0070273

RPP-RPT-29095
Revision 0

RETRIEVAL DATA REPORT FOR SINGLE-SHELL TANK 241-C-202

Prepared by
D. L. Parker

Date Published
June 2006

CH2MHILL
Hanford Group, Inc.

P.O. Box 1500
Richland, Washington

Contractor for the U. S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

CH2M HILL DOCUMENT RELEASE FORM

S

(1) Document Number:	RPP-RPT-29095	(2) Revision Number:	0	(3) Effective Date:	6/2006
(4) Document Type:	☐ Digital Image ☒ Hard copy ☐ PDF ☐ Video	(a) Number of pages (including the DRF) or number of digital images	108		
(5) Release Type	☒ New	☐ Cancel	☐ Page Change	☐ Complete Revision	
(6) Document Title:	Retrieval Data Report for Single-Shell Tank 241-C-202				
(7) Change/Release Description:	N/A				
(8) Change Justification:	N/A				

(9) Associated Structure, System, and Component (SSC) and Building Number:		
	(a) Structure Location: 200W, C Tank Farm (E 200E 6/14/06)	(c) Building Number: N/A
	(b) System Designator: 241-C-202	(d) Equipment ID Number (EIN): N/A

(10) Impacted Documents:	(a) Document Type	(b) Document Number	(c) Document Revision
	N/A		

(11) Approvals:

(a) Author (Print/Sign): D. L. Parker [signature]	Date: 6/13/06
(b) Responsible Manager (Print/Sign): R. B. Calmus [signature]	Date: 6/13/06
(c) Reviewer (Optional, Print/Sign): J. G. Field [signature]	Date: 6/13/06
(d) Reviewer (Optional, Print/Sign):	Date:

(12) Distribution:

(a) Name	(b) MSIN	(a) Name	(b) MSIN	Release Stamp
J. C. Allen-Floyd	H6-64	P. Connelly	E6-35	JUN 15 2006 DATE: STA: 15 HANFORD RELEASE ID: 65
F. J. Anderson	E6-35	R. A. Dodd	S7-83	
J. N. Appel	R2-12	S. D. Doss	S7-03	
J. W. Badden	H6-03	J. G. Field	H6-62	
D. G. Balde	S7-24	M. J. Galgoul	H6-62	
W. B. Barton	S7-70	M. N. Jaraysi	H6-03	
R. B. Calmus	H6-05	K. N. Jordan	S7-66	

(13) Clearance	(a) Cleared for Public Release	(b) Restricted Information?	(c) Restriction Type:
	☑ Yes ☐ No	☐ Yes ☑ No	

(14) Clearance Review (Print/Sign): J. D. Aardal / Janis Aardal	Date: 06/14/2006

Pg. 1 of 2

A-6003-881 (05/05)

CH2M HILL DOCUMENT RELEASE FORM (Continued)

(1) Document Number: RPP-RPT-29095	(2) Revision Number: 0	(3) Effective Date: 6/2006

(12) Distribution: (Continued)			
(a) Name	(b) MSIN	(a) Name	(b) MSIN
N. W. Kirch	R2-58	L. M. Sasaki	S7-90
M. R. Koch	S7-83	P. S. Schaus	H6-03
J. J. Luke	H6-03	M. J. Sutey	S7-70
P. C. Miller	R1-51	W. T. Thompson	S7-67
D. M. Nguyen	R2-12	J. A. Voogd	H6-03
G. W. Reddick	S7-70	F. Wickstrand	R1-29

Retrieval Data Report for Single-Shell Tank 241-C-202

D. L. Parker
CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: DRF
Cost Center: 7F500
B&R Code:

UC:
Charge Code:
Total Pages: 108

Key Words: waste, retrieval, residual, vacuum retrieval system S-112, C-202, 200-series tank, WMA C, technology, limit, HFFACO, TPA, M-45-00

Abstract:
This report describes the retrieval of waste from SST 241-C-202, which is one of four 200-series SSTs constructed to store waste in Waste Management Area C. The DOE began retrieval of waste on June 30, 2005, and completed retrieval in compliance with Milestone M-45-00 requirements on August 11, 2005. The limit of the vacuum retrieval system capacity to retrieve waste was reached.

JUN 1 5 2006
DATE:
STA: 15
HANFORD RELEASE
ID: 65

J. D. Aardal 06/14/06
Release Approval Date

Release Stamp

Approved For Public Release

RETRIEVAL DATA REPORT FOR SINGLE-SHELL TANK 241-C-202

Prepared by
D. L. Parker

Date Published
June 2006

CH2MHILL
Hanford Group, Inc.

P.O. Box 1500
Richland, Washington

Contractor for the U. S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

EXECUTIVE SUMMARY

This Retrieval Data Report (RDR) presents data showing that single-shell tank 241-C-202 (SST C-202) has been retrieved to the limits of the vacuum retrieval system (VRS) technology and that tank waste residuals in SST C-202 do not exceed 30 ft^3. These achievements satisfy the tank waste retrieval criteria established by Milestones M-45-00 and M-45-00B of the *Hanford Federal Facility Agreement and Consent Order* (HFFACO). This RDR also summarizes the potential risk to human health from waste remaining in the tank, provides details on the VRS technology and its performance in the SST C-202 retrieval campaign, and describes measures taken to prevent and detect leaks during retrieval.

The SST C-202 retrieval campaign began June 30, 2005. SST C-202 was retrieved using a VRS, which used vacuum pumps to mobilize and remove waste from the tank. Use of this system minimized both the need to add water to the tank and the in-tank pooling of liquids. Removed waste was diluted with raw water and transferred to double-shell tank 241-AN-106 (DST AN-106).

The SST C-202 leak detection, monitoring, and mitigation program used during retrieval focused on a mitigation strategy to control potential leaks. Based on the available data, there was no evidence of a tank leak occurring during SST C-202 retrieval operations.

On August 11, 2005, representatives of the U.S. Department of Energy (DOE) and CH2M HILL Hanford Group, Inc. (CH2M HILL) determined that the technical limit of the VRS to retrieve waste from SST C-202 had been reached and briefed the Washington State Department of Ecology. In determining that the VRS' capacity to remove waste from SST C-202 had been reached, DOE and CH2M HILL relied on the following:

a. Decreases over time in the specific gravity of the recovered waste stream.
b. Direct visual observation of the waste remaining in the tank bottom.
c. Analysis of retrieval data on the ratio of water used to waste retrieved.
d. Volume of residual waste at the end of each operating day.

Subsequent measurement of the residual waste in SST C-202 using topographical mapping and survey techniques in accordance with Attachment 1 to HFFACO Appendix H and RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*, established that the volume of waste remaining in SST C-202 was 19.7 ft^3, with an upper confidence level of 20.9 ft^3. SST C-202 held approximately 1,400 gal (187 ft^3) of waste at the start of retrieval. It should be noted that this starting waste volume includes both tank waste and water added to the tank during calibration and leak tests prior to the start of retrieval. Based on the difference between the starting and ending volume estimates, approximately 1,253 gal (167 ft^3) of waste were retrieved from SST C-202 and transferred to DST AN-106. No leaks from SST C-202 were detected during retrieval operations.

The inventory of constituents in the SST C-202 residual waste was determined by laboratory analysis of waste samples taken after the completion of retrieval. The risk assessment for the residual waste in SST C-202 based on sampling analyses shows that the estimated Incremental

Lifetime Cancer Risk, Hazard Index, all pathways farmer dose, and target organ dose are two to four orders of magnitude below the performance objectives prescribed for closure of the Waste Management Area C, which includes SST C-202. For the inadvertent intruder scenarios at 100 years after closure, the dose for the rural pasture, well driller, and commercial farmer scenarios are approximately three, 30, and 1,000 times below the performance objectives, respectively. However, the dose for the suburban garden scenario is approximately five times the performance objective. At 500 years after closure, all inadvertent intruder scenarios are below the performance objectives.

DOE has no recommendations for additional retrieval actions at SST C-202 because Milestone M-45-00 retrieval criteria are satisfied, and retrieval is complete.

TABLE OF CONTENTS

LIST OF APPENDIXES

LIST OF FIGURES

LIST OF TABLES

LIST OF TERMS

Abbreviations, Acronyms, and Initialisms

APF	all pathways farmer
AMS	articulating mast system
BBI	best-basis inventory
CAS	Chemical Abstracts Service
CCMS	camera/computer-aided design modeling system
CCTV	closed-circuit television system
CFR	Code of Federal Regulations
CH2M HILL	CH2M HILL Hanford Group, Inc.
COPC	constituents of potential concern
CPF	cancer potency factor
DOE	U.S. Department of Energy
DQO	data quality objectives
DST	double-shell tank
DST AN-106	double-shell tank 241-AN-106
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HIHTL	hose-in-hose transfer line
HTWOS	Hanford Tank Waste Operations Simulator
HVAC	heating, ventilation, and air conditioning
ILCR	Incremental Lifetime Cancer Risk
ITV	in-tank vehicle
LDM	leak detection and monitoring
LDMM	leak detection, monitoring, and mitigation
MBD	material balance discrepancy
MCL	maximum contaminant level
MLDUA	modified light duty utility arm
MRS	mobile retrieval system
PA	performance assessment
PCB	polychlorinated biphenyl
PUREX	plutonium-uranium extraction
QA	quality assurance
RDR	Retrieval Data Report
RfD	reference dose value
RSD	relative standard deviation
SST	single-shell tank
SST C-202	single-shell tank 241-C-202
SST C-203	single-shell tank 241-C-203
3-D	three dimensional
TWINS	Tank Waste Information Network System
TWRWP	Tank Waste Retrieval Work Plan

UCL	upper confidence level
VRS	vacuum retrieval system
WAC	Washington Administrative Code
WMA 3	Waste Management Area 3
WUF	waste unaccounted for

Units

Ci	curie
CPF	cancer potency factor available
ft^3	cubic foot
ft	foot
ft^3/min	cubic feet per minute
g	gram
gal	gallon
in.	inch
kg	kilogram
lb	pound
mL	milliliter
mrem	millirem
psi	pounds per square inch
RfD	reference dose value available
scfm	standard cubic feet per minute
yr	year
µCi	microcurie
µg	microgram

1.0 INTRODUCTION AND BACKGROUND

The *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989), Milestone M-45-00 requires the U.S. Department of Energy (DOE) to retrieve waste from all single-shell tanks (SST) at the Hanford Site. This report describes the retrieval of waste from SST 241-C-202 (SST C-202), which is one of four 200-series SSTs constructed to store waste in Waste Management Area C (WMA C). These tanks are collectively referred to as the C-200-series tanks. The DOE began retrieving waste from SST C-202 on June 30, 2005, and completed retrieval operations in compliance with Milestone M-45-00 requirements on August 11, 2005.

Where information regarding treatment, management, and disposal of the radioactive source, byproduct material, and/or special nuclear components of mixed waste (as defined by the Atomic Energy Act of 1954, as amended) has been incorporated into this document, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of Chapter 70.105, "Hazardous waste management," Revised Code of Washington and its implementing regulations, but is provided for information purposes only.

1.1 PURPOSE

This Retrieval Data Report (RDR) provides information required by Section 2.1.7 of Appendix I to the HFFACO. The report documents the SST C-202 waste retrieval campaign, waste retrieval system performance, and post-waste-retrieval activities including the residual waste volume determination and sampling and analysis of the residual waste. This report describes the performance of the retrieval system used to remove waste from SST C-202, presents data confirming that the amount of waste removed meets Milestone M-45-00 retrieval criteria, and summarizes the potential risk to human health posed by the waste remaining in the tank.

1.2 HISTORY

Construction of SST C-202 was completed in 1944. The tank was placed in service in 1947, receiving metal waste from the B Plant bismuth phosphate process through January 1948. Metal waste supernate was removed from SST C-202 in December 1953 in preparation for sluicing the metal waste solids in the tank. SST C-202 was sluiced for uranium recovery in January 1954. A visual inspection was conducted, and the tank was declared empty (RPP-15408, *Origin of Wastes in C-200 Series Single-Shell Tanks*).

In 1955 and 1956, SST C-202 received Hot Semi-Works facility waste generated from plutonium-uranium extraction (PUREX) pilot plant studies. Most of the Hot Semi-Works waste, in the form of supernate, was removed in 1970 (RPP-15408). SST C-202 was removed from service in 1976 and interim stabilized in 1981 (HNF-EP-0182, *Waste Tank Summary Report for Month Ending September 30, 2005*).

Unexplained decreases in SST C-202 waste levels that totaled approximately 450 gal were noted in 1988. These decreases were assumed to have been associated with a leak, although no unplanned release is associated with SST C-202 (HNF-EP-0182).

1.3 REGULATORY REQUIREMENTS

Retrieval of waste from SST C-202 and submittal of this RDR are requirements for closing the Hanford SST system. The HFFACO establishes volume and technology criteria for closing 200-series tanks, including SST C-202. HFFACO Milestone M-45-00 provides in part:

> Closure will follow retrieval of as much tank waste as technically possible, with tank waste residues not to exceed ... 30 ft^3 in each of the 200 series tanks, or the limit of waste retrieval technology capability, whichever is less. If the DOE believes that waste retrieval to these levels is not possible for a tank, then DOE will submit a detailed explanation to EPA and Ecology explaining why these levels cannot be achieved, and specifying the quantities of waste that the DOE proposes to leave in the tank. The request will be approved or disapproved by EPA and Ecology on a tank-by-tank basis.

Section 2.1.7 of Appendix I to the HFFACO Action Plan provides:

> **2.1.7 Retrieval Data Report/Appendix H Request for Exception**
>
> Once DOE has completed the retrieval actions described in the TWRWP, DOE will either complete and submit to Ecology within 120 days its retrieval data report, or a request for exception to retrieval criteria per Agreement Appendix H. The request for exception to retrieval criteria option is only applicable for SSTs and the requirements of that request are identified in Agreement Appendix H, Attachment 2.
>
> At a minimum, DOE's Retrieval Data Report will include:
>
> - Residual tank waste volume measurement, including associated calculations
> - The results of residual tank waste characterization
> - Retrieval technology performance documentation
> - DOE's updated post-retrieval risk assessment
> - Discussion of feasibility/viability of other available retrieval technologies, the feasibility of developing additional retrieval technologies, associated detailed cost estimates and amount of additional waste that could be removed
> - Opportunities and actions being taken to refine or develop tank waste retrieval technologies, based on lessons learned
> - LDMM monitoring and performance results
> - DOE's recommendation for further action and proposed schedule(s).

Data from this report will be used by Washington State Department of Ecology (Ecology) and DOE in making WMA-, tank- and component-specific closure decisions. Single or multiple tank and component actions will be included in this report as appropriate.

1.4 PRE-RETRIEVAL CONDITIONS

This section summarizes the physical condition of SST C-202, the ancillary equipment used during waste retrieval, and the waste residing in the tank when retrieval began.

1.4.1 Single-Shell Tank C-202 Description

SST C-202 is 20 ft in diameter with a 24.5-ft operating depth, a 25.5-ft overall height, and an operating capacity of 7,352 ft^3. The structure consists of a carbon-steel liner inside a reinforced-concrete shell. In August 2003, a manual liquid level (ENRAF[1]) gauge was installed in SST C-202 as a liquid level indicator for waste volume estimates. Figure 1-1 presents a generalized profile view of a C-200-series tank.

The SST C-202 sidewall is a vertical cylinder. The tank knuckle region curves in from the sidewall and about 36 vertical in. down to the tank bottom. The tank bottom is shaped like a shallow dish; the dish sides slope very gradually down and in to the midpoint of the tank bottom. The middle of the dish is 6 in. deeper than the top rim. The total volume of the bottom dish is approximately 43 ft^3. A weld line is visible when not covered by waste and joins plates below the rim. The portion of the tank bottom below the weld line has a volume of approximately 35 ft^3. A single stiffener ring is located at the top of the steel liner at 25 ft 6 in. above the bottom of the tank. Internal tank dimensions are documented in CVI-73550, Drawing D-20, *Typical Sections for 20 ft Tanks* and Drawing D-23, *Structural Steel Lining for 20 ft Tanks*.

1.4.2 Ancillary Equipment Providing Access to Single-Shell Tank C-202

One pump pit, six risers, and a hatchway penetrate the SST C-202 roof, providing access to the interior of the tank. Two of the risers, R-9 and R-10, are located in the pump pit. The pit and the other risers are located from the tank roof to slightly above grade. Figure 1-2 provides a top-down view of SST C-202 and includes the pit, risers, and hatchway. Table 1-1 provides basic information on the SST C-202 risers and hatchway before waste retrieval began.

1.4.3 Waste Description and Conditions

The waste in SST C-202 consisted of waste from research and development activities conducted at the Hot Semi-Works facility (RPP-15408). A summary of the waste that resided in SST C-202 at the start of retrieval is provided in the Tank Waste Information Network System (TWINS) Best Basis Inventory/Best Basis Calculation Detail, located online at http://twins.pnl.gov/data/datamenu.htm.

---

[1] ENRAF is a registered trademark of Enraf-Nonius, N.V. Verenigde Instrumentenfabrieken, Enraf-Nonius Corporation Netherlands, Rontegenweg 1, Delft, Netherlands.

Figure 1-1. Profile View of C 200-Series Tank.

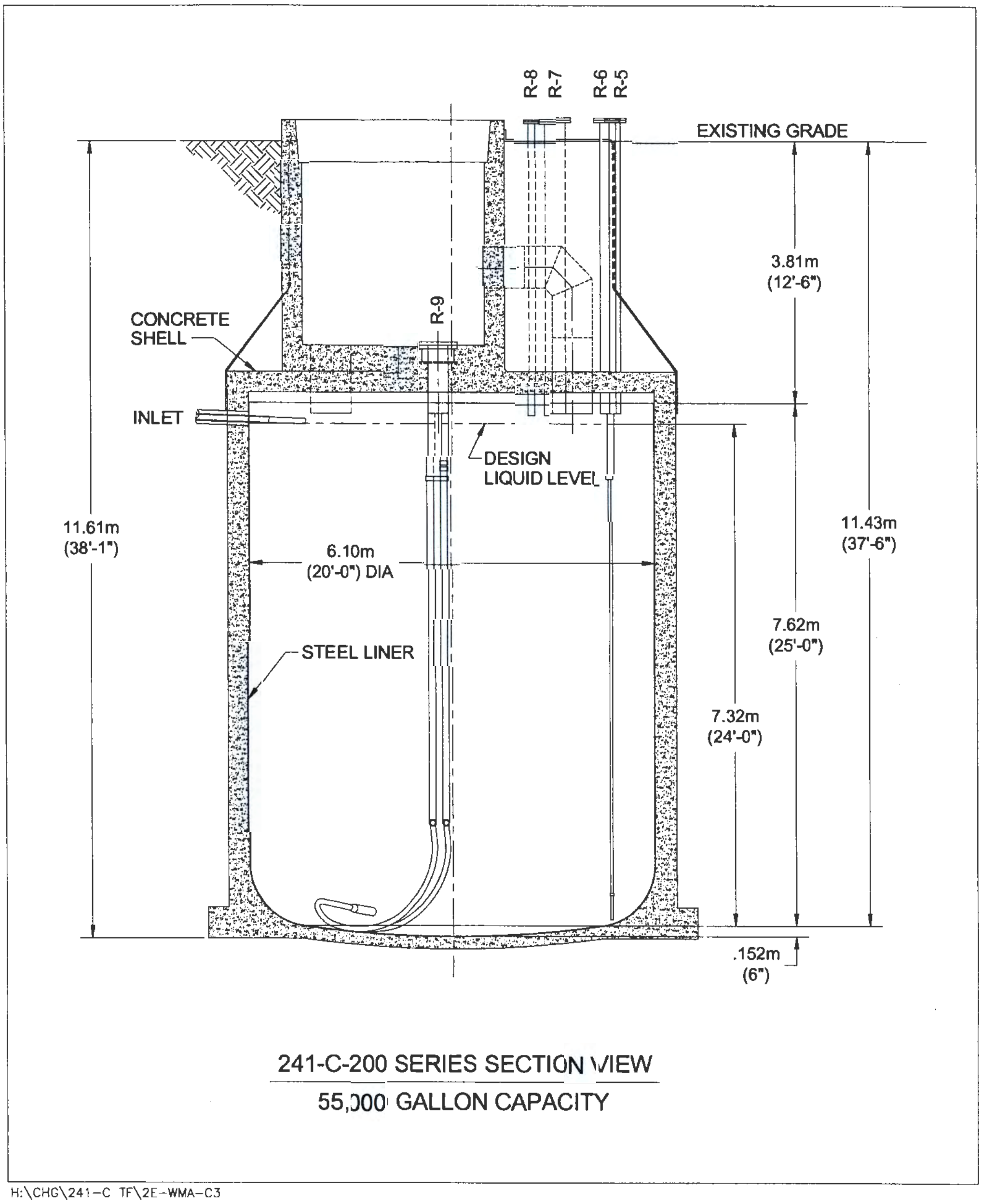


Figure 1-2. Configuration of SST C-202 and Adjacent Facilities.

