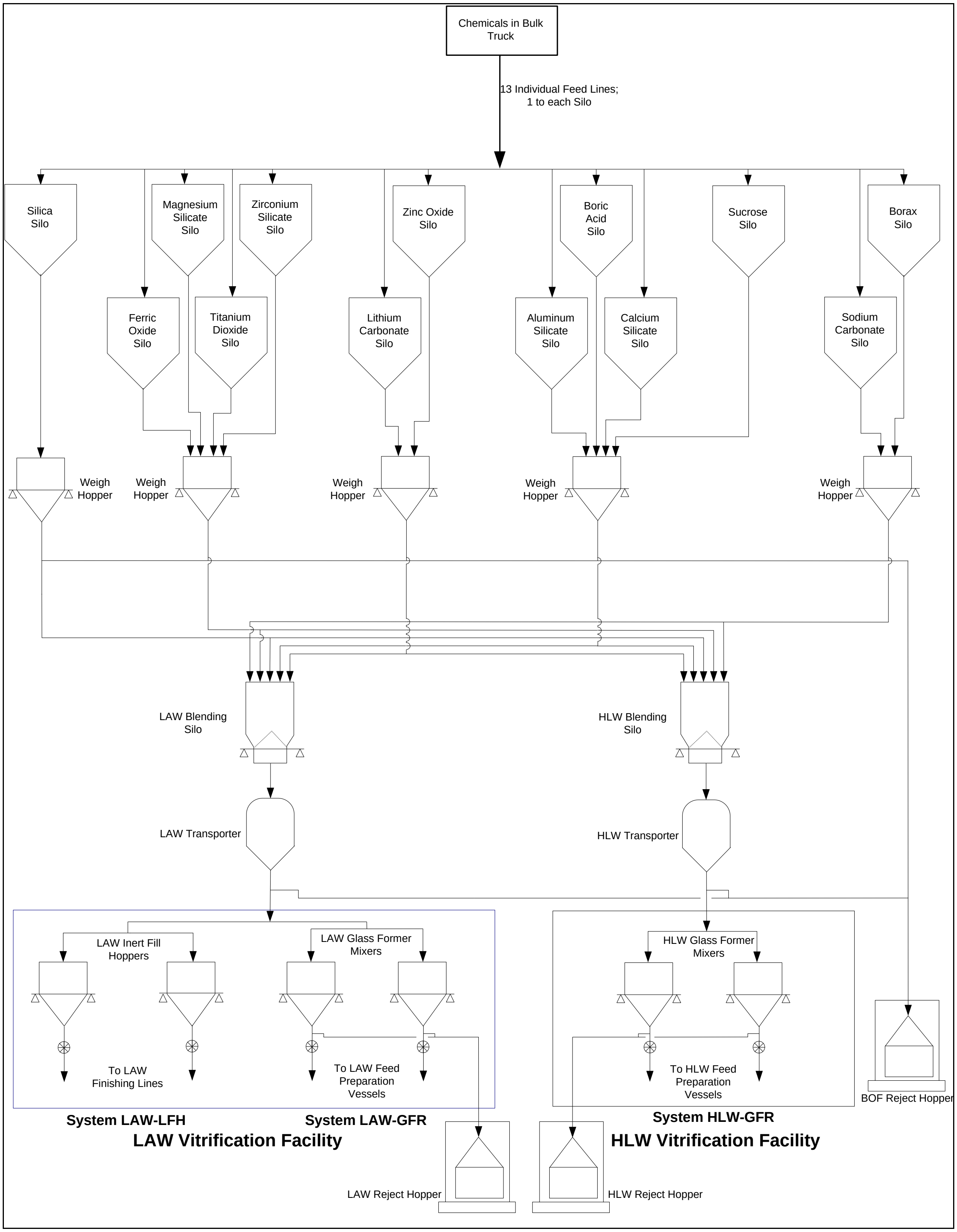


Figure B-2 Glass Former Storage Facility Flow Diagram



Appendix C

Process Overview Figures

Appendix C
Process Overview Figures

Figure C-1 Pretreatment Process Overview