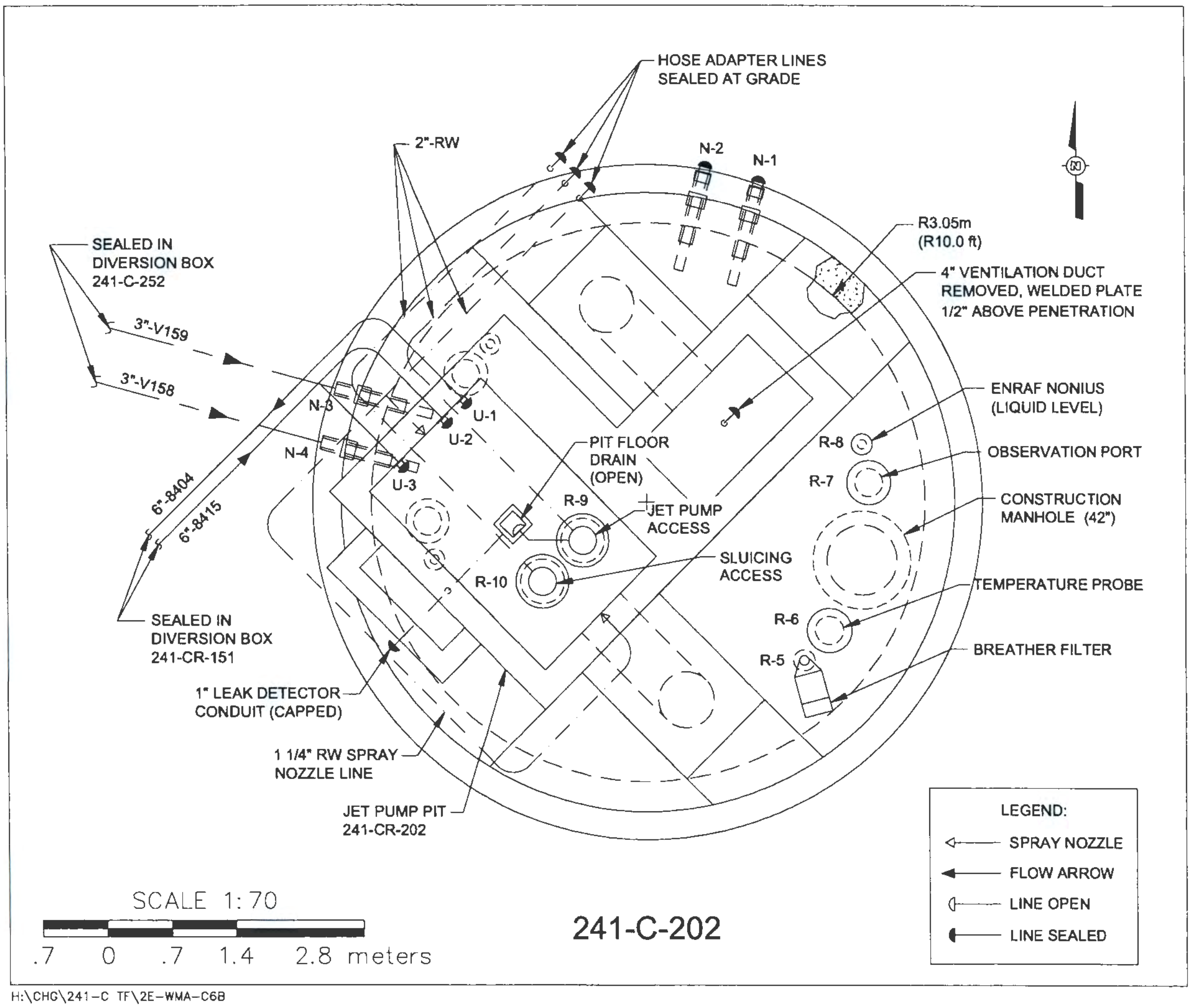


Table 1-1. Single-Shell Tank C-202 Pre-Retrieval Riser and Hatchway Descriptions.

Riser ID	Nominal Diameter (in.)	Location	Description and Pre-Retrieval Status/Use	Access
R5	4	East of jet pump pit	Breather filter—used for manual tape access	Above grade
R6	12	East of jet pump pit	Vacuum exhaust—used for temperature control	Above grade
R7	12	East of jet pump pit	Observation port—used for observation	Above grade
R8	4	East of jet pump pit	Liquid level reel—used to emplace an air filter	Above grade
R9	12	Jet pump pit	Sludge jet access	Inside pit
R10	12	Jet pump pit	Weather-covered— used for sluicing access	Inside pit
Hatchway	24	Northeast of jet pump pit	Condenser pit, weather-covered—used for general access	Via HVAC hatchway

Notes:
Primary reference sources for data are H-14-106126, Sheets 3-6; H-2-73354; and WHC–SD–WM–ER-349.
HVAC = heating, ventilation, and air conditioning.

Analysis indicated the waste in SST C-202 would have minimal heat-generating capability and that waste retrieval process fluids and chemical reactions were not expected to add heat to the tank. Therefore, no temperature monitoring was required during retrieval operations (RPP-17507, *Waiver of Temperature Requirements During Retrieval of 241-C-200 Series Tanks*).

Waste recovered from SST C-202 was transferred to double-shell tank 241-AN-106 (DST AN-106) for storage. After the waste from all C-200-series tanks is retrieved to DST AN-106, it will be sampled to define the status of the waste it holds.

1.5 DOCUMENT STRUCTURE

This RDR is organized to present information required by Section 2.1.7 of Appendix I to the HFFACO Action Plan. Table 1-2 presents a crosswalk between Section 2.1.7 requirements and sections of this RDR.

- **Section 1,** *Introduction and Background,* discusses the purpose and scope of SST C-202 waste retrieval, presents requirements applicable to the tank's retrieval campaign and this report, describes the tank and certain associated equipment, summarizes the operating history and in-tank conditions when waste retrieval began, and outlines the report structure.

- **Section 2,** *Retrieval System Description*, describes waste retrieval system design, construction and operation, lists major waste retrieval system components, depicts the waste retrieval process, and presents a waste retrieval chronology.

- **Section 3,** *Retrieval System Performance*, evaluates how well the waste retrieval system performed and indicates lessons learned and process improvements that may be implemented in future waste retrievals.
- **Section 4,** *Leak Detection, Monitoring, and Mitigation*, describes leak detection, monitoring, and mitigation (LDMM) methods and procedures, presents an LDMM chronology for SST C-202 waste retrieval, and summarizes LDMM results.
- **Section 5,** *Limits of Technology*, reports the method and findings used to determine that the selected waste retrieval technology retrieved as much tank waste as technically possible from SST C-202.
- **Section 6,** *Single-Shell Tank 241-C-202 Residual Waste Volume Measurement*, describes the method for determining the volume of residual waste in SST C-202 and presents results of the volume measurement process.
- **Section 7,** *Residual Tank Waste Characterization*, lists requirements for characterization of tank waste, describes methods and procedures used to sample and analyze the waste, and describes the results of laboratory analysis.
- **Section 8,** *Post-Retrieval Single Shell Tank 241-C-202 Risk Assessment*, summarizes the potential risk to human health from SST C-202 residual waste. This section identifies and discusses constituents of potential concern (COPC) in the waste, describes the effects of waste retrieval and closure on long-term human health risk, presents expected cumulative health effects of source terms, relates calculated risk to residual waste volume, and summarizes overall conclusions of the risk assessment.
- **Section 9,** *Additional Retrieval Technologies*, identifies other technologies considered for retrieving waste from SST C-202. This section describes available and future technologies and alternative waste retrieval scenarios, evaluates alternative methods, and assesses the utility of deploying additional technologies in SST C-202.
- **Section 10,** *Recommendations for Further Actions,* discusses recommendations for future actions associated with SST C-202 and opportunities to refine future waste retrieval operations at other tanks based on lessons learned.
- **Section 11,** *References*, contains references for material cited in the report.

Table 1-2. Crosswalk of HFFACO Appendix I, Section 2.1.7, Requirements and Corresponding Retrieval Data Report Sections.

Section 2.1.7 Requirements	RDR Section
Residual tank waste volume measurement, including associated calculations	6.0
Residual tank waste characterization data and results	7.0
Retrieval technology performance documentation	3.0, 5.0
An updated post-retrieval risk assessment	8.0
Discussion of feasibility and viability of other available retrieval technologies, the feasibility of developing additional retrieval technologies, associated detailed cost estimates, and amount of additional waste that could be removed	9.0
Opportunities and actions being taken to refine or develop tank waste retrieval technologies based on lessons learned	3.0, 10.0
LDMM monitoring and performance results	4.0
DOE's recommendations for further action and proposed schedules	10.0

2.0 RETRIEVAL SYSTEM DESCRIPTION

2.1 BASIS

The SST C-202 waste retrieval system was designed and constructed in accordance with RPP-16525, Rev. 6, *C-200-Series Tanks Retrieval Functions and Requirements*. That functions and requirements document is the predecessor to the tank waste retrieval work plan (TWRWP) now prescribed in Appendix I to the HFFACO. The SST C-202 waste retrieval system was operated in accordance with RPP-16945, Rev. 6, *Process Control Plan for the 241-C-200 Series Waste Retrieval System.*

2.2 OVERVIEW

SST C-202 was retrieved using a vacuum retrieval system (VRS) that consisted of an articulating mast system (AMS) with a vacuum head, a vacuum pump, a slurry vessel, and a number of slurry transfer pumps. Auxiliary components included a ventilation system, control trailers, and associated piping and utilities.

The AMS was remotely manipulated to retrieve waste from SST C-202. Vacuum pumps were used to create a vacuum to draw the waste up through the AMS and deposit the waste in the slurry vessel while routing air through the vacuum skid back to the SST. The deposited waste in the slurry vessel was handled as a batch. Each batch was further diluted with water as needed and pumped though an aboveground hose-in-hose transfer line (HIHTL) to DST AN-106.

2.3 WASTE RETRIEVAL SYSTEM EQUIPMENT

The VRS used the available access ports and risers on SST C-202 to install the AMS and various other supporting equipment and instruments. The AMS was connected above ground to a vessel/pump skid and a vacuum pump skid. A control trailer was used to monitor and control the waste retrieval activities and to operate the AMS. Additionally, active ventilation was connected to SST C-202 using a portable exhauster. The functions and operations of the various VRS components and skids are discussed in Sections 2.3.1 through 2.3.5. Figure 2-1 provides a schematic of the VRS.

2.3.1 Articulating Mast System

The AMS is comprised of a hydraulically powered articulating arm with a vacuum head that was rotated, extended, and retracted as necessary to reach all sections of the tank floor. Figure 2-2 provides a depiction of the AMS. A photograph of the vacuum head is provided in Figure 2-3. A series of five scarifying, high-pressure, low-volume water jets, located on the outside of the vacuum head, were used to dislodge waste as needed, and air and water were added within the mast to assist in pneumatically transporting the waste up the 40-ft mast and through piping to the slurry vessel.

Figure 2-1. Vacuum Retrieval System Schematic.

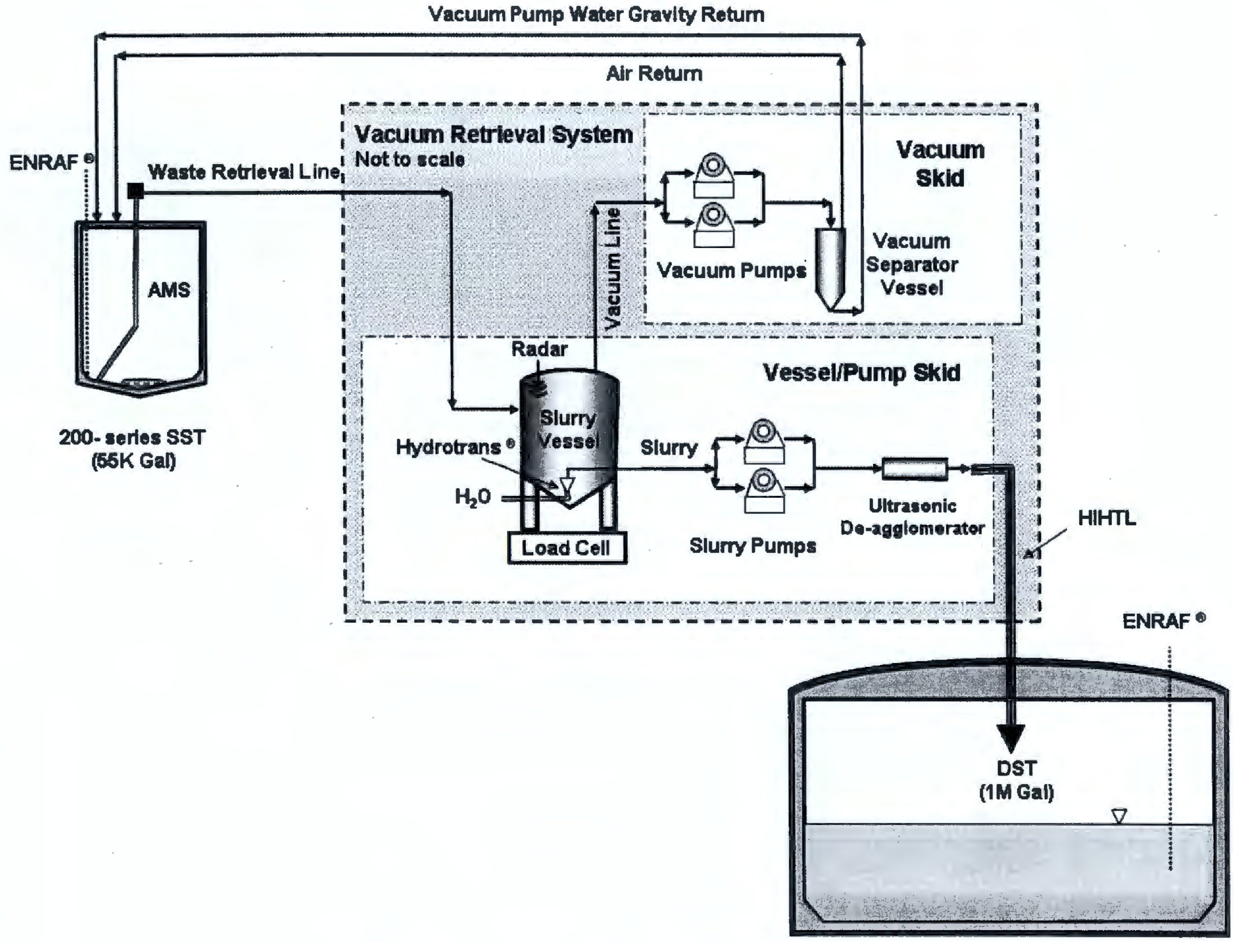


Figure 2-2. Articulating Mast System in a Single-Shell Tank.

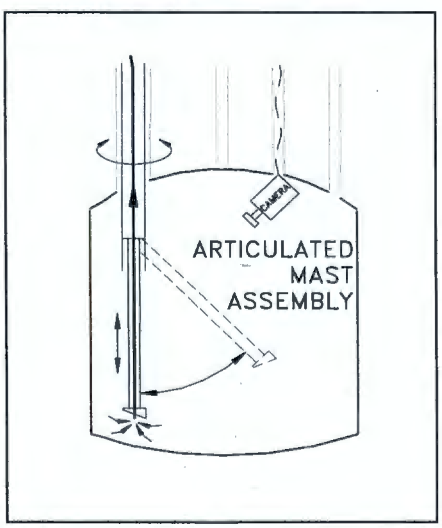
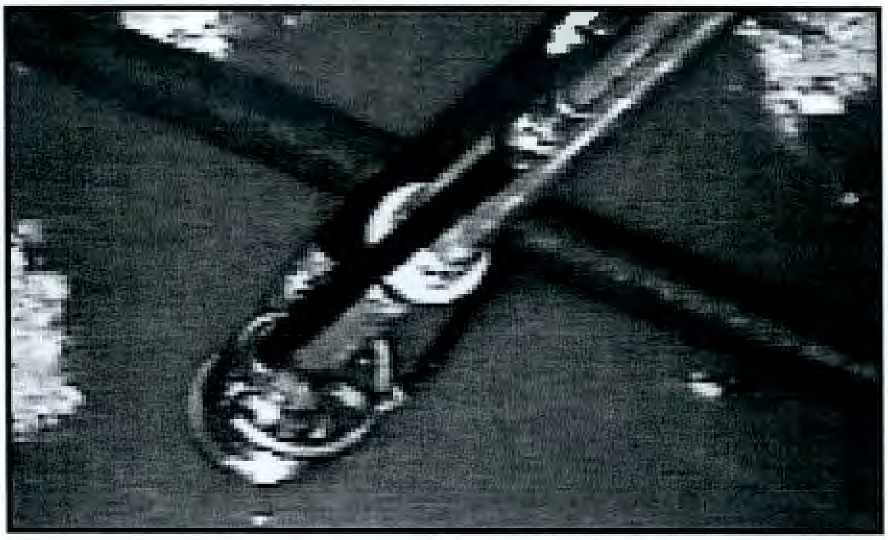


Figure 2-3. Vacuum Head on Articulating Mast System.



2.3.2 Vessel/Pump Skid

The vessel/pump skid received waste from SST C-202, collected the waste in a slurry vessel, exhausted the air to the vacuum skid, and pumped the slurry to DST AN-106. The waste entered the skid and was directed to the slurry vessel, which had a working volume of 250 gal. The slurry vessel was positioned on load cells that were used to weigh the amount of waste received. The waste was separated from the entrained gases, and when the slurry vessel was filled, waste retrieval activities were stopped.

A vacuum break valve was opened to the slurry vessel to prepare for slurry transfer to DST AN-106 through the HIHTL. The vacuum break line was connected to SST C-202. A Hydrotrans®[2] unit, in conjunction with the slurry pump, could be used to mobilize the slurry vessel contents with water and empty the slurry vessel. To prevent plugging, additional water could be added upstream of the slurry pump to maintain sufficient velocity through the HIHTL.

An ultrasonic de-agglomerator unit, located downstream from the transfer pump, was used to reduce the waste form into a homogeneous slurry. This enhanced the ability to transport waste at higher densities while minimizing water dilution volume requirements. The operator at the control interface, located inside the control trailer, manipulated dilution control based on feedback from a coriolis density meter and a pressure meter located at the output of the ultrasonic de-agglomeration unit.

2.3.3 Vacuum Skid

Two liquid-ring vacuum pumps located on the vacuum skid could be operated simultaneously as needed to achieve the desired suction at the vacuum head on the AMS. The entrained gas flow came from the vessel/pump skid. Gases from the vacuum pump combined with the pump water

[2] Hydrotrans® is a registered trademark of Dynamic Processing Solutions Ltd., Portishead, Bristol, England.

and tangentially flowed into a water separator, effectively separating the gases in a cyclone action. The gases were then returned to SST C-202.

The water in the separator was used to supply the liquid-ring vacuum pump(s). Water flowed to the pump by gravity and by the vacuum that the vacuum pump created. The water also flowed through a heat exchanger that removed the heat generated by the vacuum pump and kept the water cool. High- and low-level switches in the tank maintained the water level in the water separator. Makeup water was supplied by the utility skid, and excess water was returned to SST C-202.

2.3.4 Control Trailer

Retrieval operations were controlled and monitored remotely from a control trailer located northeast of SST C-202. A closed-circuit television system (CCTV) was used to allow the AMS to be controlled and positioned. The controls and instruments for the vacuum skid, vessel/pump skid, and CCTV and AMS control were located on one console, and video displays monitoring the pump and vessel skids were on another console.

2.3.5 Hose-in-Hose Transfer Line

The waste was transferred from the vessel/pump skid to DST AN-106 through the HIHTL. The transfer line consisted of two hoses, one within the other. The hoses were lined with ethylene propylene diene monomer rubber. The primary hose was a nominal 2-in.-diameter hose that was encased in a nominal 4-in. hose. The HIHTL was insulated and had freeze protection.

The HIHTL was flushed with 1.5 line volumes (240 gal) of water to prevent solids from settling and plugging the lines. Depending on the specific gravity of the slurry being transferred, the frequency of the flushes could range from once per retrieval batch to a single flush when the transfer line would not be used for more than 8 hours (i.e., at the end of a day's retrieval operations). Valve and pump configurations in the vessel/pump skid prevented the fluids from draining back to SST C-202.

2.4 WASTE RETRIEVAL SYSTEM INSTRUMENTATION

Various instruments were used to measure waste retrieval system performance, retrieval progress, and leak detection monitoring. These instruments included an ENRAF gauge, flowmeters, load cells, and CCTV cameras.

Liquid levels were measured in the SST and DST using an ENRAF-Nonius Series 854 servo tank gauge. The gauge functioned like a bob on a string, sensing liquid level changes through buoyancy. This instrumentation has a high degree of resolution and repeatability, is well-suited for the volumetric method in tanks with a measurable air-liquid interface, and is used throughout the tank farms.

The instrument's effectiveness for the SST was affected by the liquid level in the tank. When the liquid level dropped below the height of residual solids (typically the case), the instrument did not accurately reflect the volume of waste remaining. In addition, the ENRAF gauge was located near the tank wall, which prevented it from measuring lower than about 11.5 in. above the lowest point of the tank. Therefore, measurement of the liquid level changes in the DST receiver tank was a more accurate measure of waste retrieved.

Water use was measured at various points in the waste retrieval process. The flowmeter locations are provided in Section 3.1. The slurry vessel was mounted on load cells that measure the weight of the vessel and its contents. The capacity of the slurry vessel was also measured using a radar liquid-level instrument.

The CCTV was used during the waste retrieval campaign to monitor retrieval activities and, in conjunction with water use estimates, generate rough estimates of the remaining waste. When retrieval was completed, a video was used to generate three-dimensional (3-D) images of the contents remaining in the tank. The residual waste volume was calculated using computer-aided as-built drawings of the tank and the final configuration of the waste.

2.5 ENVIRONMENTAL CONTROLS

AIR 03-704, *Approval of Notice of Construction for 241-C-200 Series Tanks Retrieval*, and RPP-16525, Rev. 6, impose a variety of environmental controls. Application of these controls during SST C-202 waste retrieval operations is summarized in Sections 2.5.1 through 2.5.5.

2.5.1 Exhauster Operation

A portable exhauster was operated continuously while the AMS was in use to maintain tank vacuum and abate fog generation that impaired CCTV visibility. Controls were established to cease waste retrieval operations if the exhauster was not functioning. Waste retrieval process operators depended on the CCTV to safely and efficiently position the AMS suction head inside the tank to retrieve waste. The exhauster was also used to control radioactive/nonradioactive air emissions and prevent flammable gas buildup in the tank.

2.5.2 Vacuum Routing

SST C-202 was maintained under a negative pressure during waste retrieval activities. Vacuum exhaust drawn from the slurry vessel was routed back to SST C-202.

2.5.3 Leak Detection, Monitoring, and Mitigation

The waste retrieval operating strategy incorporated the philosophy of minimizing liquid available for leakage from the onset of retrieval. This was accomplished by the following:

a. Limiting the power-pack hydraulic pressure of the water feed provided to the AMS to the minimum practical for effective retrieval operations.

b. Preventing penetration of the tank bottom during AMS installation.

c. Using a video camera to monitor liquid levels inside the tank during retrieval.

d. Minimizing the presence of liquid pools to the extent practical.

The leak detection and monitoring (LDM) techniques used are discussed in Section 4.2.

2.5.4 Walkdown of Aboveground Portions of the Tank System

The aboveground portions of the tank system were visually inspected daily to identify any abnormalities in the equipment or processes that could lead to releases to the environment.

2.5.5 Secondary Containment

Leakage from the primary HIHTL (inner hose) would be contained by the secondary confinement system (outer hose) and could be detected by leak detectors, material balance data, or radiological surveys. The secondary containment system was designed to drain any fluid released from the primary hose to a common point for collection, detection, and removal.

The drains located in the vessel/pump skid; vacuum skid; heating, ventilation, and air conditioning (HVAC); and the slurry vessel were routed to SST C-202. The HIHTL, vessel/pump skid drain, and vacuum skid drain were integrated into the automatic leak detection system to shut down the system in the event of a leak.

2.6 WASTE RETRIEVAL CAMPAIGN CHRONOLOGY

Table 2-1 provides a chronological summary of the SST C-202 waste retrieval campaign. Retrieval of the waste (and water used for decontamination or flushing) was performed in batches. A batch refers to one filling and emptying of the slurry vessel, which has a capacity of 250 gal; the volume of each batch fluctuated depending on the operations being performed.

Table 2-1. Chronology of the Single-Shell Tank 241-C-202 Waste Retrieval Campaign.

Date(s)	Description
June 30, 2005	Retrieval operation began with Batch 1, a transfer of water from the slurry tank to DST AN-106. Batch 2 consisted mostly of water that had been added to SST C-202 in the days prior to startup. Waste was retrieved in Batch 2 from SST C-202 into the slurry tank, and then a portion of it was transferred from the slurry tank to DST AN-106. The transfer was shut down when a leak detector on the retrieval system alarmed.
June 30-July 8, 2005	Troubleshooting of the thermal leak detector was performed. Air flow past the detector was causing it to alarm; the problem was solved by adjusting the detector setpoint and adding a seal loop to a drain line to reduce airflow. No leak occurred on the skid.
July 11, 2005	Resumed operations, retrieving Batch 3. Operations were shut down when the exhauster was not able to maintain sufficient vacuum on SST C-202.
July 12-14, 2005	SST C-202 vacuum and exhaust rate was increased by switching the exhauster from SSTs 241-C-204 and C-202 to SST C-202 only.
July 18-20, 2005	Retrieved Batches 4 through 10. Most of the free liquid in the tank was removed by Batch 8, and retrieval began to concentrate on solids.
July 21-25, 2005	Retrieved Batches 11 through 21; retrieval techniques were similar to those used in retrieving from SST 241-C-203 (SST C-203).
July 26-August 2, 2005	Retrieved Batches 22 through 29 using retrieval techniques that attempted to minimize water use. Methods included using the scarifier at a lower flow rate (<3 gal/min) and using no air and little or no water in the AMS. Batches took longer to retrieve, but waste retrieval per batch increased.
August 4-11, 2005	Retrieved Batches 30 through 50. Water use increased as retrieval progressed and the remaining solids became more difficult to retrieve. Water was used to wash solids from the knuckle of the tank and from around debris toward the center of the tank.
August 11, 2005	Retrieval completed with a total of 51 batches transferred, two batches being only water.

3.0 RETRIEVAL SYSTEM PERFORMANCE

The goal of the SST C-202 waste retrieval campaign was "...retrieval of as much tank waste as technically possible with tank waste residues not to exceed...30 ft^3 in each of the 200-series tanks, or the limit of waste retrieval technology capability, whichever is less" (HFFACO Milestone M-45-00). This section discusses the SST C-202 waste retrieval system performance in terms of residual waste, retrieval duration, and water use. In addition, this section compares the achieved waste retrieval results against predicted performance and discusses lessons learned that may be applied on future vacuum retrievals. Retrieval and performance data are included in this section.

The SST C-202 waste retrieval system was operated 18 days over a 42-calendar-day period and recovered 1,253 gal of waste in 51 batches. The waste was retrieved at varying rates (1.5 to 100 gal of SST C-202 waste per batch) over time. The waste retrieval system performed to the limit of the technology selected, as described in Section 5.0.

3.1 WASTE RETRIEVAL PROCESS DESCRIPTION

The SST C-202 waste retrieval process consisted of low-volume water retrieval using a VRS to remove waste from the tank while minimizing water additions and liquid pooling in the tank. Vacuum pumps were used to mobilize and recover waste via the AMS and deposit the waste in a slurry vessel located above grade. Mobilized solids were diluted in the slurry vessel with raw water and then pumped to the receiver DST AN-106 through an HIHTL. The entire process was monitored to facilitate waste retrieval and minimize free liquid in the tank. The composite material received in DST AN-106 consisted of mobilized tank waste and water added to assist waste retrieval and transport.

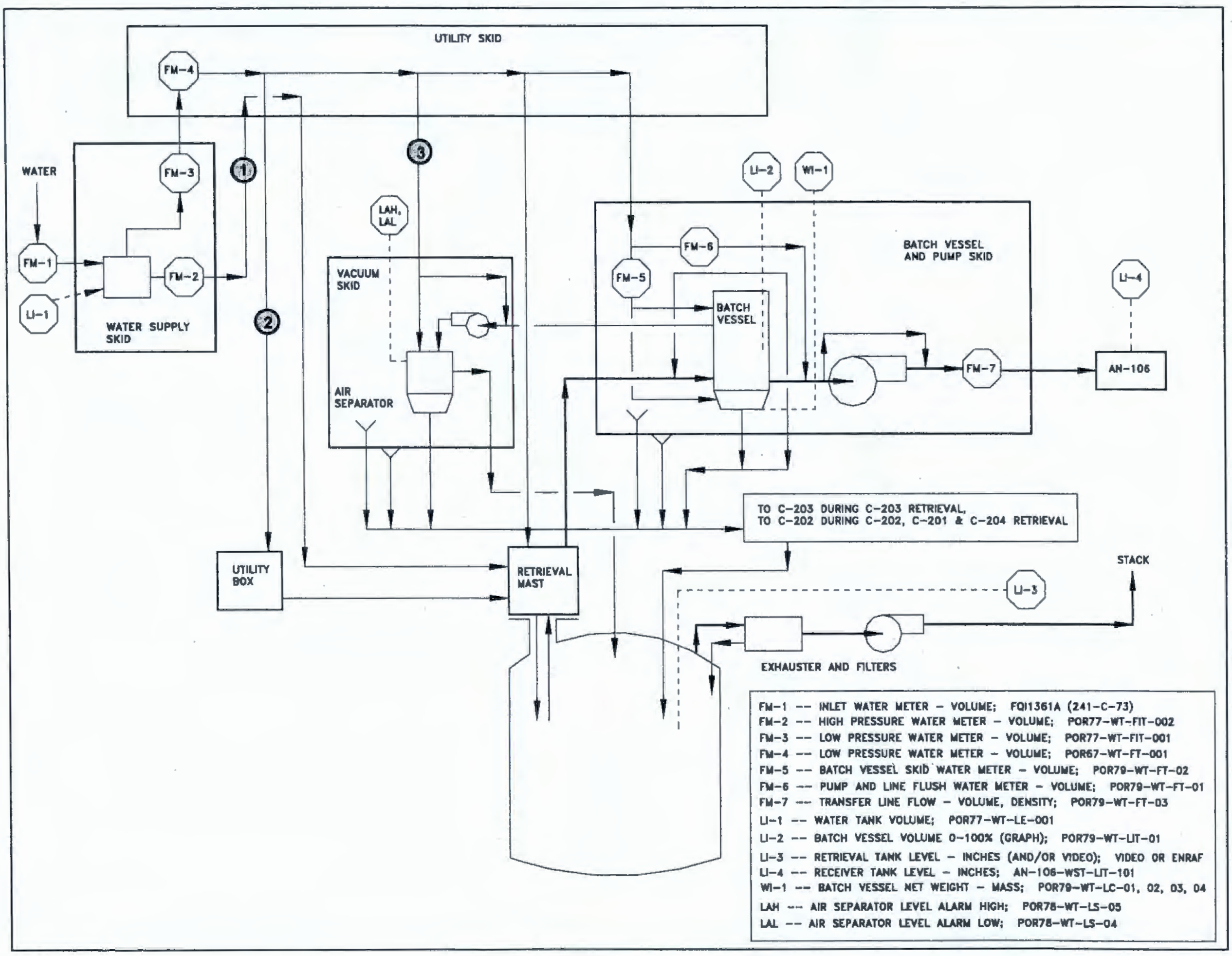
In-tank and ex-tank water was added to the waste at various stages of the process. In-tank water additions resulted primarily from waste mobilization activities and included the following:

a. Scarifying water to break up and move waste.
b. Flush water to move waste.
c. Drain water from the vacuum separator vessel.
d. Drain water from the slurry vessel.
e. Drain water from the exhauster.
f. Drain water from system maintenance.

Ex-tank water was primarily used for transport of waste solids as (1) AMS lubrication water, (2) Hydrotrans® water for mobilizing waste solids in the slurry vessel for transfer, and (3) dilution water to reduce slurry density and flush transfer lines to DST AN-106. The majority of AMS lubrication water remained in the mast and was transferred to the slurry vessel, but some could have returned to the tank when the vacuum was stopped or there was insufficient vacuum. Figure 3-1 presents a diagram of the waste retrieval instrumentation. The flowmeters shown in Figure 3-1 are described in Table 3-1. Three flowmeters were added to the waste retrieval system before retrieval from SST C-202 began to improve the accuracy or detail of the flow of water through the system. The three flowmeters are shown in Figure 3-1 and are described in Table 3-1.

The two primary sources of water were low pressure (FM-4) and high pressure (FM-2). The sum of the values from these two meters accounts for the total water used. High-pressure water was used for one purpose: in-tank scarifying. Low-pressure water was used for multiple purposes as both in-tank and ex-tank water.

Figure 3-1. C-200-Series Tanks Instrumentation Diagram.



Source: RPP-16525, Rev. 6, p. 27.
Note: Three flow meters were added to the C-200-series retrieval system before retrieval of C-202, which are as follows:

① Denotes POR77-WT-FQI-003

② Denotes POR67-WT-FQI-004

③ Denotes POR67-WT-FQI-003

Table 3-1. Single-Shell Tank 241-C-202 Retrieval Process Flowmeter Summary.

Identifier	Tag[a]	Name	Purpose
FM-1	**241-C-73**	Inlet water meter	Measures raw water delivered to Air and Water Service Building 241-C-73.
FM-2	POR77-WT-**FIT-002**	High-pressure water meter	Measures high-pressure water delivered to the scarifier on the AMS head.
FM-3	POR77-WT-**FIT-001**	Low-pressure water meter	Measures the low-pressure water delivered to the utility skid.
FM-4	POR67-WT-**FT-001**	Low-pressure water meter	Measures the low-pressure water received at the utility skid. Meters the same supply line as FM-3.
FM-5	POR79-WT-**FT-02**	Batch vessel skid water meter	Measures the amount of water delivered to the AMS for flushing solids from the AMS screen and to mobilize waste (Hydrotrans®) in the slurry vessel for transfer to DST AN-106.
FM-6	POR79-WT-**FT-01**	Pump and line flush water meter	Measures dilution water used to keep solids suspended during transport, to prime and flush transfer pumps, and to maintain waste density within prescribed limits.
FM-7	POR79-WT-**FT-03**	Transfer line flow	Measures the volume of diluted waste delivered to DST AN-106 and measures the relative density.
N/A	POR67-WT-**FQI-003**	Vacuum skid water meter	Measures the water sent to the vacuum skid, which is returned to SST C-202.
N/A	POR67-WT-**FQI-004**	Low-pressure AMS water meter	Measures low-pressure water delivered to the AMS through the NESL[3] utility box.
N/A	POR77-WT-**FQI-003**	Secondary high-pressure water meter	Measures high-pressure water delivered to the scarifier on the AMS head.

[a] Equipment tags noted on the piping and instrumentation diagrams. Abbreviations shown in bold.

3.2 WASTE RETRIEVAL TECHNOLOGY PERFORMANCE

The performance of the waste retrieval system was monitored throughout the campaign using various indicators. Water meters were used to determine trends in water use. Material balance was used during waste retrieval operations to (1) estimate the waste removed from the tank per operating day, (2) determine retrieval efficiency, and (3) determine trends in retrieval performance. Specific gravity of waste transferred to DST AN-106 was also used to monitor waste retrieval efficiency.

The material balance was calculated as the difference between the measured volume that was added to the system (water) and the measured volume removed from the system (waste and water). There is uncertainty related to these volume measurements as well as to the initial waste

[3] NESL is a trademark of Non Entry Systems Ltd., Swansea SA5 4HS United Kingdom

volume. A detailed discussion of uncertainties is found in RPP-CALC-27555, *Leak Detection Monitoring Calculation for Single-Shell Tank 241-C-202.*

The material balance calculation was performed every operating day to determine the volume of waste retrieved from SST C-202. An operating day is defined as a shift in which retrieval activities were performed, regardless of number of hours operated or waste transfers. The measured volume added to the system on each operating day was the sum of the low-pressure water (FM-4) and high-pressure water (FM-2). The measured volume removed from the system was determined by the volume increase in the DST. The material that leaves the SST system should be equivalent to the volume that arrives in the DST system.

The ENRAF gauge measurement in DST AN-106 provided daily values for liquid level. The difference between the measurement at the end of an operating day and the previous day's measurement was used to determine the volume of waste and water that had entered the tank on that operating day. The DSTs are cylindrical and measure 75 ft. in diameter, which geometrically converts to 2,750 gal of waste per inch. Each day the change in DST level was converted to gallons. The change in DST level includes the water that was added to the system and the waste that was removed from SST C-202. Subtracting the water added to the system from the DST level change provides the waste volume that was removed from SST C-202. It is calculated as follows:

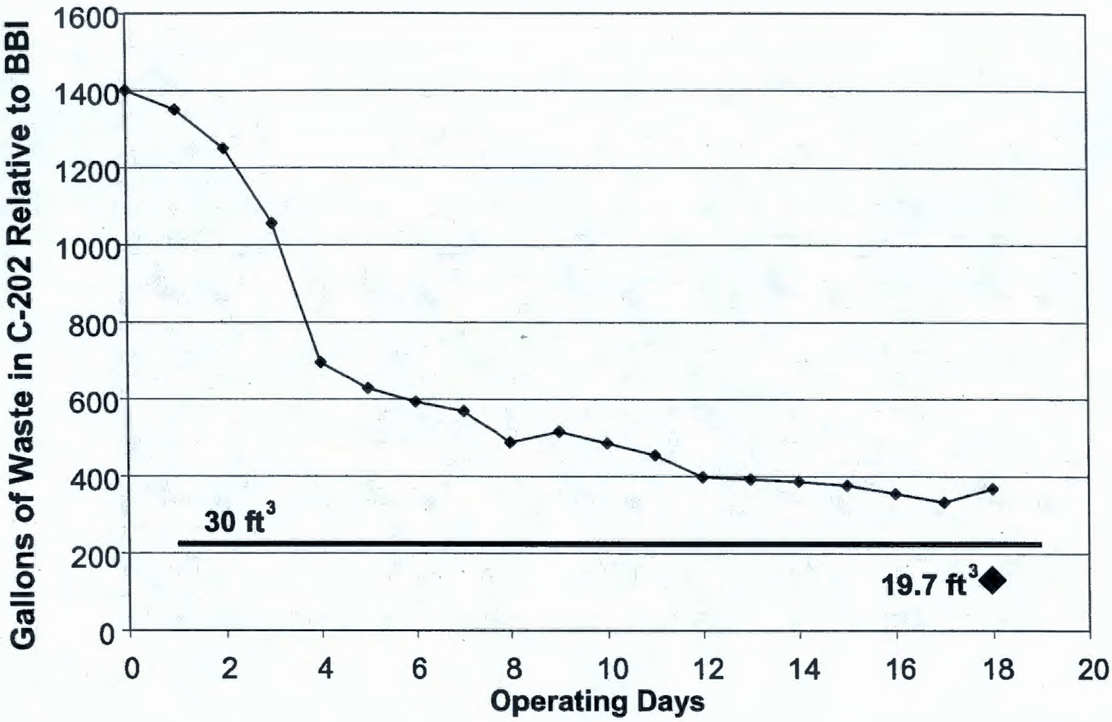
DST change (in.) x 2750 (gal/in.) – Total water added (gal) = C-202 Waste Retrieved (gal)

The waste volume retrieved from SST C-202 on each operating day was subtracted from the assumed starting waste volume in SST C-202 to produce Figure 3-2, which illustrates the SST C-202 retrieval system performance trend in terms of volume of waste remaining per operating day based on the assumed starting volume. The trend line in Figure 3-2 does not reach the residual waste volume which was determined by the final volume calculation (19.7 ft^3). This is the result of uncertainties in the initial best-basis inventory (BBI) waste volume estimate and in material balance calculations using data from process flowmeters. Therefore, the material balance results are best used for indicating the overall waste retrieval efficiency and trends in performance and not for estimating the actual waste volume.

The waste remaining in SST C-202 is calculated through video camera/computer-aided design modeling system (CCMS) and topographical mapping measurements as described in RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives* (DQO), for determining the final waste volume. The final volume determined by this method was 147 gal (19.7 ft^3) of waste in SST C-202. Further discussion of the residual waste volume measurement is presented in Section 6.0. Detailed data for each operating day for SST C-202 is found in Table 3-2, for DST AN-106 is found in Table 3-3, for water use is found in Table 3-4, and batch by batch for relative density is found in Table 3-5.

Pre-retrieval goals for the waste retrieval system performance were provided in various planning documents. The key performance measures used to evaluate the actual system performance following the campaign are described in Table 3-6.

Figure 3-2. Residual Tank Waste Volume Trend During Retrieval Campaign per Operating Day.



Note: Sporadic increasing values and waste volume remaining above its true volume are anomalies of daily material balance calculations resulting from measurement error inherent in the flowmeters, initial waste volume estimate, and system holdups.

Table 3-2. Single-Shell Tank 241-C-202 Data.

1	2	3	4		5		6	
Operating Day[a]	Date	Average Relative Density	SST Residual Volume[b]		Volume of Waste Retrieved from SST as Calculated from Material Balance[c]		Cumulative Volume of Waste Retrieved from SST per Material Balance	
			(gal)	(ft^3)[d]	(gal)	(ft^3)	(gal)	(ft^3)
0	6/28/05	--	1,400[e]	187.2	0	0.0	0	0.0
1	6/30/05	1.008	1,351	180.6	49	6.6	49	6.6
2	7/11/05	1.022	1,250	167.1	101	13.5	150	20.1
3	7/18/05	1.038	1,055	141.1	194	26.0	345	46.1
4	7/20/05	1.051	695	92.9	360	48.2	705	94.3
5	7/21/05	1.046	628	83.9	67	9.0	772	103.3
6	7/22/05	1.010	592	79.2	35	4.7	808	108.0
7	7/25/05	1.005	569	76.1	24	3.1	831	111.1
8	7/26/05	1.075	487	65.2	82	10.9	913	122.0
9	7/27/05	1.060	515	68.8	-27	-3.7	885	118.4
10	7/28/05	1.044	485	64.9	29	3.9	915	122.3
11	8/1/05	1.016	454	60.7	31	4.2	946	126.4
12	8/2/05	1.011	397	53.1	57	7.6	1,003	134.1
13	8/4/05	1.018	391	52.3	6	0.8	1,009	134.8
14	8/5/05	1.014	386	51.6	5	0.7	1,014	135.6
15	8/9/05	0.995	376	50.3	10	1.4	1,024	136.9
16	8/10/05	0.995	355	47.4	21	2.9	1,045	139.8
17	8/10/05	0.981	332	44.4	22	3.0	1,068	142.7
18	8/11/05	0.978	368	49.1	-35	-4.7	1,032	138.0

[a] An operating day is defined as a day where activities occurred (e.g., maintenance, flushes, water additions, transfers), but there may or may not have been actual waste retrieval.