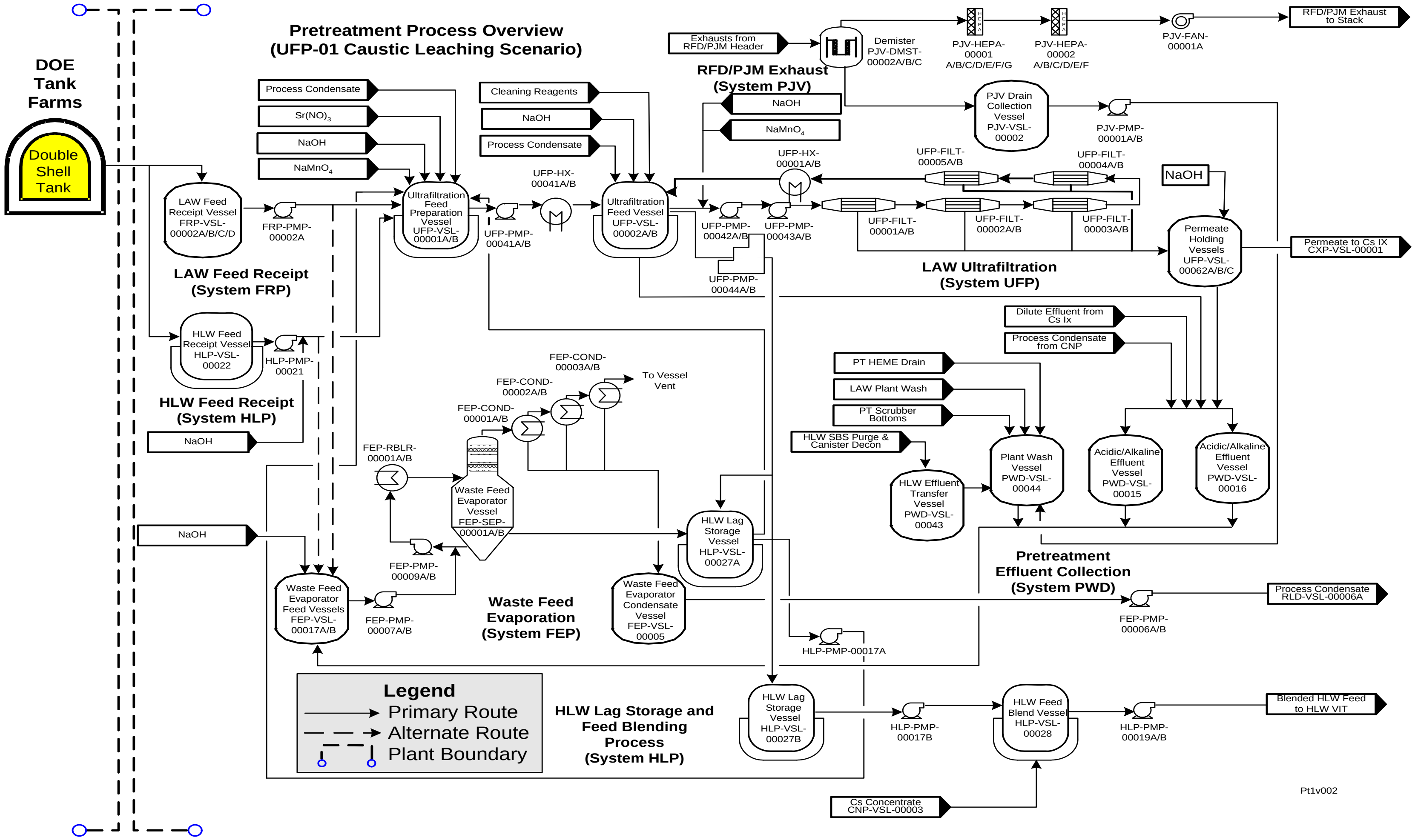


Figure C-1 Pretreatment Process Overview (continued)

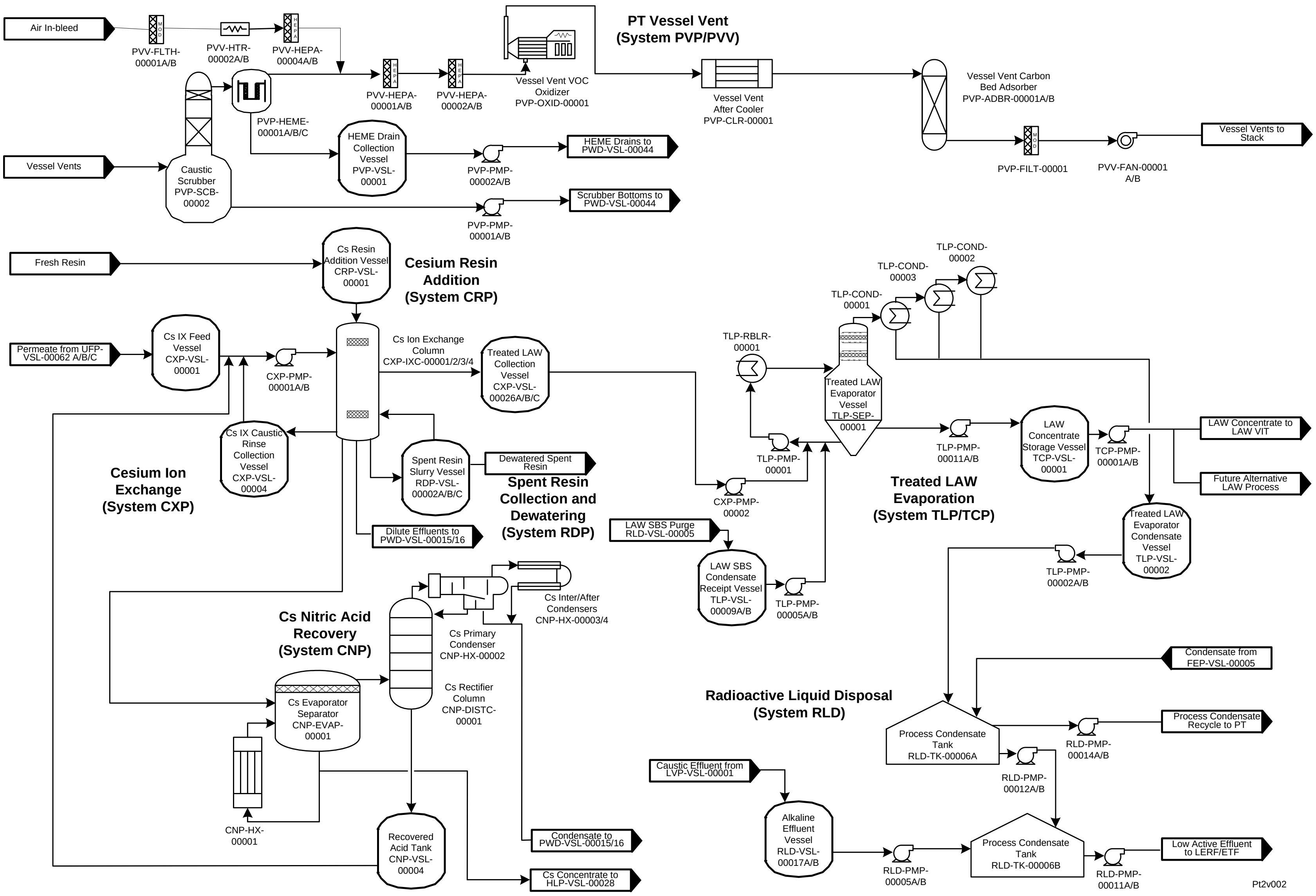
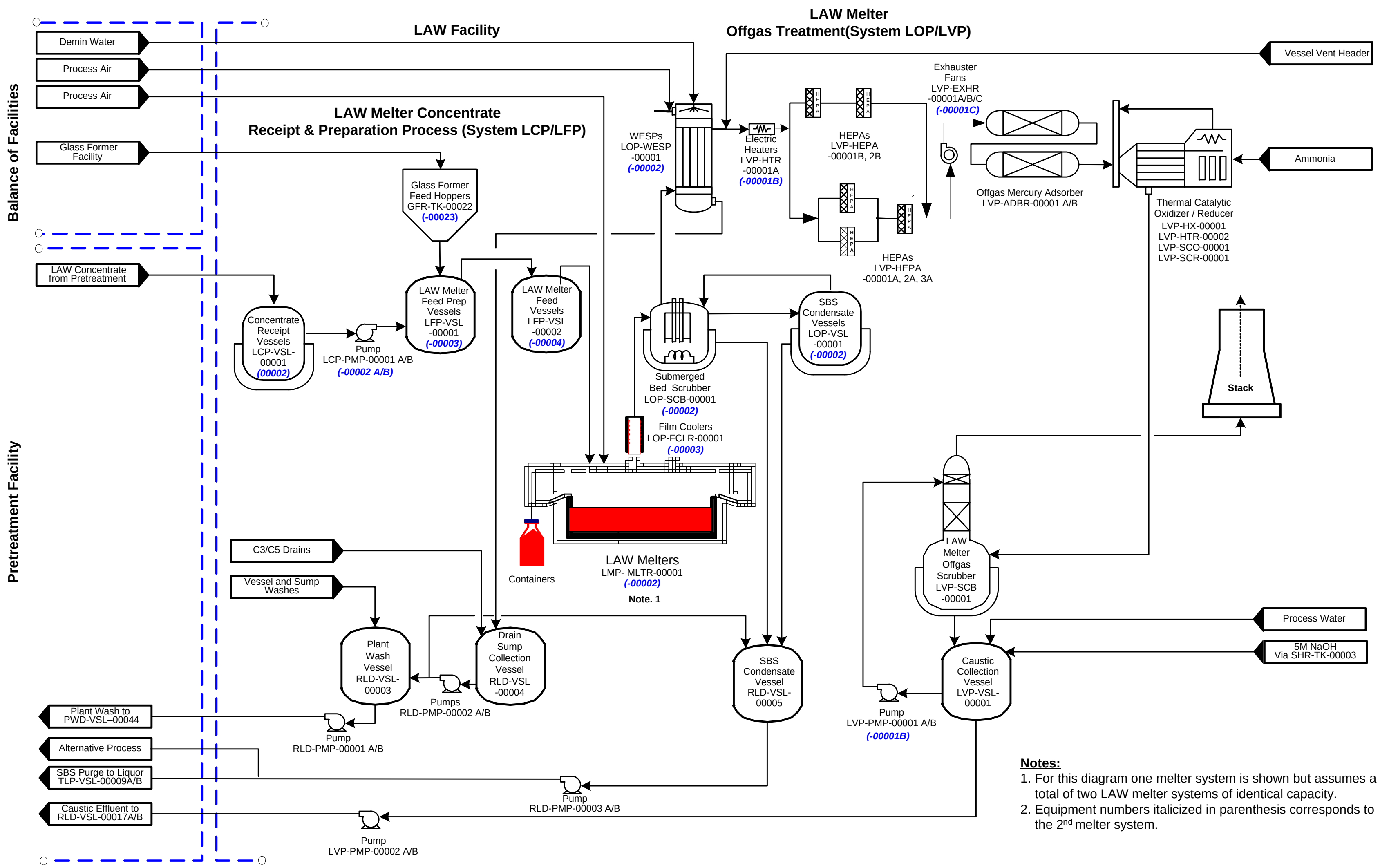