[b] Based on the daily starting SST C-202 residual volume minus the volume of waste retrieved from SST C-202 (column 4).

[c] Volume based on total volume of diluted waste transferred to DST AN-106 minus the volume of water added to the system (same as column 4 in Table 3-3). All readings contain error due to flow meter uncertainty and sometimes result in negative readings, also periodically, addition of water exceeds removal of waste, resulting in a negative daily volume retrieved.

[d] Conversion to cubic feet is 1 gal = 0.1337 ft^3.

[e] The starting waste volume of approximately 1,400 gal includes both tank waste and water added to the tank during calibration and leak tests, prior to the start of retrieval (RPP-CALC-26943, *Tank 241-C-202 Retrieval: Calculation of Initial Waste Volume*).

Table 3-3. Double-Shell Tank 241-AN-106 Data.

1	2	3	4		5		6	7	
Operating Day[a]	Date	DST ENRAF gauge[b]	Volume of Waste Received[c]		Volume of Diluted Waste Received at DST[d]		Space per Gallon of Waste[e]	Remaining Allocated Space for Retrieval[f]	
		(in.)	(gal)	(ft^3)[g]	(gal)	(ft^3)	(unitless)	(gal)	(ft^3)
0	6/28/05		0	0.0	0	0.0	0.0	140,000	18,718
1	6/30/05	338.77	49	6.6	220	29.4	4.4	139,780	18,689
2	7/11/05	338.91	101	13.5	385	51.5	3.8	139,395	18,637
3	7/18/05	339.09	194	26.0	495	66.2	2.5	138,900	18,571
4	7/20/05	339.47	360	48.2	1,045	139.7	2.9	137,855	18,431
5	7/21/05	339.7	67	9.0	632	84.6	9.4	137,223	18,347
6	7/22/05	340.05	35	4.7	963	128.7	27.5	136,260	18,218
7	7/25/05	340.53	24	3.1	1,320	176.5	56.1	134,940	18,041
8	7/26/05	340.72	82	10.9	523	69.9	6.4	134,418	17,972
9	7/27/05	340.95	-27	-3.7	632	84.6	-23.1	133,785	17,887
10	7/28/05	341.14	29	3.9	522	69.9	17.9	133,263	17,817
11	8/1/05	341.43	31	4.2	798	106.6	25.6	132,465	17,711
12	8/2/05	341.8	57	7.6	1,018	136.0	17.9	131,448	17,575
13	8/4/05	342.3	6	0.8	1,375	183.8	231.5	130,073	17,391
14	8/5/05	342.58	5	0.7	770	102.9	143.9	129,303	17,288
15	8/9/05	342.78	10	1.4	550	73.5	54.3	128,753	17,214
16	8/10/05	343.1	21	2.9	880	117.7	41.2	127,873	17,097
17	8/10/05	343.49	22	3.0	1,072	143.4	48.2	126,800	16,953
18	8/11/05	343.99	-35	-4.7	1,375	183.8	-39.0	125,425	16,769

[a] An operating day is defined as a day where activities occurred (e.g., maintenance, flushes, water additions, transfers), but there may or may not have been actual waste retrieval.

[b] ENRAF gauge measurement of liquid level in DST AN-106 (LI-4 in Figure 3-1), accurate to 0.01 in.

[c] Volume is difference between the daily diluted waste received at DST AN-106 (column 4) and the daily water added to the system [the sum of column 3 (FM-2) and column 5 (FM-4) in Table 3-4]. Includes adjustments made on 6/30, 8/9, 8/10, and 8/11 to account for water left in slurry vessel without transferring.

[d] Total daily volume of water and waste received at DST AN-106 based on surface level change.

[e] Gallons of DST space consumed (column 5) per gallon of SST C-202 waste received (column 4) at DST AN-106.

[f] Remaining allocated DST space is the total allocated DST space for the retrieval of SST C-202, 241-C-201, and 241-C-204. The Hanford Tank Waste Operations Simulator (HTWOS) model allocates 140,000 gal of DST space for the retrieval of the remaining C-200-series tanks.

[g] Conversion to cubic feet is 1 gal = 0.1337 ft^3.

Table 3-4. Water Use Data.

1	2		3		4		5		6	
Day of Activity[a]	FM-2 Water Added for Scarifying		FM-3 Low Pressure Water Meter		FM-4 Raw Water Supply		FM-5 Hydrotrans Water Added to Slurry		FM-6 Pump and Line Flush Water	
	(gal)	(ft^3)[b]	(gal)	(ft^3)	(gal)	(ft^3)	(gal)	(ft^3)	(gal)	(ft^3)
0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1	0	0.0	17	2.3	21	2.7	0	0.0	0	0.0
2	0	0.0	284	37.9	284	38.0	0	0.0	253	33.8
3	0	0.0	298	39.9	301	40.2	0	0.0	253	33.8
4	58	7.8	543	72.7	626	83.7	168	22.4	262	35.0
5	82	10.9	427	57.1	484	64.6	65	8.7	262	35.0
6	166	22.2	674	90.1	761	101.8	280	37.4	257	34.4
7	178	23.9	995	133.1	1,118	149.5	456	60.9	292	39.1
8	0	0.0	400	53.5	441	58.9	42	5.6	242	32.3
9	77	10.3	525	70.2	583	77.9	132	17.6	310	41.4
10	0	0.0	446	59.6	493	65.9	109	14.5	254	34.0
11	0	0.0	691	92.3	766	102.5	315	42.1	257	34.4
12	76	10.1	757	101.2	885	118.3	301	40.3	256	34.2
13	202	27.0	1,095	146.4	1,167	156.1	672	89.8	254	34.0
14	191	25.6	560	74.9	573	76.6	245	32.7	256	34.2
15	119	15.9	493	65.9	523	69.9	63	8.4	375	50.2
16	298	39.9	383	51.2	459	61.4	267	35.8	40	5.3
17	20	2.7	941	125.8	1,062	142.0	531	71.0	312	41.7
18	0	0.0	1,173	156.8	1,400	187.1	648	86.6	254	34.0
Total	**1,468**	**196**	**10,702**	**1,431**	**11,946**	**1,597**	**4,292**	**574**	**4,389**	**587**

[a] An operating day is defined as a day when activities occurred (e.g., maintenance, flushes, water additions, transfers), but there may or may not have been actual waste retrieval.

[b] Conversion to cubic feet is 1 gal = 0.1337 ft^3.

Table 3-5. Single-Shell Tank 241-C-202 Retrieval Batch Relative Densities.

Batch[a]	Date	Relative Density[b]	Batch	Date	Relative Density	Batch	Date	Relative Density
1	6/30/05	1.002	18	7/25/05	1.016	35	8/5/05	1.011
2	6/30/05	1.008	19	7/25/05	0.983	36	8/9/05	1.024
3	7/11/05	1.022	20	7/25/05	1.000	37	8/9/05	0.967
4	7/18/05	1.034	21	7/25/05	1.014	38	8/10/05	0.995
5	7/18/05	1.042	22	7/26/05	1.075	39	8/10/05	1.011
6	7/20/05	1.054	23	7/27/05	1.080	40	8/10/05	0.989
7	7/20/05	1.050	24	7/27/05	1.040	41	8/10/05	0.984
8	7/20/05	1.068	25	7/28/05	1.044	42	8/10/05	0.949
9	7/20/05	1.052	26	8/1/05	1.016	43	8/10/05	0.991
10	7/20/05	1.032	27	8/2/05	0.998	44	8/10/05	0.984
11	7/21/05	1.052	28	8/2/05	1.024	45	8/11/05	0.995
12	7/21/05	1.040	29	8/2/05	1.012	46	8/11/05	1.001
13	7/22/05	1.028	30	8/4/05	1.024	47	8/11/05	0.991
14	7/22/05	0.981	31	8/4/05	1.029	48	8/11/05	0.942
15	7/22/05	1.009	32	8/4/05	1.009	49	8/11/05	0.991
16	7/22/05	1.023	33	8/4/05	1.009	50	8/11/05	0.946
17	7/25/05	1.012	34	8/5/05	1.017	51	8/11/05	--

[a] A batch consists of transferred waste pumped out of SST C-202. Each batch may not have been full before the transfer was initiated. Batches include two water batches (1 and 38).

[b] Average relative density (also referred to as specific gravity) measured by coriolis device on transfer line from SST C-202 to DST AN-106. Data for batch 51 was unavailable because the slurry vessel was filled but not transferred. Readings less than 1.00 are attributed to entrained air in the slurry stream or occasional low readings near the beginning or end of the slurry transfers.

Table 3-6. System Performance Summary.

	Estimated Prior to Retrieval Start	Actual	Achieved Expectations?
Remaining tank waste residues volume (ft^3)	<30[a]	19.7[b]	Yes
Retrieval time (days)	25	18	Yes
Retrieval rate (gal of waste per batch)	9[c]	26[d]	Yes
Total water use (gal)	40,000[e]	13,414[f]	Yes

[a] Defined by the HFFACO as "retrieval of as much waste as technically possible, with tank residues not to exceed...30 ft^3 in each of the 200-series tanks, or the limit of waste retrieval technology capability, whichever is less."

[b] Remaining tank waste residues volume reported in RPP-27512, *Post-Retrieval Waste Volume Determination for Single-Shell Tank 241 C-202.*

[c] This is calculated using a batch volume of 250 gal (RPP-16945, *Process Control Plan for the 241-C-200 Series Waste Retrieval System,* Section 2.3.1, page 13), and SST C-202 initial waste volume of 1,400 gal (based on RPP-CALC-26943). It was predicted that it would take 40,000 gal of water to retrieve 1,400 gal of waste. Therefore about 29 gal of water is used per gal of waste retrieved. A 250 gal batch of slurry would therefore contains about 9 gal of waste.

[d] Retrieval rate was calculated using the volume retrieved from SST C-202 and the total batches, as follows:

Volume of waste retrieved from SST (1,253 gal) ÷ Total number of batches (47) = 26.

[e] Estimated total water use for retrieval of SST C-202 was revised upward from the volume estimated in RPP-16525 based on operational experience gained at SST C-203.

[f] Total water use = 11,946 gal (FM-4) + 1,468 gal (FM-2) = 13,414 gal

3.3 PREDICTED VERSUS ACTUAL TECHNOLOGY PERFORMANCE

The waste retrieval data was used to evaluate the system's performance against the pre-retrieval goals; results of the evaluation are summarized in Table 3-6. The system exceeded expectations for the residual waste volume estimate, retrieval time, and total water use. The post-retrieval calculations indicated that the performance indicators for retrieval rate fell short of its target. The performance curves presented in this section indicate that the system performed to expectations until the end of the campaign, when less waste was available for retrieval.

3.3.1 Residual Waste Volume

The VRS was estimated to be able to accomplish "retrieval of as much waste as technically possible, with tank residues not to exceed...30 ft^3 in each of the 200-series tanks, or the limit of waste retrieval technology capability, whichever is less" according to the HFFACO. The system successfully met this goal. The performance of the system to its limits and the final residual volume are discussed in Sections 5.0 and 6.0, respectively. The waste retrieval technology was effective enough that a physical change between the initial and final waste was observed during waste retrieval. Initially, the white or yellow crystalline material over dark waste was retrieved, leaving a dark granular material mixed with dark- and light-colored gravel-like material in SST C-202.

3.3.2 Water Use

Before retrieval began, the projected water use was estimated to be 40,000 gal based on retrieval experience with SST C-203. The waste retrieval campaign used an estimated 13,414 gal of water. In-tank water use totaled about 3,900 gal and ex-tank water use was about 9,500 gal. Water use was significantly reduced for the SST C-202 retrieval campaign compared to the SST C-203 retrieval campaign. Transfer line flushes were decreased from every third batch for SST C-203 to once per operating day for SST C-202. The reduction was made after trends in operating data showed that the waste was sufficiently diluted (relative density less than 1.1) prior to entering the DST to minimize the risk of line plugging. This reduced water use per gallon of waste retrieved for transfer line flushes by approximately 50%. However, transfer line flushes still accounted for about one-third of the water used for waste retrieval.

Water use also increased as the waste became more gravel-like and less mud-like. The retrieval was more effective in removing the mobile, mud-like waste than the solid, gravel-like waste. Removing the gravel-like waste required greater amounts of both in-tank and ex-tank water. Figure 3-3 presents water use on each operating day of the SST C-202 retrieval campaign separated into in-tank and ex-tank water. In-tank water use increased noticeably as more solids were encountered after operating day 4 (Figure 3-4). Overall, far more ex-tank water was used than in-tank water as indicated in Figure 3-5, reducing the risk of leak loss associated with the volume of water used. Water use and disposition results are explained further in Table 3-7.

Figure 3-3. Daily Comparison of In-tank and Ex-tank Water.

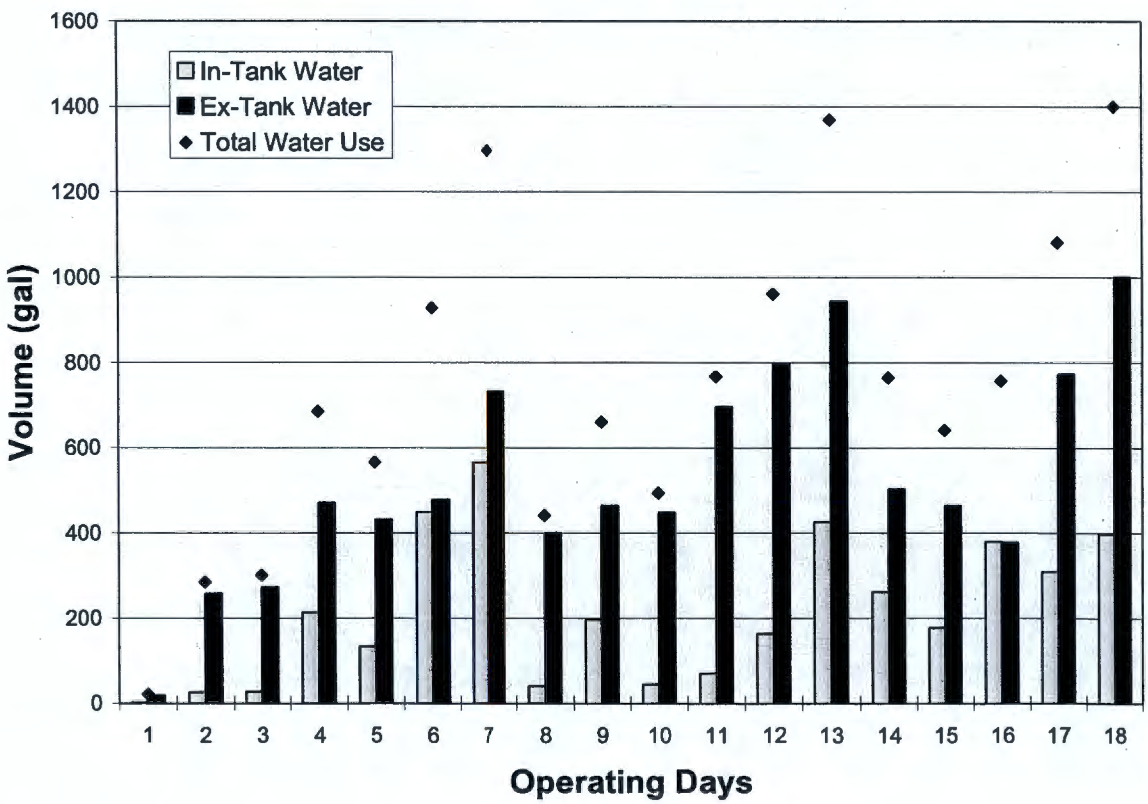
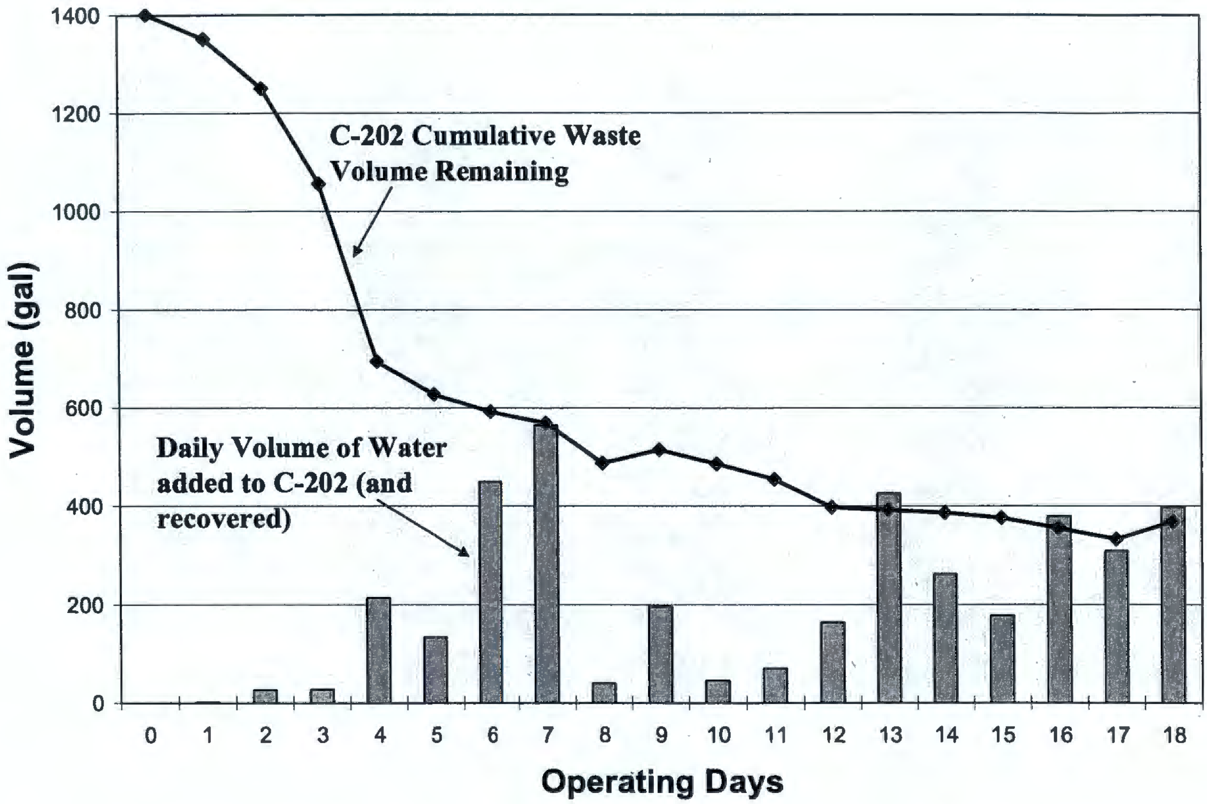


Figure 3-4. Daily In-tank Water Use.



Note: Sporadic increasing SST 241-C-202 volume is an anomaly of daily material balance calculations resulting from measurement error inherent in the flowmeters and system holdups.

Figure 3-5. Overall Proportion of In-tank and Ex-tank Water.

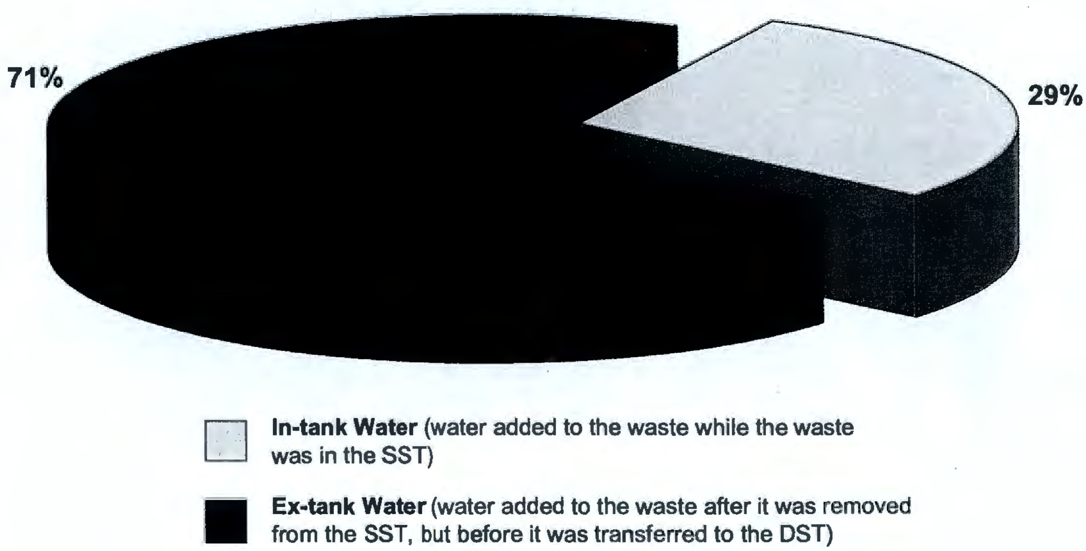


Table 3-7. Water Use and Disposition.