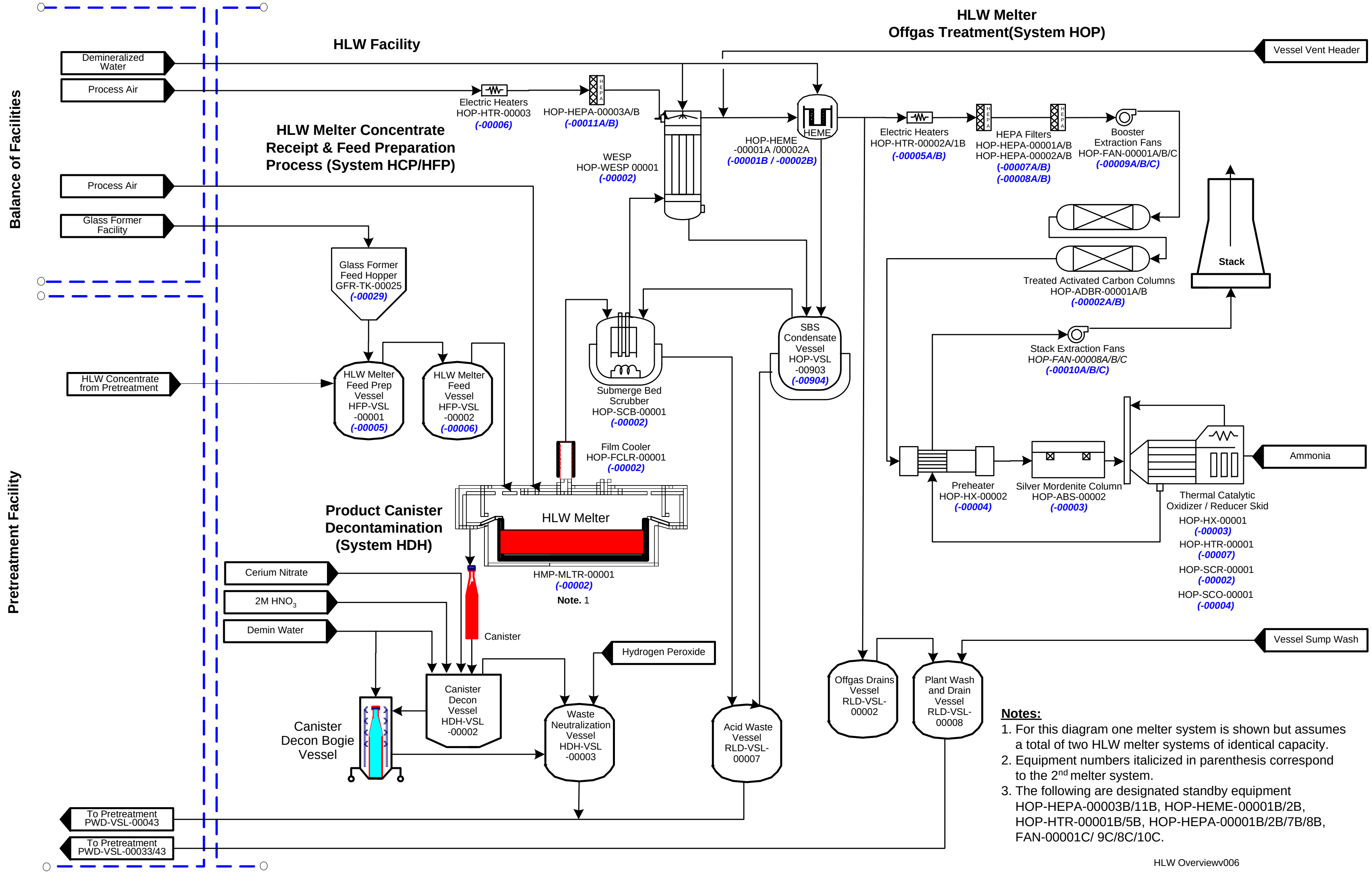
Figure C-2 LAW Vitrification Process Overview



Notes:

1. For this diagram one melter system is shown but assumes a total of two LAW melter systems of identical capacity.
2. Equipment numbers italicized in parenthesis corresponds to the 2nd melter system.

Figure C-3 HLW Vitrification Process Overview



Notes:

1. For this diagram one melter system is shown but assumes a total of two HLW melter systems of identical capacity.
2. Equipment numbers italicized in parenthesis correspond to the 2nd melter system.
3. The following are designated standby equipment HOP-HEPA-00003B/11B, HOP-HEME-00001B/2B, HOP-HTR-00001B/5B, HOP-HEPA-00001B/2B/7B/8B, FAN-00001C/ 9C/8C/10C.