Water Use	Actual (gal)	Entered C-202?	Description of Estimation Method[a]
Transport and mobilize waste solids	7,496	No	Total amounts recorded by FM-6 and FM-5 minus the amount attributed to washing and slurry vessel drains.[b]
Water returned to SST C-202 from vessel/pump skid	1,185	Yes	Values recorded by FM-5 attributed to washing and slurry vessel drains.
AMS lubrication water	2,033	No[c]	Total amount recorded by FM-4 minus the sum of the total amounts recorded by FM-5, FM-6, and the amount attributed to vacuum separator vessel makeup water.
Scarifying	1,468	Yes	Total amount recorded by FM-2.
Vacuum separator vessel makeup water	1,232	Yes	Total amounts recorded by FM-4 while water was added to vacuum separator vessel.
Total assumed to have passed through SST C-202 prior to being deposited into DST AN-106 (i.e., in-tank water)	3,885	Yes	Summation of values above with 'Yes' in the third column of this table.
Ex-tank water	9,529	No	Summation of values above with 'N' in the third column of this table
Total water used	13,414	NA	Summation of FM-2 and FM-4.

[a] See Table 3-1 for a description of all FM (flowmeter) numbers.

[b] Hydrotrans water (for mobilizing the waste) was estimated to be 3,107 gal by subtracting the wash water estimate of 1,185 gal from the total for FM-5 (4,292 gal). Water for transporting waste (FM-6) was recorded as 4,389 gal. The sum was 3,107 + 4,389 = 7,496.

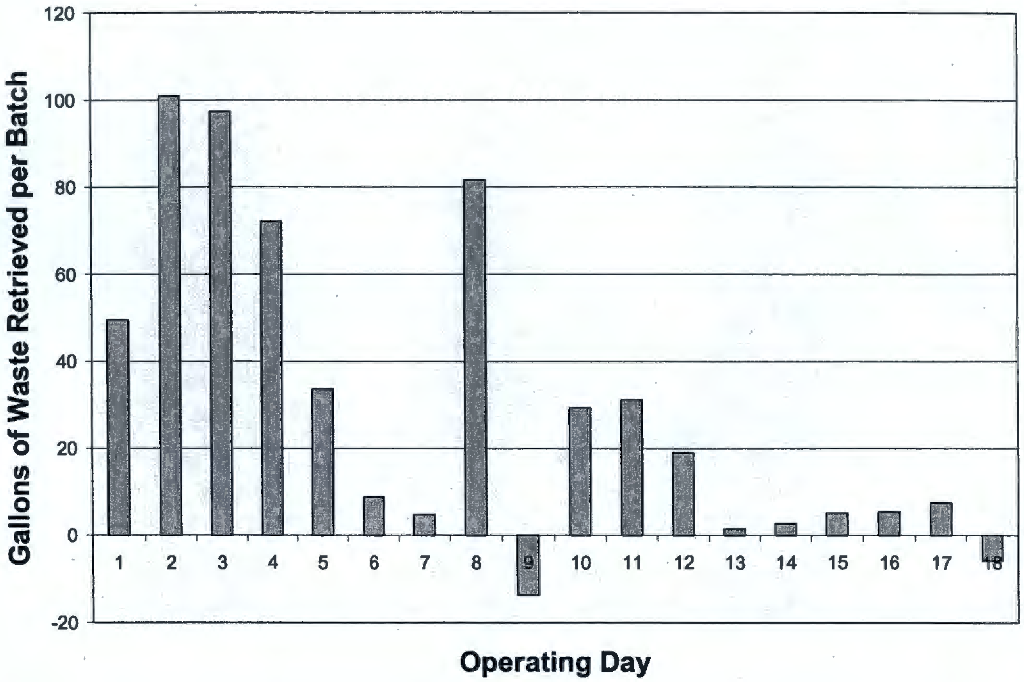
[c] Some volume of AMS lubrication water returned to SST C-202; it could have drained to the tank when the vacuum was stopped or when there was insufficient vacuum.

3.3.3 Waste Retrieval Rate

The preliminary estimate of the retrieval rate for the SST C-202 campaign was developed using the batch volume and predicted water use. The batch volume is 250 gal based on the size of the batch vessel, the predicted water use is 40,000 gal, and the waste volume to be retrieved is 1,400 gal. The ratio of water to waste is about 29 to 1, resulting in a predicted retrieval rate of 9 gal per batch. On average, the system performed at 26 gal per batch, above the estimated pre-retrieval rate.

The waste retrieval rate generally met expectations until day 13 of the campaign. After day 13, retrieval results diminished, showing little daily progress. Operating day 9 showed a negative retrieval rate in Figure 3-6 due to the material balance showing negative waste retrieved. Operating day 18, the last day of retrieval, showed a negative waste volume retrieved. This involved system maintenance requiring addition of water to flush system components, but did not result in significant retrieval of waste, where more water was added than waste retrieved.

Figure 3-6. Waste Retrieval Rate During Campaign.



Note: Sporadic values less than zero are anomalies of daily material balance calculations resulting from measurement error inherent in the flowmeters, initial waste volume estimate, and system holdups.

3.3.4 Retrieval Time

The pre-retrieval estimate of 25 days was based on performance data from the retrieval of SST C-203. The retrieval rate was assumed to be comparable, and the number of days was scaled to account for less initial waste volume. Lessons learned from the retrieval of SST C-203 were successfully applied to estimate retrieval time required for retrieval of SST C-202.

The pre-retrieval estimate provided sufficient time to retrieve SST C-202 to the limits of the technology selected. The VRS had retrieved about 50% of the total residual waste by day 5 of the campaign and the system continued to recover measurable volumes of waste through day 12. The campaign was continued another 6 days to recover additional waste until the limits of technology was reached.

On beginning retrieval of SST C-202, the waste characteristics were muddy with small particulate waste, which was easily retrieved in the first few days. As more waste was removed from the tank, the residual waste became more difficult to retrieve. The waste broke into chunks and had a gravelly appearance. This material required more effort to be lifted out of the tank and remain suspended through the waste retrieval system process.

3.4 CONCLUSION

The VRS successfully met HFFACO requirements of "...retrieval of as much tank waste as technically possible with tank waste residues not to exceed...30 ft^3 in each of the 200-series tanks, or the limit of waste retrieval technology capability, whichever is less" for the SST C-202 waste retrieval campaign. Compared to performance goals, the SST C-202 waste retrieval system met or exceeded expectations in residual waste, water use, retrieval rate per batch, and retrieval time in days.

4.0 LEAK DETECTION, MONITORING, AND MITIGATION

The LDMM program was implemented to protect the workers, public, and environment from leaks of radioactive liquid waste. The LDMM program includes technologies and methods used prior to, during, and after waste retrieval to detect leaks, reduce the potential for a leak to occur, or minimize leak volumes. Additionally, the LDMM program quantifies liquid waste release volumes should a release be detected. There was no evidence of a leak during retrieval of waste from SST C-202.

Unlike the 100-series tanks, the C-200-series tanks do not have drywells in the vicinity of the tank wall to detect or measure leaks. SST C-202 was categorized as an 'assumed leaker' in 1988 based on level decreases; 450 gal of waste was estimated to have leaked from SST C-202 (HNF-EP-0182) (see Section 1.2). In the intervening years between its categorization as an 'assumed leaker' and recent retrieval, not enough liquid was present in the tank to warrant additional LDMM measures. This tank was given higher priority for retrieval and a leak mitigation strategy that strictly controlled the amount of liquids used was implemented. RPP-16525, Rev. 6, establishes that a mass balance will be performed at the conclusion of retrieval as the leak detection and monitoring (LDM) method.

The approach described in RPP-16525, Rev. 6, is based on preventing leakage, minimizing leak volumes if a leak should occur, and using available process control data for indication of possible leakage. The strategy implemented was to not allow additional volumes of liquid into SST C-202 beyond that required to break up the waste close to the vacuum head for subsequent removal.

The following sections describe the LDMM requirements, LDM implementation, mitigative approach, chronology, results, and lessons learned. The major results for the LDMM program during SST C-202 waste retrieval are as follows:

a. There was no evidence of a leak during waste retrieval based on results of in-tank liquid level monitoring and skid leak detectors.
b. The material balance calculation results supported no evidence of a leak during retrieval (see Section 4.2.1.3).
c. Water minimization was implemented as part of leak mitigation.

4.1 REQUIREMENTS

The LDM system incorporating mitigation was established in RPP-16525, Rev. 6. Requirements are also contained in the safety basis controls given in RPP-17190, *Safety Evaluation of the Waste Retrieval System Vacuum System for 241-C Tank Farms 200-Series Tanks*, and HNF-SD-WM-TSR-006, *Technical Safety Requirements for Tank Farms,* specifically Technical Safety Requirement (TSR) Limiting Condition for Operation (LCO) Section 3.1.1, "Transfer Leak Detection Systems." Material balances during transfers are required by the TSR Administrative Control (AC) Section 5.11, "Transfer Control," and RPP-12711, *Temporary Waste Transfer Line Management Program Plan.*

The primary procedures governing notification and reporting of leaks are TFC-OPS-OPER-C-24, *Occurrence Reporting and Processing of Operations Information*, and TFC-ESHQ-ENV_FS-C-01, *Environmental Notification.*

4.2 LEAK DETECTION AND MONITORING

During retrieval of waste from SST C-202, LDM was accomplished by the use of ENRAF gauges in DST AN-106, visual inspection, leak detectors, radiological monitoring, and material balances as shown in Table 4-1 and discussed in Sections 4.2.1 through 4.2.3.

Table 4-1. Leak Detection and Monitoring Methods for Each Waste Retrieval System Component.

Component	LDM Method
SST C-202	Visual inspection, material balance, limited liquid level monitoring
DST AN-106	Liquid level monitoring, annulus leak detectors, radiation monitoring for annulus exhaust air
Ancillary equipment (skids, HIHTL)	Leak detectors

4.2.1 Single-Shell Tank C-202

4.2.1.1. Liquid Level Monitoring. The overall waste retrieval operating strategy for SST C-202 was to reduce the tank liquid inventory and minimize liquid additions during waste retrieval operations. Liquid levels were monitored to evaluate liquid inventories and indicate potential leaks in the system to implement this strategy. The ENRAF device installed in SST C-202 did not have a consistent liquid surface to measure and was not relied on for leak detection purposes. See Section 2.4 for a description of how the instrument functions.

4.2.1.2. Visual Inspection. Before initiating waste retrieval operations, a visual assessment and documentation of in-tank conditions in SST C-202 were performed using an in-tank video camera. Throughout waste retrieval, the CCTV system was used to identify the waste surface condition, qualitatively assess the amount of liquid in the tank, observe any significant changes, and implement the mitigation strategy of minimizing liquid pools.

Observations of the waste surface in SST C-202 indicate that the surface level decrease corresponded with waste retrieval activities. Unexpected increases or decreases in the surface level of SST C-202 were not observed. Because surface liquid had been minimized in SST C-202 prior to extended downtimes, evaporative loss was not noted during waste retrieval. One exception was between June 30 and July 18 when surface liquid could not be retrieved due to a skid-mounted leak detector alarm and exhauster modifications, which halted retrieval. No significant level change was observed during this downtime.

4.2.1.3. Material Balance. Material balances are primarily used for process performance measurements (see Section 3.2). However, they also provide useful information for determining gross indications of leaks in the system. The material balance is performed to account for all of the water and waste that moves through the system. A material balance discrepancy (MBD) occurs when the amount of material going in and coming out does not match the change in the system. This calculation is presented in RPP-CALC-27555. The material balance is calculated using this basic equation:

Material balance discrepancy (MBD) = start volume + additions – removals – ending volume

Waste transfers have permissible MBD limits based on system-specific variables and estimated accuracies of instrumentation. On completion of retrieval, an overall MBD was calculated. The MBD limit was calculated as the limit of error associated with all volume measurements or volume estimates associated with the SST C-202 retrieval process. Should the MBD exceed the limit of error, the difference between the MBD and the limit of error is called waste unaccounted for (WUF). Therefore, if the MBD is

a. Negative, the WUF = 0.
b. Positive but $\leq$ limit of error associated with the SST C-202 retrieval volume measurements or volume estimates, the WUF = 0.
c. Positive and > limit of error associated with the SST C-202 retrieval volume measurements or volume estimates, the WUF = MBD – limit of error.

The limit of error is assumed to be the following:

limit of error = $(\Sigma\, U_i^2)^{1/2}$

where U_1 = uncertainty with stream 1, U_2 = uncertainty with stream 2, etc.

The square-root-of-the-sum-of-squares method for estimating the limit of error is based on an assumption of independence between the variables. Details of the uncertainty calculations can be found in RPP-CALC-27555.

Because of the greater accuracy associated with the DST AN-106 ENRAF gauge when compared to the accuracy of the flowmeter/totalizer, the same system used in Section 3.2, which included the SST C-202 retrieval system and DST AN-106, was selected as the primary system around which the material balance was performed.

The primary system material balance had an MBD of -168 gal, well within the uncertainty of ±419 gal. The WUF for the primary MBD is therefore by definition zero, thereby supporting no evidence of a leak during retrieval. More detailed results are presented in RPP-CALC-27555.

4.2.2 Double-Shell Tank AN-106

4.2.2.1. Liquid Level Monitoring. Daily liquid level measurements were recorded for the receiving DST AN-106. The ENRAF gauge is capable of accurately measuring liquid level changes of 0.01 in. See Section 2.4 for a description of how the instrument functions.

During waste retrieval there was no evidence of a release from DST AN-106 based on results of liquid level monitoring. A consistent increase in liquid level was noted in DST AN-106 throughout retrieval. The DST AN-106 liquid level increase corresponded with the material balance results for SST C-202.

4.2.2.2. Leak Detectors. DST AN-106 is monitored for leaks in the inner shell by a conductivity probe leak detection system installed in the tank annulus during tank construction. Slots cut in the concrete that support the tank at the bottom are designed to drain any leakage to the annulus floor. Conductivity probe assemblies on the annulus floor would activate an audible alarm and an annunciator panel light in the event of liquid leaking to the annulus so that mitigation would begin. Throughout the SST C-202 waste retrieval campaign, no leaks were detected by any of the leak detectors in DST AN-106.

4.2.2.3. Radiation Monitoring. A continuous air monitor operated to detect airborne radionuclides entrained in the ventilation exhaust stream of the annulus of DST AN-106. Detection of radiation exceeding a set limit in the annulus of the DST would activate an audible alarm and an annunciator panel light, initiating mitigative action.

The continuous air monitor for the DST AN-106 annulus detected no radiation levels above background during retrieval that could have been attributed to leak-induced airborne radionuclides.

4.2.3 Ancillary Equipment

Leak detectors were installed in the vessel/pump skid, vacuum skid, and HIHTL (secondary containment structures) to detect the presence of liquid through conductivity, which would activate alarms and shut down the waste retrieval system. Leak detectors were also placed in skid drain lines that were anticipated to be used in the event of a leak but otherwise should have remained dry. These skid leak detectors would have provided immediate notification of a leak from any ancillary equipment in the SST C-202 waste retrieval system, allowing initiation of appropriate mitigation actions.

A leak detector alarmed on June 30, 2005. Transfer of waste from the slurry vessel to DST AN-106 was stopped. After investigation, it was determined that air flow past the detector was causing it to erroneously alarm. The problem was solved by adjusting the detector setpoint and adding a seal loop to a drain line to reduce the air flow past the detector.

Throughout the SST C-202 waste retrieval campaign, no leaks were detected by any of the leak detectors on the skids or HIHTL.

4.3 MITIGATION

Leak mitigation was accomplished through design features and the operational strategy developed for the VRS. Mitigation included actions that reduced the chance of a leak and the environmental impact of a leak should one have occurred. The potential for a leak to occur and its effects should a leak occur, were proactively minimized throughout the waste retrieval operations. Key mitigative actions are described in Sections 4.3.1 through 4.3.3.

4.3.1 Single-Shell Tank C-202

A summary of the SST C-202 mitigation strategy is as follows:

a. Addition of water to the retrieval tank was minimized and liquid pools that formed were removed to the extent practical.

b. Waste was retrieved to the extent practical by working from the center of the tank outwards. In the center-out waste retrieval strategy, dissolved waste and interstitial liquids drain quickly into a central pool and can be rapidly pumped from the tank if a leak is observed.

c. Waste retrieval activities were performed only while a video camera was in place to observe the AMS vacuum head and waste surface.

d. Equipment handling controls were used to minimize the potential for dropping equipment into the tank, which could penetrate the tank bottom during installation.

e. The hydraulic pressure to the AMS was reduced to the extent practical while still permitting acceptable AMS operation to minimize the potential for putting excessive pressure on the tank wall during retrieval operations.

f. A benchmark level was maintained to ensure a low head of introduced liquid. The waste level did not exceed this benchmark. For SST C-202, the benchmark was 12 in., as measured by manual tape from the tank sidewall (2,065 gal of waste).

The SST C-202 retrieval process lasted only 42 calendar days, minimizing the amount of time for retrieval liquids to leak from the tank. As discussed in Section 3.0, the waste retrieval process took less time than planned and less water was used during retrieval than expected. The mitigative approach was implemented to ensure that the indicators of potential leakage from SST C-202 was carefully monitored at all times.

4.3.2 Double-Shell Tank AN-106

The only tank used to receive SST C-202 tank waste was DST AN-106. Mitigating actions for a leak from DST AN-106 primary tank piping into the secondary DST containment system during a waste transfer from SST C-202 would have included (1) stopping the flow of waste into the tank system (stopping the transfer), (2) pumping waste in the primary tank to another DST until the liquid level in the secondary containment was no longer increasing, and (3) removing the waste from the secondary containment system as soon as practicable. Leaks at or near the DST AN-106 tank bottom may also have required saltwell jet pumping to remove trapped liquids from between solid layers in the tank. Transfer line leakage would drain back to the batch vessel/pump skid and subsequently to SST C-202.

4.3.3 Ancillary Equipment

Should a leak have occurred within the skids, the liquid would have drained to SST C-202, not to the surrounding soils. Any water that collected in the skid floor pan would have activated a leak detector, which would shut down all skid operations. Should a leak have occurred within the skid, the waste retrieval process would have halted automatically when the leak detector activated and shut down the transfer pumps. The process could also have been halted manually if the leak was visually observed during routine inspections. Any detected leaks would have been mitigated before the process was restarted. The response to a leak would have been the same regardless of leak rate, and an occurrence report would have been issued in accordance with requirements established in TFC-OPS-OPER-C-24.

Leakage from an HIHTL transfer line (inner hose) into an encasement (outer hose) would have drained to an alarm location and a collection tank. The transfer would have been shut down when the alarm was activated. Response to transfer leak detection alarms and mitigation actions would have been performed in accordance with procedure TO-220-106, *Transfer from 241-200 Series Tanks to 241-AN-106*.

4.3.4 Mitigation Results

The leak mitigation strategy was implemented throughout retrieval. As a result:

a. Retrieval activities were clearly visible under the video camera.
b. Water use was limited and fell below the predicted volume.
c. The 12-in. liquid level baseline for operating was maintained.
d. The mitigation approach from Section 4.3 was fully implemented.

As described in the mitigation strategy, the hydraulic pressure to the AMS was limited to prevent internal tank damage. Additionally, the AMS speed was limited such that only deliberate, slow movements could be made, protecting tank walls from accidental blows by the AMS.

Minimization of water use exceeded expectations (13,414 gal); about 10,700 gal of the water was used for skid line flushes and Hydrotrans® operation and did not enter SST C-202 (see Section 3.3). This volume of water was necessary to transfer the slurry uphill to DST AN-106 and flush the lines adequately to prevent line plugging. The remaining approximately 3,900 gal was used for in-tank purposes: scarifying, flushing solids from the tank knuckle, and water discharged from the vacuum separator. No gross indications of leakage were observed during waste retrieval.

The volume of water in the tank was minimized during retrieval. On a typical day of retrieval, about 75 gal of water were added at a time and about 3 minutes passed between water addition and waste retrieval with the AMS. One exception to this rule was between June 30 and July 18 when retrieval was stopped due to a leak detector alarm and exhauster modifications, leaving surface liquid in the tank.

The final volume of waste in SST C-202, 147 gal (19.7 ft^3), was determined through topographical mapping. According to RPP-27512, *Post-Retrieval Waste Volume Determination for Single-Shell Tank 241-C-202*, there is a waste layer with an average thickness of 1.25 in. along the bottom of the tank. By reducing the volume of waste, the available volume for liquid pools, interstitial liquid, or a hydraulic head has been reduced. Consequently, the potential for leaks as well as the volume of a potential leak are minimized.

4.4 CONCLUSION

Based on the available data (presented in Sections 4.2 and 4.3), no evidence of a tank leak occurred during SST C-202 waste retrieval operations. The SST C-202 LDMM program focused on a mitigation strategy to successfully control potential leaks. This strategy included the following:

a. Minimize residual tank waste.
b. Minimize in-tank water use.
c. Minimize standing liquid pools in the tank.
d. Control and monitor additions of water.
e. Visually monitor tank conditions and retrieval operations.
f. Retrieve from the center of the tank out to minimize water accumulation around the tank knuckle.

The goal of the LDMM program for SST C-202, according to the plan set forth in RPP-16525, Rev. 6, was successfully achieved.

5.0 LIMITS OF TECHNOLOGY

HFFACO Milestone M-45-00 states in part: "Closure will follow retrieval of as much tank waste as technically possible, with tank waste residues not to exceed … 30 ft^3 in each of the 200 series tanks, or the limit of waste retrieval technology capability, whichever is less." In addition, HFFACO Milestone M-45-00B, which identifies requirements for demonstration retrievals such as the SST 241-C-201 retrieval, provides in part: "Waste shall be retrieved to the DST system to the limits of the technology (or technologies) selected."

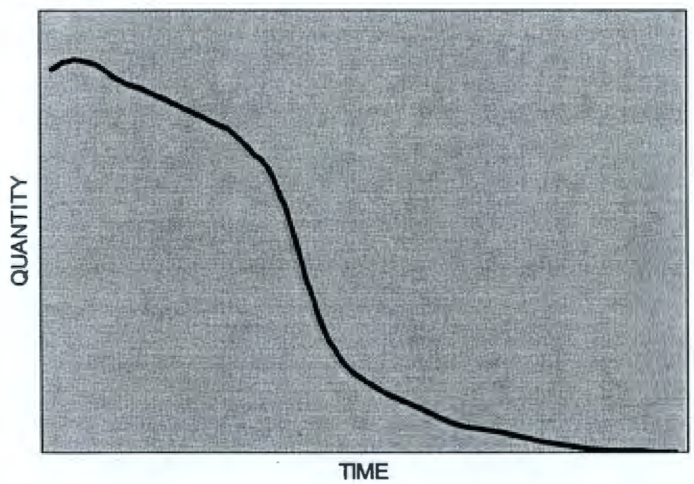
This section presents information showing that the VRS retrieved as much waste from SST C-202 as technically possible, and that the limits of the VRS technology were met during the SST C-202 waste retrieval campaign. Though VRS system improvements were implemented midway through the campaign, retrieval performance eventually decreased to the point where only negligible waste was being retrieved with each additional batch.

Unless otherwise noted, data in this section were developed in accordance with procedure TFC-ENG-CHEM-P-47, *Single-Shell Tank Retrieval Completion Evaluation.*

5.1 IDENTIFYING LIMITS OF TECHNOLOGY

Neither M-45-00 nor M-45-00B prescribes a method or criteria for deciding when a technology has reached the limit of its capability to retrieve waste. Figure 5-1 illustrates the general concept of diminishing returns over time as retrieval progresses and a retrieval technology reaches its limit.

Figure 5-1. Limits of Technology Model.



Note: Figure does not represent actual retrieval results. Actual results for SST C-202 are shown graphically in Figure 3-2.

During the earliest portion of the hypothetical campaign, relatively small volumes of waste are removed as adjustments are made to the system to maximize the efficiency of the technology.

During the middle period, the operational parameters have been optimized and efficient operation of the technology removes relatively large volumes of waste.

In later stages, the small volume of waste remaining and the reduced operational efficiencies cause retrieval time to increase in relation to volume of waste recovered. In the final days, the quantity of waste recovered approaches zero, indicating that retrieval efficiency has diminished to the point where the limit of the technology has been reached.

Several types of data were available to establish that the limit of the VRS capacity to retrieve waste from SST C-202 had been reached. DOE and CH2M HILL relied on the following:

a. Decreases over time in the specific gravity of the recovered waste stream.
b. Direct visual observation of the volume of waste remaining in the tank bottom.
c. Ratio of water used to waste recovered.
d. Volume of residual waste at the end of each operating day.

5.2 DETERMINATION THAT LIMITS OF TECHNOLOGY WERE REACHED

Data from instrumentation indicated that by August 11, 2005, no additional waste was being recovered by the VRS. Onsite representatives of DOE and CH2M HILL concurred that the limit of the VRS capacity to retrieve waste from SST C-202 had been reached, and Ecology was briefed.

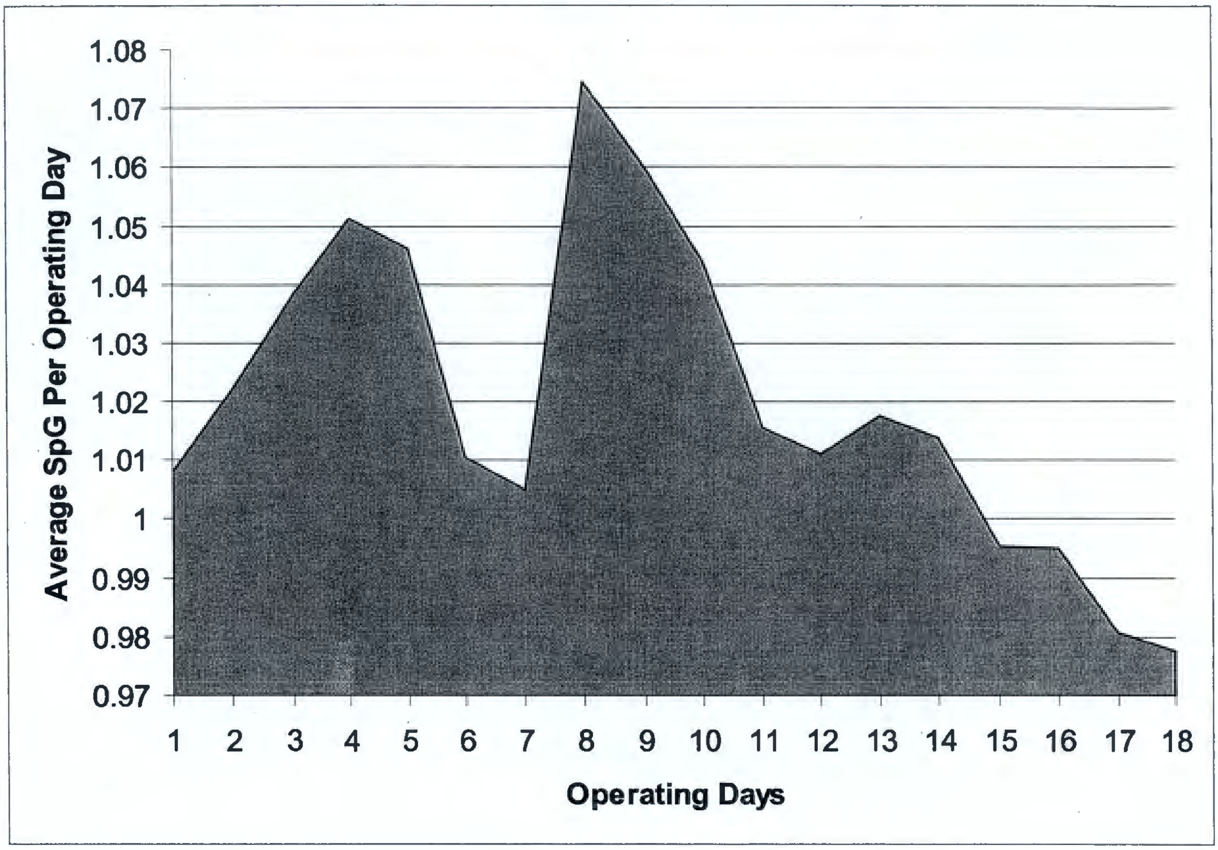
Waste retrieval operations were subsequently terminated, the system was flushed, and steps were initiated to start post-retrieval sampling and residual volume measurements. Sections 5.2.1 through 5.2.3 describe factors contributing to confirmation that the retrieval limit had been reached.

5.2.1 Trend in Specific Gravity of the Waste Slurry

The specific gravity of undiluted waste from SST C-202 was substantially higher than the specific gravity of water used to transport the waste. Water, however, composed most of the waste slurry volume. Initially, the composite specific gravity of the slurry was higher than the specific gravity of water but lower than the specific gravity of undiluted waste. As the volume of retrieved waste diminished over time, the specific gravity of the slurry declined until it approximated the specific gravity of water.

Figure 5-2 shows the specific gravity of the waste slurry on a per operating day basis. On most operating days, several slurry batches were transferred to DST AN-106. While the specific gravity of individual batches varied from one batch to another, a clear trend of declining specific gravity (the specific gravity of the slurry declined toward 1.0) was indicated over the course of the campaign. In the later stages of the campaign, the specific gravity of the slurry did not vary greatly from 1.0, indicating that the content of the slurry was approximating water, and that the limit of the VRS to retrieve waste had been reached. The data shown in Figure 5-2 are taken from Table 3-5.

Figure 5-2. Specific Gravity of Retrieval Slurry.



5.2.2 Results of Visual Observations

A video camera inside SST C-202 allowed for real-time monitoring of retrieval activities and results throughout the retrieval campaign. Video observation of physical characteristics of the tank and objects in the tank aided in measuring residual waste volume change at the end of retrieval. As retrieval progressed, the reduction in waste volume could be observed. The value of visual observation for assessing whether the technology was reaching its limit increased as the waste surface receded below the lower weld of SST C-202, as discussed in the following.

The dish bottom in the C-200-series tanks has an approximate volume of 35 ft^3 at the weld line (RPP-13019, *Determination of Hanford Waste Tank Volumes*). The volume of remaining waste was approximated when the surface of the residual waste dropped below the top of the dish and then below the weld line. On August 5, 2005, the weld line was visible around almost the entire tank. The waste was not level across the tank but formed a thin layer, which provided confidence that less than 35 ft^3 remained in SST C-202. At the point where the limit of the VRS technology to retrieve waste was reached, changes in waste volume were no longer being observed and the waste surface was sufficiently beneath the weld line to ensure that the volume of residual waste in the dish was well below 30 ft^3 (see photographs in Section 6.0).

During retrieval, the change in physical characteristics of the waste was also observed. The dark brown to black sludge-like solids were easily retrievable. As retrieval progressed, much of the remaining waste in the bottom of the tank was granular and gravel-like material. During the last batches of retrieval, this granular and gravel-like material was observed to be resistant to retrieval and was left in SST C-202 despite repeated efforts to remove it. The granular material would not pass through the screen on the mast head. The slurry liquid that was being retrieved was also much lighter than during initial retrieval indicating that most of the small particulate waste had been removed. Video observation provided the confirmation that the limit of the VRS technology had been reached.

5.2.3 Trend in Ratio of Water Used to Waste Recovered

Water was used to scarify (break up) waste forms in SST C-202 and to transport waste in slurry from SST C-202 to DST AN-106, the receiving tank, and for other purposes described in Section 3.1. Volumes of water used for some or all of these purposes were measured on each operating day. The ratio of waste retrieved to water used was an indicator of waste retrieval efficiency. Approaching the limits of technology was indicated by diminishing waste recovery on a constant or increasing water use.

Figure 5-3 measures the capacity of the VRS to recover waste from SST C-202 by comparing waste retrieved and dilute waste generated on each operating day. The trend shown in Figure 5-2 during the last 6 operating days is that very large amounts of water were being used, and very small volumes of waste were retrieved. In contrast, earlier operating days show a higher return in terms of retrieved waste indicating limits of technology were reached.

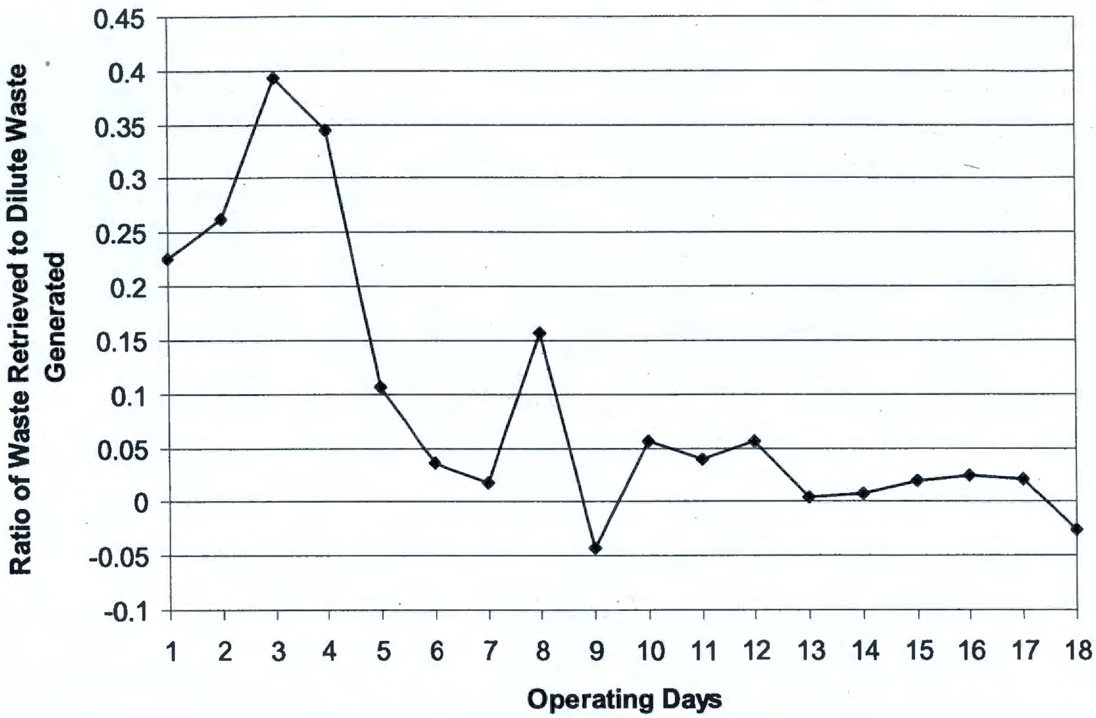
5.2.4 Trends in Volume of Residual Waste

Another indicator of retrieval efficiency was the residual waste volume at the end of each operating day tracked over time. The residual waste volume at the end of each operating day was determined by subtracting the total volume of waste removed per day from the residual volume at the start of that day's operations. A plot of the residual volumes or cumulative volume retrieved at the end of each successive operating day presented data that indicated the relative efficiency of the technology over time.

Figure 5-4, which presents data taken from Table 3-2, plots the residual waste in SST C-202 at the end of each operating day, as derived from material balances. The trend reported in this figure corresponds to that of a technology meeting its limits as indicated by a diminishing change in the residual waste volume over time and no measurable change over the last 3 operating days.

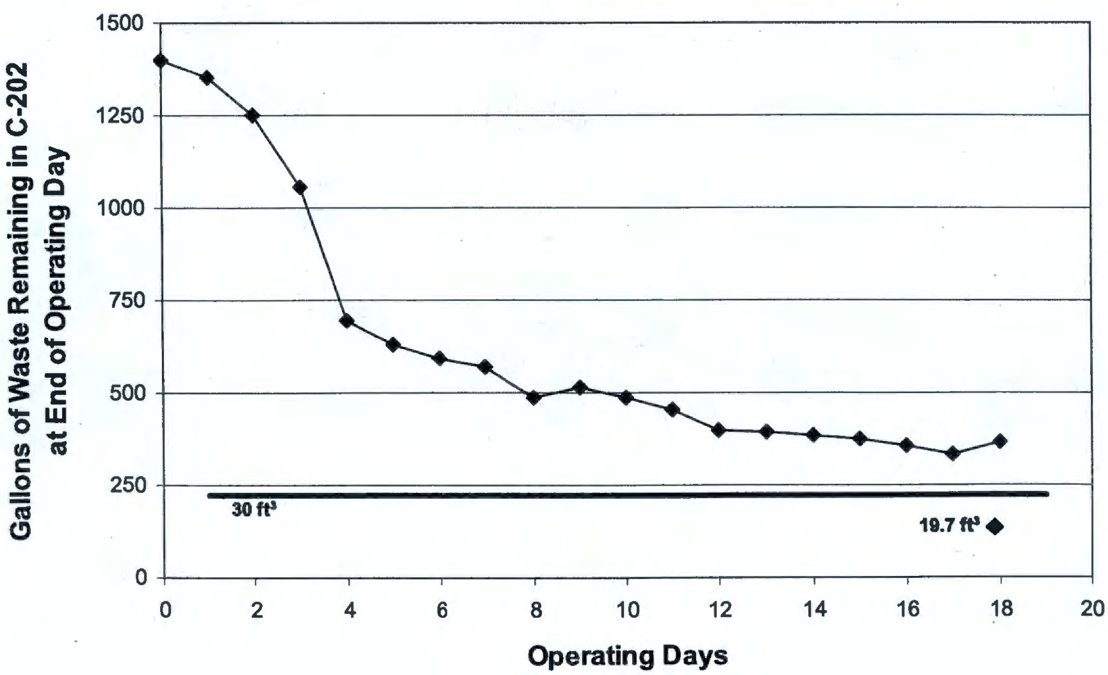
The trend toward diminishing returns shown in Figure 5-4 compares well with the model for reaching the limit of technology shown in Figure 5-1. The trend for the last 7 operating days shown in Figure 5-4 is nearly level, indicating that no more than a small amount of waste was being recovered on any day. Figure 5-4 does not show the trend line reaching below the 30 ft^3 volume criteria, an inconsistency that results from daily measurement uncertainties in waste transferred to DST AN-106 and in the volume of water used for retrieval and does not affect the validity of the trend line. Figure 5-4 includes a marker at 19.7 ft^3, the actual volume of waste remaining in SST C-202 at the end of operating day 18, the end of the campaign.

Figure 5-3. Retrieval Performance Measured by Ratio of Waste Retrieved to Dilute Waste Generated and Shipped to Double-Shell Tank 241-AN-106 per Operating Day.



Note: Sporadic values less than zero are anomalies of daily material balance calculations resulting from measurement error inherent in the flowmeters, initial waste volume estimate, and system holdups.

Figure 5-4. Residual Tank Waste Volume During Retrieval Campaign.



5.3 CONCLUSION

The limits of technology requirement established in HFFACO Milestones M-45-00 and M-45-00B were met for SST C-202 waste retrieval. Data from instrumentation confirmed that the VRS reached the limit of its capacity to retrieve waste from SST C-202.

6.0 SINGLE-SHELL TANK 241-C-202 RESIDUAL WASTE VOLUME MEASUREMENT

This section presents information demonstrating that substantially less than 30 ft^3 of residual waste remains in SST C-202, thereby meeting one of the two waste retrieval criteria contained in HFFACO Milestone M-45-00. Retrieval operations continued until the limit of the VRS capacity to remove waste from SST C-202 was reached, as described in Section 5.0. A post-retrieval measurement of the residual waste volume was performed using the topographical mapping and survey techniques required by RPP-23403. This measurement established that the volume of the waste remaining in SST C-202 was 19.7 ft^3, with an upper bounding limit of 20.9 ft^3.

6.1 RESIDUAL WASTE VOLUME MEASUREMENT PROCESS

The use of a CCMS to calculate the volume of residual waste, as described in RPP 23403, met the HFFACO Appendix H, Attachment 1, standard for determining if retrieval criteria were met. The CCMS approach is summarized in this section and is described in full in RPP-CALC-27512. A secondary volume estimate made from a preliminary video recording taken at the time retrieval operations concluded confirmed the CCMS result.

Video Camera/Computer-aided Design Modeling System

The total measured volume of residual waste in SST C-202 was the sum of volumes remaining in the tank dish, on tank walls, on the stiffener ring (all shown in Figure 6-1), and in the void spaces in equipment left in the tank. The CCMS method was used to calculate the volume remaining in the dish. The waste volumes remaining on the tank wall, stiffener ring, and in void spaces were estimated using video observations, records, and equipment drawings.

To implement the CCMS method, an in-tank video of SST C-202 was recorded on August 19, 2005. The video documented the location of residual solids and liquid waste remaining in the tank. The video was taken by a camera located in Riser 5 at heights of 23 ft 6 in., 13 ft 6 in., and 3 ft 6 in. above the bottom of the tank. Figure 6-1 presents a section view of SST C-202 showing representative camera elevations used for the August 19 video.