HLW Overviewv006

Appendix D

Container Drawings

Appendix D
Container Drawings

Document Number	Revision	Document Title
24590-LAW-M0-LRH-00004001	2	LAW Vitrification System LRH Product Container Assembly
24590-LAW-M0-LRH-00004002	2	LAW Vitrification System LRH Product Container Weldment Details
24590-LAW-M0-LRH-00004003	0	LAW Vitrification System LRH Product Container Details
24590-LAW-M0-LRH-00004004	1	LAW Vitrification System LRH Product Container Details

Figure D-1 LAW Vitrification System LRH Product Container Assembly

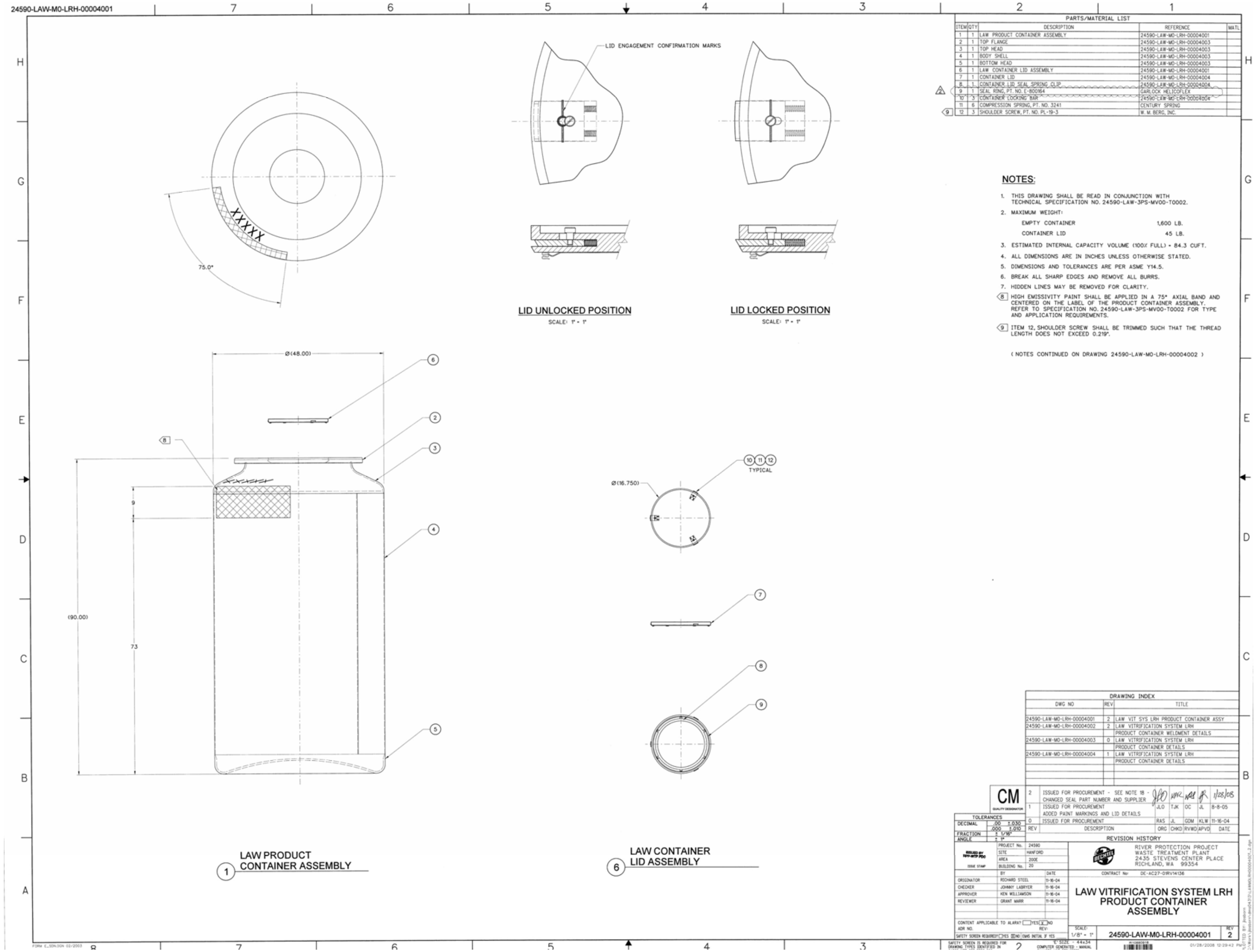


Figure D-2 LAW Vitrification System LRH Product Container Weldment Details

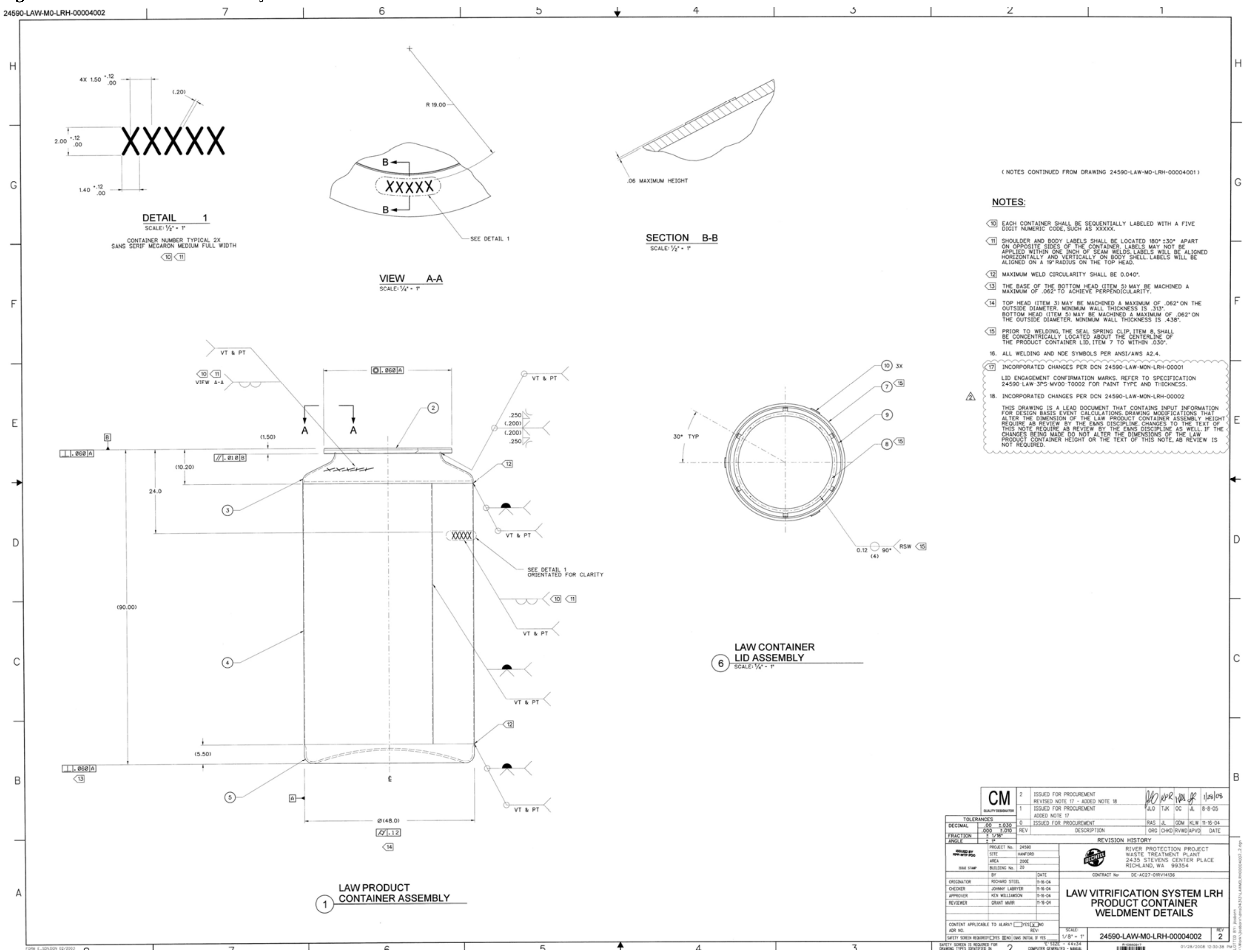


Figure D-3 LAW Vitrification System LRH Product Container Details

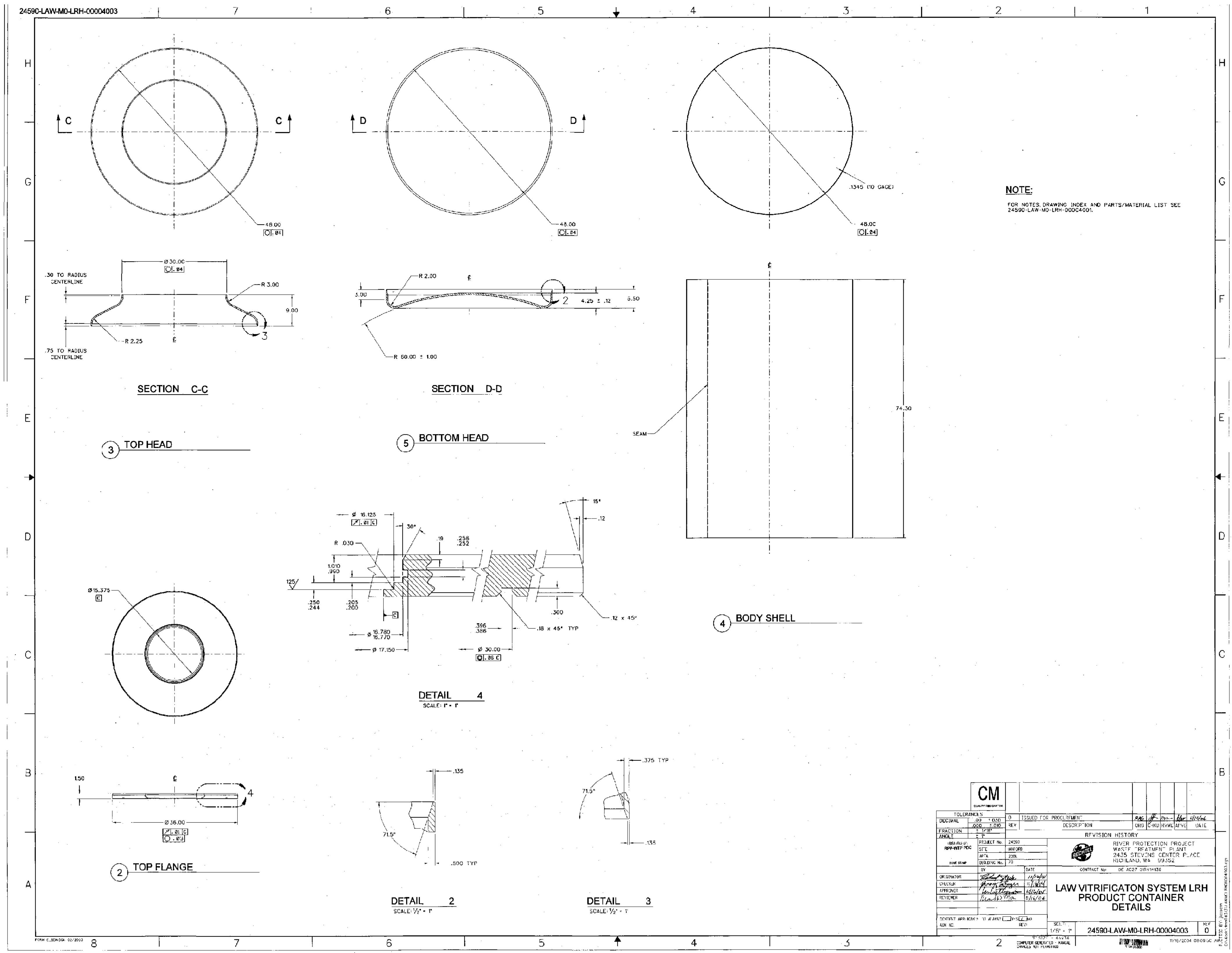
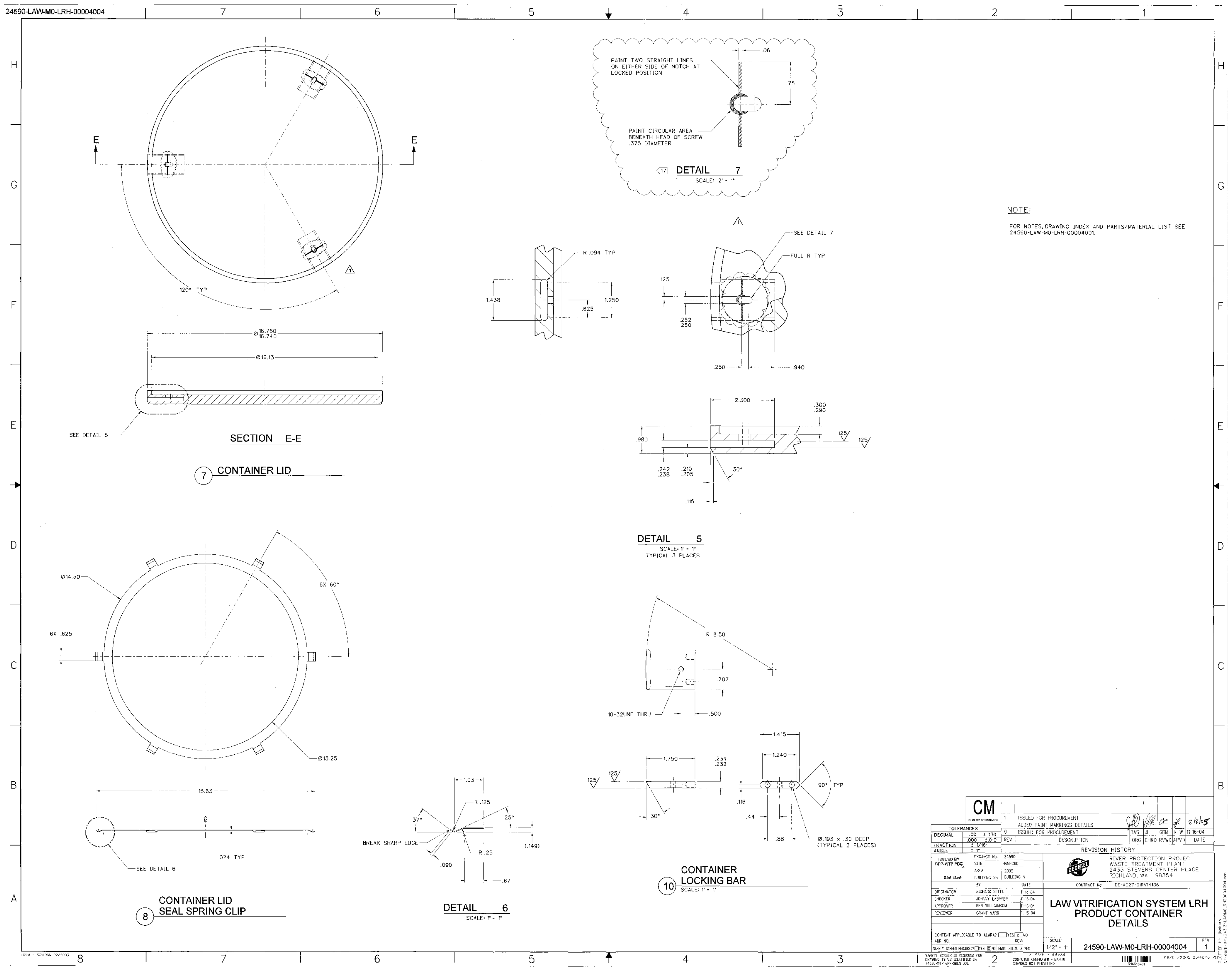


Figure D-4 LAW Vitrification System LRH Product Container Details



Appendix E

Example Chemical and Physical Properties for Low-Activity Waste and Immobilized Low-Activity Waste

Appendix E
Example Chemical and Physical Properties for Low-Activity Waste and Immobilized Low-Activity Waste

Table E-1 Example Chemical Compositions of Pretreated Envelope A, B, and C LAW

	Envelope A	Envelope B	Envelope C
Tank	AP-101	AZ-101	AN-107
Chemical Species	mg/L	mg/L	mg/L
Al	6310	5280	768
As	-	13.5	<6.8
B	84.3	7.75	1.2
Ba	-	<0.20	109
Ca	-	<5.0	886
Cd	-	-	22.2
Cr	130	569.5	6.4
Cu	-	-	10.6
Fe	-	<0.50	2.8
Hg	-	0.0116	-
K	2390	3800	751
Mo	-	85.3	13.3
Na	111500	99000	94675
P	-	482	42.5
Pb	-	6.65	22.3
Si	-	52.5	<13.6
Sn	-	44	<40.8
Sr	-	<0.30	7.0
Ti	-	2.55	<0.68
V	-	1.35	<1.36
W	-	51	58
Zn	-	1.65	4.4
Zr	-	1.95	<1.36
Ion Chromatography	mg/L	mg/L	mg/L
Br	-	685	<500
Cl	1380	<130	<500
F	2240	1900	3000
NO2	34000	61900	29550
NO3	96200	52950	173000
C2O4	968	1000	<1000
PO4	883	1600	<1000
SO4	2480	16500	970
TIC	-	6380	2070
TOC	-	345	13100
NH3	-	4.11	6.5
Source	Smith et al. 2004b	Smith et al. 2004a	Smith et al. 2000

Significant figures reproduced as reported.

Table E-2 Example Radionuclide Compositions for Pretreated Envelope A, B, and C LAW

	Envelope A	**Envelope B**	**Envelope C**
Tank	AP-101	AZ-101	AN-107
Isotope	mCi/L	mCi/L	mCi/L
3H	3.19E-3	3.24E-2	-
14C	4.71E-4	1.92E-3	-
51Cr	<7.0E-5	<4E-4	-
59Fe	<2.0E-5	<2E-5	-
60Co	2.05E-3	1.68E-5	3.96E-2
63Ni	2.07E-3	-	-
79Se	9.0E-6	1.40E-4	<2E-6
88Y	<1.0E-5	<1E-5	<2.4E-4
90Sr	5.38E-2	1.60E-1	2.43E-3
95Nb	<8.0E-6	9.33E-4	1.09E-3
99Tc	3.42E-4	9.33E-4	4.90E-2
103Ru	<8.0E-6	<5E-5	-
106RuRh	6.0E-4	-<3E-4	-
113Sn	<1.0E-5	<7E-5	5.59E-5
125Sb	1.26E-3	9.98E-3	<8.4E-5
126SnSb	2.2E-4	2.23E-3	<3.6E-5
134Cs	<9.0E-6	<2E-5	-
137Cs	8.0E-5	3.56E-2	7.33E-2
144Ce	<6.0E-5	<3E-4	-
151Sm	7.79E-4	6.04E-5	-
152Eu	<2.0E-5	<2E-5	-
154Eu	5.22E-5	<2E-5	3.10E-3
155Eu	2.57E-5	<2E-4	2.17E-3
232Th	<2.0E-5	<8E-5	-
236Pu	<4.0E-8	<6E-8	-
237Np	-	-	1.22E-5
238Pu	2.4E-6	1.07E-6	-
239Pu	1.74E-5	9.25E-6	3.88E-4
239Pu + 240Pu	-	-	-
241Pu	1.14E-4	5.24E-5	-
241Am	1.01E-4	6.75E-7	1.35E-3
242Cm	7.8E-8	<5E-8	-
243Cm + 244Cm	8.3E-7	<1E-7	-
Total Alpha	7.51E-5	-	<2E-3
Total U	1.09 mg/L	-	2.9 mg/L
Source	Smith et al. 2004b	Smith et al. 2004a	Smith et al. 2000

Significant figures reproduced as reported.

Table E-3 Example LAW Glasses for Envelope A, B, and C Wastes

Sub-Envelope	A1	A2	A2	A3	B1	B2	C1	C2
Tank	AN-103 AN-105 AP-104 / SY-101	AW-101	AP-101	AN-104	AZ-101	AZ-102	AN-107	AN-102
Na_2O wt%[a]	20 %	20 %	18.5 %	14.5 % 14.6 %	5.5 %	5.0 % 5.5 %	14.4 %	12 %
K_2O wt%	0.4 %	2 %	3.9 %	0.26 % 0.33 %	0.2 %	0.2 % 0.12 %	0.1 %	0.14 % 0.09 %
SO_3 wt%	0.2 %	0.2 %	0.4 %	0.35 % 0.37 %	0.65 %	0.8 % 0.65 %	0.3 %	0.47 % 0.63 %
Glass Selected	LAWA44	LAWA88	LAWA126	LAWA102 LAWA137	LAWB83	LAWB88 LAWB96	LAWC22	LAWC31 LAWC35

Data from Muller and Pegg 2003a, Muller and Pegg 2004

a The WTP contract requires a minimum Na_2O loading of 14 wt% for Envelope A, 3 wt% for Envelope B, and 10 wt% for Envelope C glasses. Significant figures reproduced as reported.