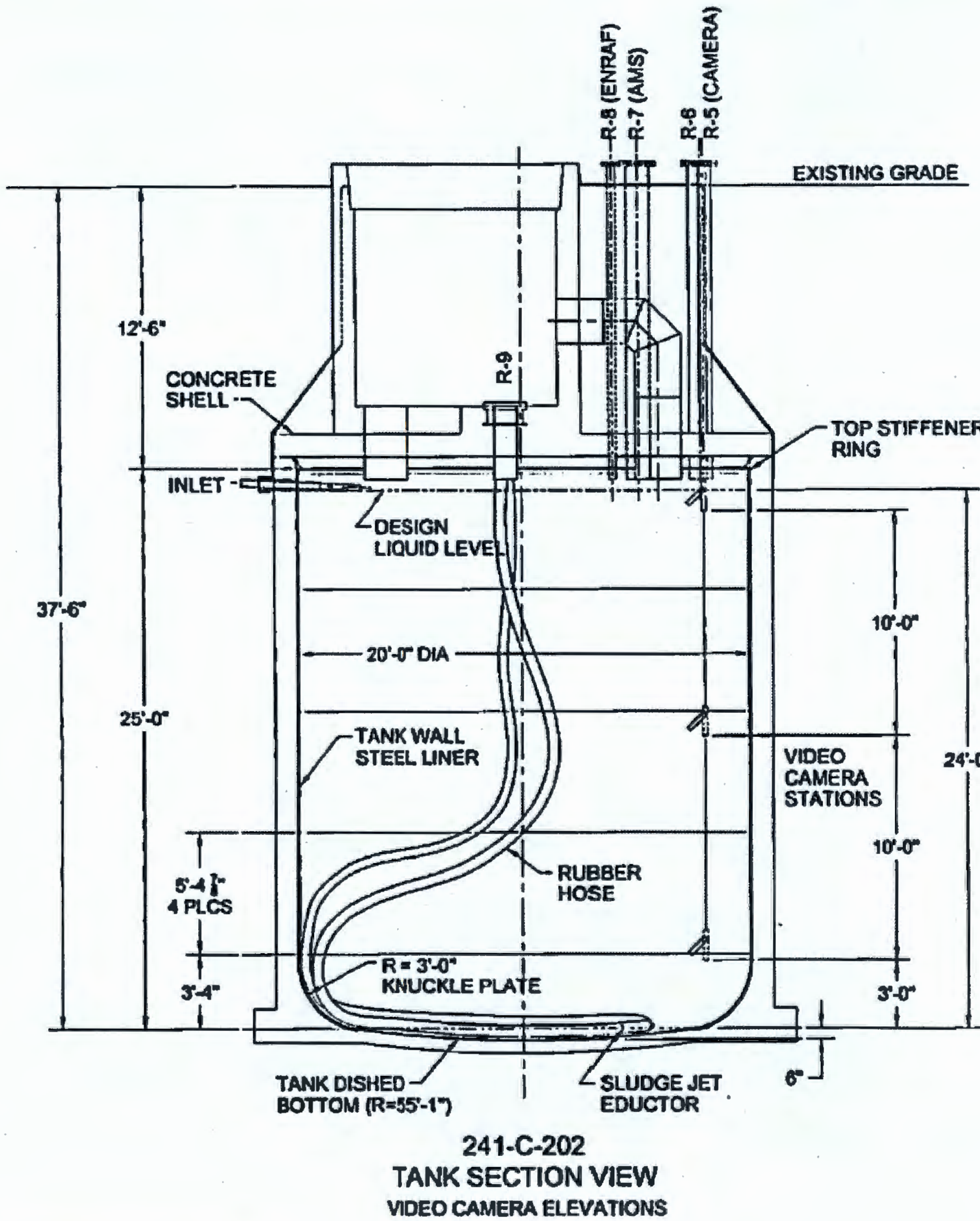
Autodesk® Land Desktop 2004, Release R16 software was used as part of the CCMS approach. Using the software, a 3-D model of the SST C-202 interior was built, volumes of residual waste formations in the bottom dish were modeled and determined, and a digital terrain model of the waste surface was built that was used to determine the overall volume of residual waste in the dish. Once the residual waste volume in the bottom of the dish is determined, the 95% upper confidence level (UCL) is determined using the following statistically based equation:

$$\textit{Actual Waste Volume @ 95\% UCL, } ft^3 = 1.043 \times \textit{CCMS In-Tank Volume Est. } ft^3 + 0.852\, ft^3$$

Autodesk® Land Desktop is a registered trademark of Autodesk, Inc., San Rafael, California.

The development of this regression equation is described in RPP-RPT-22891, *Revised Methodology to Calculating Residual Waste Volume at 95% Confidence Interval*, and has been adopted in RPP-23403.

Figure 6-1. Single-Shell Tank 241-C-202 Section View Showing Camera Elevations Used in August 19, 2005, Video Recording.



Video recordings taken on June 27, 2005 (before waste retrieval), and August 19, 2005 (after waste retrieval), showed that small amounts of waste remained on the SST C-202 wall. The total amount of waste on the wall, including the knuckle, was estimated by calculating the average waste thickness and percentage of waste coverage on the wall.

SST C-202 has a single stiffener ring located at the top of its steel liner, 25 ft 6 in. above the bottom of the tank (see Figure 6-1). A visual examination of the stiffener ring was conducted to determine the presence and size of any waste clumps or waste film on the ring.

The only pieces of equipment left in SST C-202 that had void space potentially containing waste were the AMS, the thermocouple tree, and a sludge jet eductor. The volume of residual waste left in this equipment was calculated by using (1) the in-tank video, (2) records identifying equipment remaining in the tank, (3) equipment drawings, and (4) process knowledge to estimate the dimensions of equipment and void spaces as well as debris.

6.2 VIDEO CAMERA/CAD MODELING SYSTEM RESULTS

Waste was retrieved from SST C-202 until the limits of the VRS technology were met. RPP-23403 defines the final residual waste volume as the residual waste volume in the tank dish at the 95% UCL (equation shown in Section 6.1.1) plus the actual residual waste volume on the stiffener rings, equipment void space, and tank walls. Using this definition, the upper bounding limit for post-retrieval waste in SST C-202 is estimated to be a volume no greater than 20.9 ft^3. Table 6-1 presents the total post-retrieval volume together with waste volumes associated with various tank components.

Table 6-1. Single-Shell Tank 241-C-202 Total Waste Volume and Component Waste Volumes.

Component	Waste Volume (ft^3)	Upper Bounding Estimate (ft^3)
In the bottom (dish) of the tank (solids and liquids)	8.5	9.7[a]
In equipment in the tank	6.1	N/A
On the stiffener ring	0	0
On the tank wall	5.1	N/A
Total[b]	19.7	20.9

[a] RPP-23403 estimated error for waste in bottom of tank is calculated using volume at 95% UCL, $ft^3 = 1.043 \times \text{volume}, ft^3 + 0.852\ ft^3$.

[b] Total of upper bounding estimate for volume in dish bottom and waste volumes for other components.

Residual solids in the tank bottom appeared uniformly spread out, covering most of the bottom dish at an average 1.25-in. thickness. A portion of the bottom dish was visible. Three small liquid pools were seen in the bottom dish on top of and around the solid waste layer. Two of the pools lie along the eductor piping, while the third lies in the northeast quadrant of the solid waste. Table 6-2 shows the volumes of solids and liquids estimated by the CCMS.

Table 6-2. Single-Shell Tank 241-C-202 Waste Volume in Tank Bottom.

Component	Waste Volume (ft^3)
Solid phase	8.2
Supernate phase	0.3
Total	8.5

The post-retrieval tank waste contour map (Figure 6-2) shows the configuration of residual waste in the dish bottom. The SST C-202 isometric model (Figure 6-3) portrays the volume of the residual waste in relation to the volume and configuration of the bottom dish and tank knuckle regions of SST C-202.

Figures 6-4 and 6-5 are still pictures taken from the August 11, 2005, video. They show portions of the tank wall and the tank bottom, respectively. Figures 6-6 and 6-7, taken from the August 19, 2005 video provide panoramic and close-up views of the tank bottom, respectively.

On completion of retrieval, the AMS was flushed and drained to remove any waste. It was assumed that no residual waste was then left in the AMS.

Before the waste retrieval campaign began, the thermocouple tree stood on the bottom of the tank with its top end leaning against the tank wall. During the campaign, it lay across the tank, with both ends placed above the waste in the bottom. Toward the end of retrieval operations, it was repositioned to allow waste around it to be retrieved. The top of the thermocouple tree remained above the waste at all times and away from retrieval activity; the thermocouple tree was therefore assumed to contain no residual waste.

The sludge jet eductor has a void space that was assumed to be filled with waste. The conservative estimate for residual waste in the void space of the sludge jet eductor was 6.1 ft^3.

Other equipment in the tank included sludge plummets previously used to measure sludge levels, steel tapes and cables, chunks of concrete, and a roll of tape. None of these items contained void spaces or hollow cores.

Evaluation of the August 19, 2005, video indicated that the knuckle region of SST C-202 was clean. Most of the waste from this region appears to have been rinsed or flushed into the tank dish. Small amounts of waste were observed on the remainder of the tank wall. The average thickness of this waste was estimated to be 1/16-in., based on the contrast of shadows cast by auxiliary lighting in the August 19, 2005 video. The percentage of tank wall above the dish covered by waste was conservatively estimated at 65%. An upper bounding percentage of wall covered was estimated at 70%. The 70% uncertainty is not additive with the upper bounding estimate for residual waste in the tank bottom because the two figures were calculated by numerically and qualitatively different methods.

Figure 6-2. Single-Shell Tank 241-C-202 Post-Retrieval Tank Waste Contour Map.

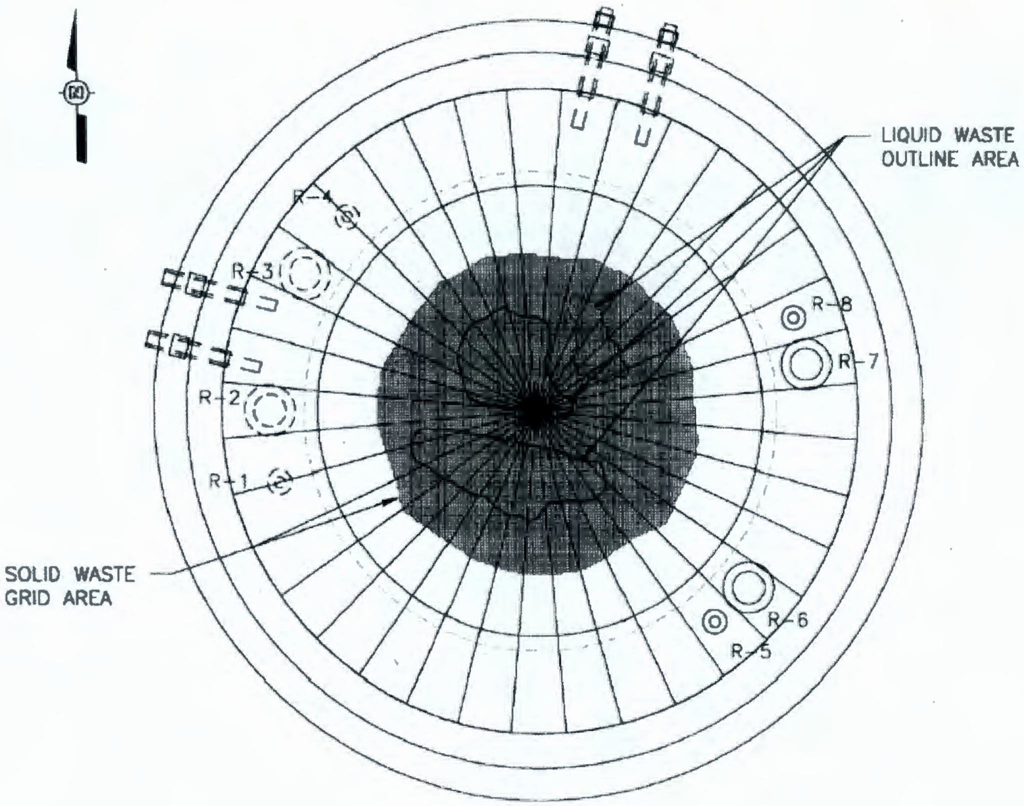


Figure 6-3. Single-Shell Tank 241-C-202 Post-Retrieval Tank Waste Digital Terrain Model.

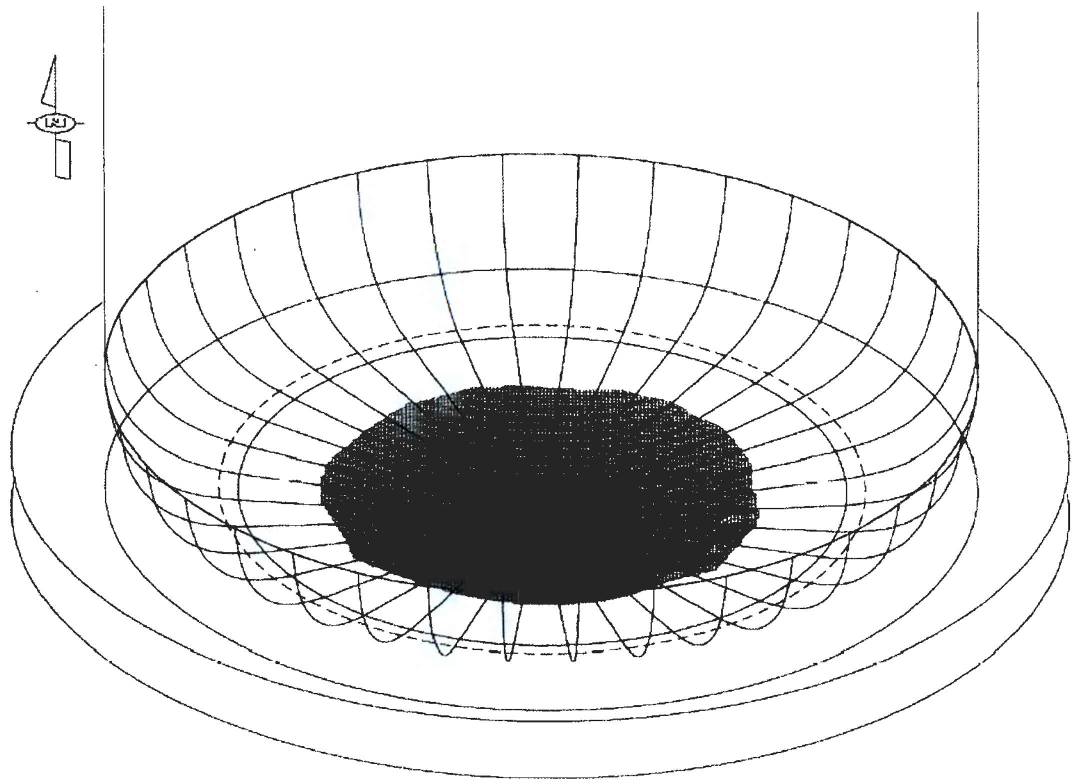


Figure 6-4. Portion of the Single-Shell Tank 241-C-202 on August 11, 2005.

Figure 6-5. Portion of the Single-Shell Tank 241-C-202 Bottom Dish on August 11, 2005.

Figure 6-6. Single-Shell Tank 241-C-202 Bottom from Camera Elevation of Approximately 23 Feet on August 19, 2005.

Figure 6-7. Single-Shell Tank 241-C-202 Bottom from Camera Elevation of Approximately 3 Feet on August 19, 2005.

SST C-202 has a single stiffener ring located 25 ft 6 in. above the tank bottom at the top of the tank liner. The tank overflow lines are located 1 ft below the stiffener ring, at 24 ft 6 in. above the tank bottom. The maximum historic level for waste stored in the tank was 24 ft. No waste was observed on the stiffener ring, and no waste is assumed to remain on it.

6.3 CONCLUSIONS

The calculated volume of residual waste in SST C-202 is 19.7 ft^3. The upper bounding estimate of the residual waste volume is 20.9 ft^3. Even using the upper bounding limits for residual waste, the total residual waste volume in SST C-202 is well below 30 ft^3.

The SST C-202 waste retrieval data and photographic information provided results that were consistent with the CCMS calculations regarding the residual volume in the tank dish.

7.0 RESIDUAL TANK WASTE CHARACTERIZATION

This section describes the results of residual tank waste characterization for SST C-202. Two statistical estimates of residual waste inventory based on laboratory analysis of waste samples taken after completion of retrieval are presented: an average and a 95% UCL inventory. The calculated inventories will be used as input for calculating the potential risk to human health that arises from the residual waste. This risk assessment is discussed in Section 8.0.

7.1 SAMPLING AND ANALYSIS OF RESIDUAL WASTE

The following three documents provide guidance and requirements for sampling and analysis of residual waste:

a. RPP-PLAN-23827, *Sampling and Analysis Plan for Single-Shell Tank (SST) Component Closure*. This document identifies regulatory requirements for field sampling, laboratory analysis, and data reporting for residual waste samples to ensure appropriate data are collected to support SST closure activities.

b. RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*. This document describes the sampling and analysis strategy, developed by implementing the DQO process, to ensure appropriate data are collected to support SST closure activities.

c. RPP-PLAN-23680, *Sampling and Analysis Plan for Residual Waste Solids in the C-200 Series Tanks*. This document summarizes the sampling and analysis requirements in the above documents and provides additional guidance and clarification for satisfying the requirements. The guidance and clarification are necessary to address conditions that are specific to the C-200 series tanks including SSTs C-201, 202, 203, and 204.

Collection and analysis of the SST C-202 residual waste samples and calculations of the constituent inventories based on the sample results are described in RPP-RPT-29202, *Tank 241-C-202 Residual Waste Inventory Estimates for Component Closure Risk Assessment,* and summarized in Sections 7.2 through 7.4.

7.2 SAMPLING AT SINGLE-SHELL TANK C-202

The finger trap method was used to obtain samples of residual waste in SST C-202. This is one of two methods considered acceptable for collecting samples of residual solids in a tank (RPP-23403). Sampling of the residual waste in SST C-202 was conducted initially on November 8, 2005. A video camera was used to guide the sampling effort. Five finger trap grabs were collected on that day. The amounts of solids obtained were insufficient for analysis (6.5 to 30.8 g per sample). Four more samples were collected on November 10, 2005. Minor adjustments were made to the sampling technique, and substantially better solids recoveries were achieved with these later samples. Two composites were prepared: one composite from the five finger trap grabs taken on day 1 and another from the four finger trap grabs taken on day 2. The composite samples were analyzed in accordance with the guidance documents.

7.3 SAMPLE ANALYSES

The 222-S Laboratory at Hanford used 21 analysis techniques to obtain the concentration of various organic constituents, inorganic constituents, and radionuclides. A list of the techniques is presented in Table 7-1. Analysis of the samples resulted in concentration estimates for 158 constituents in the SST C-202 residual waste. A description of the analysis techniques and analytical data appears in RPP-RPT-26925, *Final Report for Tank 241-C-202 Post-Retrieval Solid Finger Trap Grab Samples*. Electronic data were also loaded into TWINS.

The 222-S Laboratory maintains a quality assurance (QA) program to ensure data quality (ATL-MP-1011, *ATL Quality Assurance Project Plan for 222-S Laboratory*). The analyses were performed according to the QA program requirements. In addition, the DQO (RPP-23403) specifies quality control criteria (e.g., standard recovery, matrix spike recovery, relative difference between duplicate analyses) that are specific to the closure project. The DQO also provides direction for addressing data that do not meet the criteria. Results for most constituents satisfied the DQO criteria; those that did not meet the criteria were addressed according to the direction provided in the DQO. RPP-PLAN-23827 contains the same data quality requirements as the DQO. The sample data were evaluated against the requirements in RPP-PLAN-23827 and judged acceptable for use in the risk assessment.

Estimates of average concentrations and uncertainty in the concentration estimates (presented as relative standard deviation) are shown in Appendix A, Table A-1.

7.4 COMPUTATION OF RESIDUAL INVENTORY

This section describes the method for calculating two inventories: an average inventory and the 95% UCL inventory. The average inventory for residual waste constituents in SST C-202 was calculated by multiplying the mean concentration, the mean density, and the waste volume (i.e., inventory = concentration x density x volume). Because residual waste concentration data were reported on a per unit weight basis (see Table A-1 in Appendix A), a mean density was used to convert the concentration data to a per unit volume basis.

Analytical data and the statistical model used for estimating the means and standard deviations for concentration, density, and waste volumes are discussed in RPP-RPT-29202. For constituents that had concentrations below the detection limits, the value of the detection limits were used for calculating the mean concentrations. In accordance with BBI protocol, the relative standard deviations for nondetected constituents are assumed to be 100% (RPP-6924, *Statistical Methods for Estimating the Uncertainty in the Best-Basis Inventories*).

The 95% UCL inventory is an upper-bounding estimate of the inventory; it was calculated using a statistical method described in RPP-6924. The input for this calculation includes the means and standard deviations for sample concentrations, sample density, and total residual waste volume. Details of the method and formula used for deriving this inventory are described in RPP-RPT-29202.

Estimates of the average inventory and the 95% UCL inventory for the SST C-202 residual waste constituents are presented in Appendix A, Tables A-2 and A-3.

Table 7-1. Single-Shell Tank C-202 Residual Waste Sample Analysis Techniques.