Table E-4 Typical Components in Envelope A ILAW Glass Formulations

Source Tanks	**SY-101 / AP-104** (Muller and Pegg 2003e)			**AP-101** (Muller and Pegg 2003b)			**AN-104** (Muller et al. 2004)		
ID	Waste	GFCs	LAWA44 (glass)	Waste	GFCs	LAWA126 (glass)	Waste	GFCs	LAWA137 (glass)
Loading	24.31 %	75.69 %		24.68 %	75.31 %		20.15 %	79.85 %	
Primary Components (Oxide wt%)									
Al_2O_3	2.53	3.65	6.17	1.35	4.30	5.65	3.42	2.63	6.05
B_2O_3	0.02	8.86	8.87	0.01	9.84	9.85	0.19	9.72	9.91
CaO	0.03	1.95	1.98	-	1.99	2.00	-	5.03	5.03
Cl	0.57	-	0.57	0.20	-	0.20	0.76	-	0.76
Cr_2O_3	0.07	-	0.07	0.02	-	0.02	0.03	-	0.03
F	0.22	-	0.22	0.30	-	0.30	0.02	-	0.02
Fe_2O_3	-	6.96	6.96	-	5.56	5.56	-	5.36	5.36
K_2O	0.26	-	0.26	3.88	-	3.88	0.62	-	0.62
Li_2O	-	-	-	-	-	-	0.01	2.46	2.48
MgO	-	1.97	1.97	-	1.48	1.48	-	1.48	1.48
MoO_3	-	-	-	-	-	-	0.01	-	0.01
Na_2O	20.00	-	20.000	18.46	-	18.46	14.64	-	14.64
P_2O_5	0.35	-	0.35	0.08	-	0.08	0.11	-	0.11
SiO_2	0.02	44.43	44.45	0.03	44.18	44.22	0.07	46.00	46.07
SO_3	0.25	-	0.25	0.35	-	0.35	0.28	-	0.28
TiO_2	-	1.97	1.97	-	2.00	2.00	-	1.13	1.13
ZnO	-	2.91	2.91	-	2.96	2.96	-	3.04	3.04
ZrO	-	2.99	2.99	-	3.00	3.00	-	3.00	3.00
Total	24.31	75.69	100.00	24.68	75.31	100.00	20.15	79.85	100.00

Significant figures reproduced as reported.

Table E-5 Typical Components in Envelope B ILAW Glass Formulations

Source Tanks	**AZ 101** (Muller and Pegg 2003d)			**AZ-102** (Muller and Pegg 2003c)		
ID	Waste	GFCs	LAWB83 (glass)	Waste	GFCs	LAWB88 (glass)
Loading	6.68 %	93.32 %		6.28 %	93.72 %	
Primary Components (Oxide wt%)						
Al_2O_3	0.40	5.80	6.21	0.06	6.42	6.48
B_2O_3	-	10.04	10.04	-	12.98	12.98
CaO	-	6.78	6.78	-	7.97	7.97
Cl	-	-	-	0.01	-	0.01
Cr_2O_3	0.03	-	0.03	0.06	-	0.06
F	0.07	-	0.07	0.05	-	0.05
Fe_2O_3	-	5.29	5.29	-	2.20	2.20
K_2O	0.18	-	0.18	0.21	-	0.21
Li_2O	-	4.31	4.31	-	4.69	4.69
MgO	-	2.99	2.99	-	1.41	1.41
MoO_3	0.01	-	0.01	-	-	-
Na_2O	5.37	-	5.37	5.00	-	5.00
P_2O_5	0.05	-	0.05	-	-	-
SiO_2	0.01	48.67	48.68	0.01	50.00	50.01
SO_3	0.55	-	0.55	0.85	-	0.85
TiO_2	-	1.40	1.40	-	-	-
ZnO	-	4.85	4.85	-	4.87	4.87
ZrO	-	3.17	3.17	-	3.19	3.19
Total	6.68	93.32	100.00	6.28	93.72	100.00

Significant figures reproduced as reported.

Table E-6 Typical Components in Envelope C ILAW Glass Formulations

Source Tanks	**AN-107 Waste** (Muller et al. 2001)			**AN-102** (Muller and Pegg 2004)		
ID	Waste	GFCs	LAWC22 (glass)	Waste	GFCs	LAWC35 (glass)
Loading	16.25 %	83.75 %		13.95 %	86.05 %	
Primary Components (Oxide wt%)						
Al_2O_3	0.6289	5.45	6.0800	0.89	5.18	6.07
B_2O_3	0.0000	10.07	10.0679	-	9.42	9.42
BaO	0.0000	-	0.0000	-	-	-
Bi_2O_3	0.0029	-	0.0029	-	-	-
CaO	0.0384	5.08	5.1172	0.03	7.32	7.35
CdO	0.0000	-	0.0000	-	-	-
Cl	0.0897	-	0.0897	0.39	-	0.39
Cr_2O_3	0.0213	-	0.0213	0.01	-	0.01
Cs_2O	0.0006	-	0.0006	0.15 (spike)	-	0.15 (spike)
F	0.1617	-	0.1617	0.11	-	0.11
Fe_2O_3	0.1925	5.24	5.4307	0.01	3.59	3.60
K_2O	0.0949	-	0.0949	0.09	-	0.09
La_2O_3	0.0019	-	0.0019	-	-	-
Li_2O	0.0000	2.51	2.5050	-	3.25	3.25
MgO	0.0000	1.51	1.5132	-	1.49	1.49
MnO_2	0.0367	-	0.0367	-	-	-
Na_2O	14.4000	-	14.4000	11.97	-	11.97
NiO	0.0301	-	0.0301	-	-	-
PbO	0.0206	-	0.0206	-	-	-
P_2O_5	0.1739	-	0.1739	0.16	-	0.16
SiO_2	0.0069	46.66	46.6670	0.01	47.23	47.24
SO_3	0.3407	-	0.3407	0.63	-	0.63
SrO	0.0004	-	0.0004	-	-	-
TiO_2	0.0000	1.14	1.1433	-	1.08	-
UO_2	0.0038	-	0.0038	-	-	-
ZnO	0.0000	3.07	3.0694	-	3.99	3.99
ZrO	0.0064	3.02	3.0268	-	3.00	3.00
Total	16.2526	83.7474	100.00	14.45	85.55	100.00

NA = not analyzed
Data from Muller 2001. Significant figures reproduced as reported.

Table E-7 Example Radionuclide Concentrations in Envelope A, B, and C LAW Glasses

	Envelope A	Envelope B	Envelope C	
Tank	AP-101	AZ-101	AN-107	
Glass	LAWA126	LAWB83	LAWC15	
Waste Loading (wt% Na)	18.5 %	5.5 %	14.4 %	Specification Limit
Isotope	Ci/m^3	Ci/m^3	Ci/m^3	Ci/m^3
60Co	6.35E-3	1.71E-5	1.66E-1	-
63Ni	6.43E-3	1.24E-4	-	<700
90Sr	1.67E-1	1.63E-1	1.01E-2	<20
95Nb	-	-	4.54E-3	-
99Tc	-	-	2.05E-1	<3.0
106RuRh	1.86E-3	-	-	-
113Sn	-	-	8.74E-5	-
125Sb	3.90E-3	1.01E-2	-	-
126SnSb	6.83E-4	2.26E-3	-	-
137Cs	2.47E-4	3.6E-2	3.07E-1	<0.3, <3.0 [a]
151Sm	2.42E-3	3.43E-5	-	-
154Eu	-	-	1.29E-2	-
155Eu	-	-	9.05E-3	-
237Np	-	-	5.10E-5	-
238Pu	7.53E-6	1.09E-6	-	-
239Pu	5.38E-5	9.41E-6	1.62E-3	-
241Pu	-	5.31E-5	-	-
241Am	3.12E-4	6.85E-7	5.63E-3	-
Total Alpha, nCi/g	0.087	<0.46	2.88	<100
Source	Smith et al. 2004b	Smith et al. 2004a	Smith et al. 2000	

a WTP contract specification 2.2.2.8, Radionuclide Concentration Limitations, sets a maximum ^{137}Cs concentration of 3 Ci/m^3. WTP contract standard C.7, Facility Specification, section (d)(1)(iii) Cs Removal, sets a ^{137}Cs concentration limit of 0.3 Ci/m^3 to facilitate the maintenance concept established for the ILAW melter system. Significant figures reproduced as reported.

Table E-8 Compressive Strength (MPa) Measurements for LAW Glasses

	LAWA44	LAWA102	LAWB45	LAWC21
Waste Simulant	AN-103 / AN-105	AN-104	AZ-101 / AZ-102	AN-102
Maximum	899.6 MPa	61 MPa	533.2 MPa	854.7 MPa
Minimum	32.5 MPa	39.5 MPa	27 MPa	44.9 MPa
# of Measurements	34	5	5	5

Data from Muller et al. 2001. Significant figures reproduced as reported.

Table E-9 Processing and Product Compliance Properties of Representative LAW Glasses

Sub-Envelope	**A1**	**A2**	**A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Tank	AN-105	AW-101	AP-101	AN-104	AZ-101	AZ-102	AN-107	AN-102
Formulation	LAWA44	LAWA88	LAWA126	LAWA102	LAWB83	LAWB96	LAWC22	LAWC31
Waste Loading, wt% Na_2O	20	20	18.5	14.5	5.5	~3	14.4	12.0
Density, g/cm^3	2.67	2.69	2.69	2.61	2.75	-	2.67	2.71
Glass Transition, °C	511	494	496	476	500	-	481	464
Liquidus (<950 °C)	<850	<850	<850	<850	<750	-	<750	<750
Viscosity (10-150P at 1100 °C)	114	96	104	114	90	79	60	117
Electrical Conductivity (0.1-0.7 S/cm at 1100 °C)	0.435	0.472	0.327	0.435	0.175	0.12	0.378	0.223
PCT (contract limit <2.0 g/m^2)	0.371 B 0.358 Na 0.164 Si	0.434 B 0.426 Na 0.171 Si	0.528 B 0.524 Na 0.166 Si	0.275 B 0.222 Na 0.164 Si	0.306 B 0.263 Na 0.115 Si	0.28 B 0.28 Na 0.12 Si	0.518 B 0.469 Na 0.181 Si	0.275 B 0.313 Na 0.120 Si
VHT (contract limit <50 g/(m^2 •d))	1.0	1.3	2.5	9.6	1.8	-	1.0	12

Data from Muller and Pegg 2003a, Muller and Pegg 2004. Significant figures reproduced as reported.

Table E-10 TCLP Results for Example ILAW Glasses from Actual Waste Glasses

Sub-Envelope	**A1**	**A2**	**A2**	**B1**	**B2**	**C1**	**C2**	
Tank	AN-103	AW-101	AP-101	AZ-101	AZ-102	AN-107	AN-102	UTS Limit[c]
Formulation	LAWA44	LAWA88	LAWA126	LAWB83	LAWB88	LAWC15	LAWC21	mg/L
Ag [a]	< 0.00459	0.0011	<0.005	<0.004	<0.06	0.0011	< 0.041	0.14
As [a]	< 0.020	<0.006	<0.036	<0.045	<0.03	0.010	< 0.005	5
Ba [a]	2.46	0.043	0.32	0.24	0.23	0.04	3	21
Be	<0.000889	<0.0005	<0.0002	<0.0002	<0.002	<0.0005	<0.002	1.22
Cd [a]	< 0.00133	<0.0003	<0.0038	<0.006	<0.02	0.013	<0.012	0.11
Cr [a]	0.00844	0.14	0.007	0.008	<0.08	0.44	<0.025	0.6
Hg	<0.0005	<0.001	0.00083	0.000085	<0.002	<0.001	<0.0001	0.025
Ni	0.00944	0.33	<0.013	<0.014	<0.06	0.51	0.065	11
Pb [a]	< 0.033	0.029	<0.023	<0.034	<0.4	0.030	< 0.3	0.75
Sb	0.0780	<0.0007	<0.28	<0.043	0.25	<0.0007	< 0.2	1.15
Se [a]	< 0.0166	<0.013	<0.036	<0.042	<0.1	<0.013	0.015	5.7
Tl	< 0.0676	<0.010	0.000213	0.00011	<0.5	<0.010	< 0.6	0.2
V [b]	-	-	<0.0039	<0.003	0.036	-	-	1.6
Zn [b]	-	-	1.2	0.79	1.8	-	-	4.3
Source	Ferrara et al. 2001	Urie 2001	Smith et al. 2004b	Smith et al. 2004a	Ferrara et al. 2003	Urie 2001	Ferrara et al. 2002	

Data from Muller 2001, beryllium was not included in the glass formulation. Significant figures reproduced as reported.

a High level waste vitrification is the current LDR technology-based standard (40 CFR 268.40) for mixed high level radioactive waste with toxicity characteristic concentrations of the indicated constituent.

b Zinc and vanadium are exempt from regulation as a UHC under the provisions of 40 CFR 268.2(i).

c 40 CFR 268.48, US Environmental Protection Agency