Analysis Technique	SW-846 Method[a]	Constituents
Inorganic Analyses		
Gravimetric	Not applicable	Bulk density
pH measurement	9045C	pH
Ion selective electrode	9215	Sulfide
Thermogravimetric analysis	Not applicable	Weight percent water
Spectrophotometric	9014	Cyanide
Cold vapor atomic absorption	7471A	Mercury
Ion chromatography	EPA 300.7	Ammonium
Ion chromatography	9056	Anions
Inductively coupled plasma/mass spectrometry	6020	Uranium, neptunium, thorium isotopes, technetium-99
Inductively coupled plasma/atomic emission spectrometry	6010B	Cations (metals)
Radiochemical Analyses		
Gamma energy analysis	Not applicable	Gamma-energy emitters
Separation/beta counting	Not applicable	Strontium-90
Liquid scintillation	Not applicable	Carbon-14
Separation/gamma energy analysis	Not applicable	Iodine-129
Liquid scintillation	Not applicable	Selenium-79
Liquid scintillation	Not applicable	Tritium
Alpha energy analysis	Not applicable	Alpha-energy emitters
Liquid scintillation	Not applicable	Nickel-63
Organic Analyses		
Volatile organic analysis by gas chromatography/mass spectrometry	8260B	Volatile organic compounds
Semivolatile organic analysis by gas chromatography/mass spectrometry	8270C	Semivolatile organic compounds
Gas chromatography/electron capture detection	8082	Polychlorinated biphenyls

[a] SW-846, *Test Method for Evaluating Solid Waste, Physical/Chemical Method.*

8.0 POST-RETRIEVAL SINGLE-SHELL TANK 241-C-202 RISK ASSESSMENT

The potential impacts to human health posed by the residual waste in SST C-202 were calculated using the methodology documented in DOE/ORP-2005-01, *Single-Shell Tank Performance Assessment*. Figure 8-1 provides a schematic of the process used for the SST C-202 risk assessment, and this methodology is described in detail in Chapter 3 of DOE/ORP-2005-01. It should be noted that the DOE/ORP-2005-01 methodology supersedes the WMA C risk assessment methodology provided in RPP-13774, *Single-Shell Tank System Closure Plan*.

As noted above, the risk assessment results presented in this RDR were developed using the same methodology as that used in DOE/ORP-2005-01. However, the source term used in this SST C-202 risk assessment was derived from post-retrieval measured residual waste volume (see Section 6.0) and post-retrieval sample results (see Section 7.0) that were not available for use in DOE/ORP-2005-01. The source term presented in this RDR will be incorporated into future revisions of DOE/ORP-2005-01 and the WMA C performance assessment.

Effects were calculated using the nominal and 95% UCL inventory. Results show that for the groundwater pathway the effects associated with SST C-202 were well below performance objectives. For all inadvertent intruder scenarios other than the suburban garden scenario (a sensitivity case) at 100 years after closure, the effects associated with SST C-202 were well below performance objectives. For the suburban garden scenario at 500 years after closure, the effects are below performance objectives.

8.1 CONSTITUENTS EVALUATED

Following retrieval, the residual waste was sampled and analyzed. This risk assessment is based on the analytical results from the post-retrieval sample (Section 7.0).

Analytical data for SST C-202 were collected and analyzed as defined by the closure data quality objectives. The post-retrieval samples were analyzed for 160 constituents [i.e., radionuclides, volatile organic compounds, semivolatile organic compounds, polychlorinated biphenyls, and inorganics (including metals and conventional parameters)] in accordance with approved 222-S Laboratory procedures based on U.S. Environmental Protection Agency (EPA) approved methods. However, analytes flagged as a nondetect were evaluated at one-half the detection limit in accordance with EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final*. Table 8-1 presents a complete listing of the analytes evaluated, whether or not the analyte was detected, and whether a radiological dose, reference dose, or cancer potency factor is published for that analyte.

Figure 8-1. Single-Shell Tank C-202 Residual Waste Inventory and Risk Assessment Process.

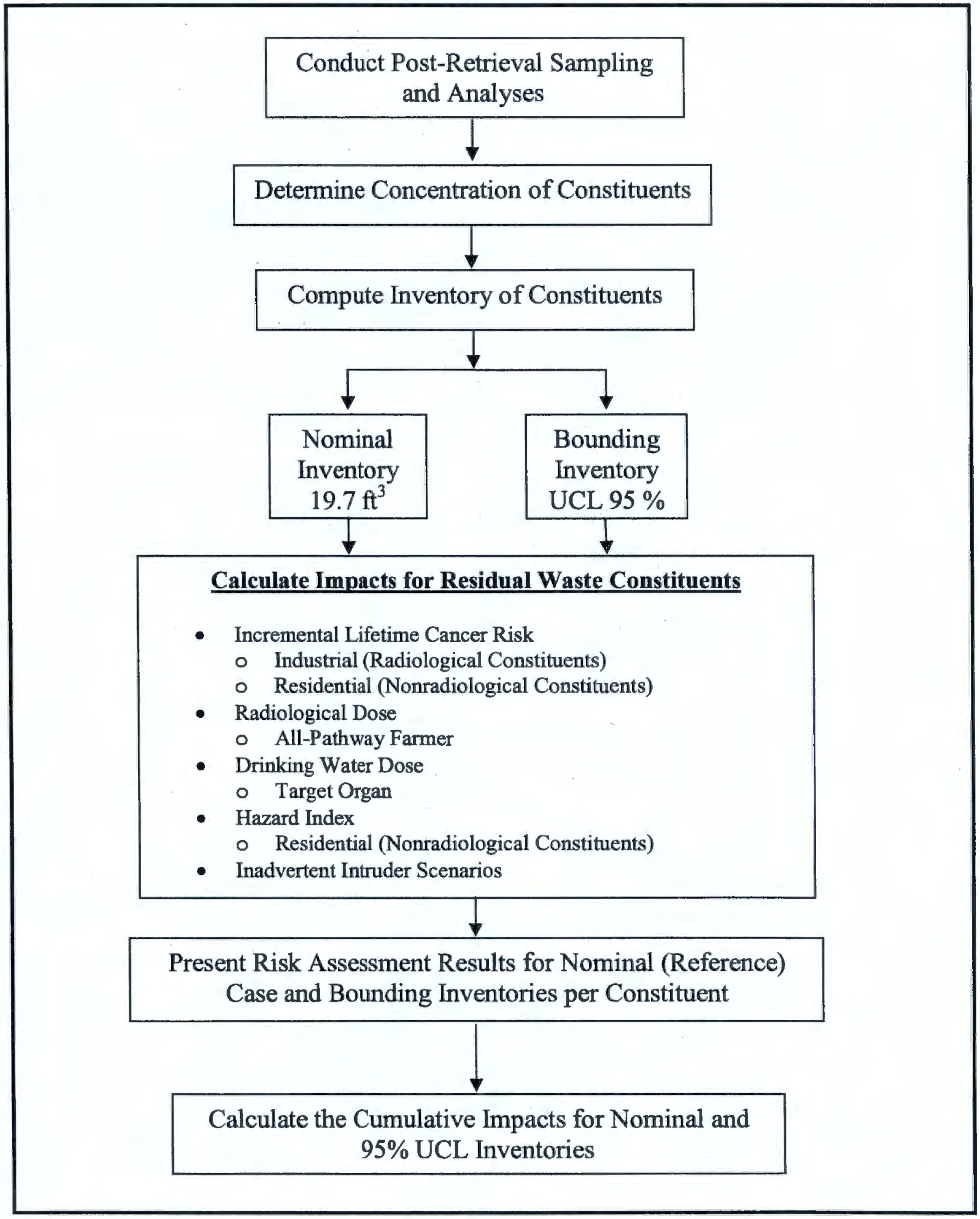


Table 8-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte	Available Toxicity Information	Isotope/ CAS	Analyte	Available Toxicity Information
^{63}Ni	Nickel-63	Dose/CPF	7782-49-2	Selenium	Rfd
^{90}Sr	Strontium-89/90	Dose/CPF	7440-22-4	Silver	Rfd
^{99}Tc	Technetium-99	Dose/CPF	7440-28-0	Thallium	Rfd
^{129}I	Iodine-129	Dose/CPF	7440-62-2	Vanadium	Rfd
^{137}Cs	Cesium-137	Dose/CPF	71-55-6	1,1,1-Trichloroethane	Rfd
^{228}Th	Thorium-228	Dose/CPF	76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	Rfd
^{232}Th	Thorium-232	Dose/CPF	75-35-4	1,1-Dichloroethene	Rfd
^{234}U	Uranium-234	Dose/CPF	120-82-1	1,2,4-Trichlorobenzene	Rfd
^{235}U	Uranium-235	Dose/CPF	95-95-4	2,4,5-Trichlorophenol	Rfd
236U	Uranium-236	Dose/CPF	121-14-2	2,4-Dinitrotoluene	Rfd
^{238}U	Uranium-238	Dose/CPF	95-57-8	2-Chlorophenol	Rfd
^{237}Np	Neptunium-237	Dose/CPF	110-80-5	2-Ethoxyethanol	Rfd
^{239}Pu	Plutonium-239	Dose/CPF	95-48-7	2-Methylphenol	Rfd
^{240}Pu	Plutonium-240	Dose/CPF	106-44-5	Cresol (p)	Rfd
^{241}Pu	Plutonium-241	Dose/CPF	83-32-9	Acenaphthene	Rfd
^{241}Am	Americium-241	Dose/CPF	85-68-7	Butylbenzylphthalate	Rfd
7429-90-5	Aluminum	Rfd	75-15-0	Carbon disulfide	Rfd
7440-39-3	Barium	Rfd	108-90-7	Chlorobenzene	Rfd
7440-43-9	Cadmium	Rfd	108-94-1	Cyclohexanone	Rfd
18540-29-9	Chromium	Rfd	60-29-7	Ethyl ether	Rfd
7440-48-4	Cobalt	Rfd	84-74-2	Di-n-butylphthalate	Rfd
7440-50-8	Copper	Rfd	117-84-0	Di-n-octylphthalate	Rfd
57-12-5	Cyanide	Rfd	141-78-6	Ethyl acetate	Rfd
16984-48-8	Fluoride	Rfd	100-41-4	Ethylbenzene	Rfd

Table 8-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte	Available Toxicity Information	Isotope/ CAS	Analyte	Available Toxicity Information
7439-89-6	Iron	Rfd	206-44-0	Fluoranthene	Rfd
7439-96-5	Manganese	Rfd	78-83-1	Isobutanol	Rfd
7440-02-0	Nickel	Rfd	108-39-4	Cresol (m)	Rfd
14797-55-8	Nitrate	Rfd	108-38-3	Xylene (m)	Rfd
14797-65-0	Nitrite	Rfd	91-20-3	Naphthalene	Rfd
7723-14-0	Phosphorus	Rfd	71-36-3	1-Butanol	Rfd
7440-24-6	Strontium	Rfd	98-95-3	Nitrobenzene	Rfd
7440-31-5	Tin	Rfd	95-50-1	1,2-Dichlorobenzene	Rfd
7440-61-1	Uranium	Rfd	95-47-6	Xylene (o)	Rfd
7440-66-6	Zinc	Rfd	108-95-2	Phenol	Rfd
78-93-3	2-Butanone	Rfd	106-42-3	Xylene (p)	Rfd
67-64-1	Acetone	Rfd	129-00-0	Pyrene	Rfd
108-10-1	Hexone	Rfd	110-86-1	Pyridine	Rfd
126-73-8	Tributyl phosphate	RfD/CPF	108-88-3	Toluene	Rfd
14798-03-9	Ammonium ion by ion chromatography	No RfD or CPF	75-69-4	Trichlorofluoromethane	Rfd
7440-69-9	Bismuth	No RfD or CPF	1330-20-7	Xylenes (total)	Rfd
7440-70-2	Calcium	No RfD or CPF	7440-38-2	Arsenic	RfD/CPF
16887-00-6	Chloride	No RfD or CPF	79-34-5	1,1,2,2-Tetrachloroethane	RfD/CPF
7440-53-1	Europium	No RfD or CPF	79-00-5	1,1,2-Trichloroethane	RfD/CPF
12311-97-6	Formate	No RfD or CPF	79-01-6	Trichloroethene	RfD/CPF
7439-92-1	Lead	No RfD or CPF	107-06-2	1,2-Dichloroethane	RfD/CPF

Table 8-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte	Available Toxicity Information	Isotope/ CAS	Analyte	Available Toxicity Information
7439-95-4	Magnesium	No RfD or CPF	106-46-7	1,4-Dichlorobenzene	RfD/CPF
7439-97-6	Mercury	No RfD or CPF	88-06-2	2,4,6-Trichlorophenol	RfD/CPF
338-70-5	Oxalate	No RfD or CPF	71-43-2	Benzene	RfD/CPF
14265-44-2	Phosphate	No RfD or CPF	56-23-5	Carbon tetrachloride	RfD/CPF
7440-10-0	Praseodymium	No RfD or CPF	75-01-4	Vinyl chloride	RfD/CPF
7440-21-3	Silicon	No RfD or CPF	67-66-3	Chloroform	RfD/CPF
7440-23-5	Sodium	No RfD or CPF	75-09-2	Methylenechloride	RfD/CPF
14808-79-8	Sulfate	No RfD or CPF	87-68-3	Hexachlorobutadiene	RfD/CPF
7704-34-9	Sulfur	No RfD or CPF	67-72-1	Hexachloroethane	RfD/CPF
7440-29-1	Thorium	No RfD or CPF	87-86-5	Pentachlorophenol	RfD/CPF
7440-32-6	Titanium	No RfD or CPF	127-18-4	Tetrachloroethene	RfD/CPF
7440-67-7	Zirconium	No RfD or CPF	542-75-6	Trans-1,3-Dichloropropene	RfD/CPF
71-50-1	Acetate	No RfD or CPF	24959-67-9	Bromide	No RfD or CPF
100-02-7	4-Nitrophenol	No RfD or CPF	7440-45-1	Cerium	No RfD or CPF
^{3}H	Tritium	Dose/CPF	7439-91-0	Lanthanum	No RfD or CPF
^{14}C	Carbon-14	Dose/CPF	7440-00-8	Neodymium	No RfD or CPF

Table 8-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte	Available Toxicity Information	Isotope/ CAS	Analyte	Available Toxicity Information
^{60}Co	Cobalt-60	Dose/CPF	7440-03-1	Niobium	No RfD or CPF
^{79}Se	Selenium-79	Dose/CPF	7440-05-3	Palladium	No RfD or CPF
^{125}Sb	Antimony-125	Dose/CPF	7440-09-7	Potassium	No RfD or CPF
^{152}Eu	Europium-152	Dose/CPF	7440-16-6	Rhodium	No RfD or CPF
^{154}Eu	Europium-154	Dose/CPF	7440-17-7	Rubidium	No RfD or CPF
^{155}Eu	Europium-155	Dose/CPF	7440-18-8	Ruthenium	No RfD or CPF
^{230}Th	Thorium-230	Dose/CPF	7440-19-9	Samarium	No RfD or CPF
^{233}U	Uranium-233	Dose/CPF	18496-25-8	Sulfide	No RfD or CPF
^{238}Pu	Plutonium-238	Dose/CPF	7440-25-7	Tantalum	No RfD or CPF
^{242}Cm	Curium-242	Dose/CPF	13494-80-9	Tellurium	No RfD or CPF
^{243}Cm	Curium-243	Dose/CPF	7440-33-7	Tungsten	No RfD or CPF
^{244}Cm	Curium-244	Dose/CPF	7440-65-5	Yttrium	No RfD or CPF
621-64-7	N-Nitroso-di-n-propylamine	CPF	128-37-0	2,6-Bis(1,1-dimethylethyl)-4-methylphenol	No RfD or CPF
1336-36-3	Aroclors (total PCB)	CPF	79-46-9	2-Nitropropane	No RfD or CPF
7440-36-0	Antimony	Rfd	1319-77-3	Cresol	No RfD or CPF
7440-41-7	Beryllium	Rfd	GLYCOLATE	Glycolate	No RfD or CPF

Table 8-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte	Available Toxicity Information	Isotope/ CAS	Analyte	Available Toxicity Information
7440-42-8	Boron	Rfd	59-89-2	Morpholine, 4-nitroso-	No RfD or CPF
7439-93-2	Lithium	Rfd	88-75-5	2-Nitrophenol	No RfD or CPF
7439-98-7	Molybdenum	Rfd	59-50-7	4-Chloro-3-methylphenol	No RfD or CPF

Notes:
CPF = cancer potency factor available
Dose = radiological dose value available
RfD = reference dose value available
No RfD/CPF = no published information for a reference dose or cancer potency factor for this chemical.
Gray shaded area indicates nondetect for this analyte

8.2 RESULTS FOR INDIVIDUAL CONTAMINANTS FOR POST-RETRIEVAL SINGLE-SHELL TANK 241-C-202

Table 8-2 identifies the main contributors to the incremental lifetime cancer risk (ILCR) (industrial and residential scenarios), groundwater dose [all pathways farmer (APF) scenario], and drinking water dose for radiological components of the residual waste remaining in SST C-202. Table 8-3 identifies the primary hazardous chemicals that contribute to ILCR and the Hazard Quotient. A complete listing of all analytes for which there is either a dose (radiological), cancer potency factor (radiological and nonradiological) and reference dose (nonradiological) is provided in Tables A-1 and A-2 of Appendix A. In each of these tables, the following columns are provided.

a. **Analyte Name**.
b. **Detect** is an indicator as to whether an analyte was detected in the laboratory.
c. **Inventory**. The inventory shown here for nondetects is calculated at one-half the detection limit.
d. **WMA C Fenceline Concentration** is the maximum modeled concentration for a constituent at the WMA C fenceline over the modeling period. In some cases, individual analytes may not have a corresponding concentration at the fenceline because short-lived radionuclides will decay away before the contaminant can arrive at the WMA C fenceline. Relatively immobile contaminants (i.e., K_d greater than 0.6 mg/L) will also result in a zero concentration at the fenceline as they will not reach the fenceline within 10,000 years (based on assumptions and transport modeling approach used).
e. **Peak Year** is the year in which the simulation estimates that peak concentration for a given analyte arrives at the fenceline.

Table 8-2. Estimated Maximum Incremental Lifetime Cancer Risk/Radiological Dose During the Modeling Period for Primary Radionuclides.

Analyte	Detect	Inventory (Ci)	WMA C Fenceline Conc. (pCi/L)	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Lifetime Cancer Risk Scenarios (Groundwater)[b]		Radiological Dose Groundwater (mrem/yr)[b]	Radiological Dose Beta/Photon (mrem/yr)[b]
							Industrial	Residential	All Pathway Farmer	Drinking Water
^{99}Tc	Yes	2.55E-03	1.02E-02	10461	0	2.11E+05	1.40E-10	3.42E-09	1.78E-05	4.53E-05
^{129}I	Yes	7.49E-06	<0.001[c]	DNA	0.2	1.57E+07	Dropped[d]	Dropped[d]	Dropped[d]	Dropped[d]
^{234}U	Yes	3.59E-02	0	DNA	0.6	2.46E+05	0	0	0	N/A
$^{235+D}$U	Yes	1.45E-03	0	DNA	0.6	7.04E+08	0	0	0	N/A
^{236}U	Yes	3.59E-04	0	DNA	0.6	2.34E+07	0	0	0	N/A
$^{238+D}$U	Yes	3.35E-02	0	DNA	0.6	4.47E+09	0	0	0	N/A
^{14}C	No	2.57E-04	<0.001[c]	9781	0	5.73E+03	Dropped[d]	Dropped[d]	Dropped[d]	Dropped[d]
^{233}U	No	1.79E-02	0		0.6	1.59E+05	0	0	0	N/A
Performance objective[e]							1-0E-6 to 1.0E-4[f]	1-0E-6 to 1.0E-4[f]	25[g]	4[h]

[a] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, for the basis for the K_d values listed for the radionuclides.

[b] All exposure scenarios are described in HNF-SD-WM-TI-707.

[c] Simulation predicted contaminant arrives at the fenceline, but at a concentration (0.001 pCi/L) that is much below the minimum detection limit for standard analytical methods.

[d] Dropped from the analysis because the simulation predicted concentration (0.001 pCi/L) is much below the minimum detection limit for standard analytical methods.

[e] Performance objectives apply to the cumulative (i.e., all contaminants) for the entire WMA.

[f] EPA/540/R-99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A, Directive* 9200.4-31P.

[g] DOE O 435.1, *Radioactive Waste Management.*

[h] 66 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

Notes:

DNA = did not arrive at fenceline within the modeling period

N/A = radionuclide is not a beta/photon emitter.

Shaded cells are nondetects and the inventory used in the risk assessment is calculated at one-half the minimum detection limit.

Table 8-3. Estimated Maximum Value for Incremental Lifetime Cancer Risk and Hazard Quotient per Nonradionuclides. (2 sheets)

Analyte	Detected	Inventory (kg)	WMA C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[a]	Incremental Lifetime Cancer Risk Scenarios (Groundwater)[b]	Hazard Quotient Scenarios (Groundwater)[b]
						WAC-173-340 Method B	WAC-173-340 Method B
Chromium	Yes	9.27	0.0381	10481	0	No CPF	9.79E-04
Fluoride	Yes	2.31	0.00948	10481	0	No CPF	9.88E-06
Nitrite	Yes	0.46	0.00189	10481	0	No CPF	1.18E-06
Nitrate	Yes	1.27	0.00523	10481	0	No CPF	2.04E-07
Tributyl phosphate	Yes	5.41	0	DNA	0.6	0	0
n-Butyl alcohol (1-butanol)	No	0.59	0.00242	10481	0	No CPF	1.51E-06
Isobutanol	No	0.78	0.00319	10481	0	No CPF	6.64E-07
2-Ethoxyethanol	No	0.32	0.0013	10481	0	No CPF	2.03E-07
Cyclohexanone	No	0.95	0.00391	10481	0	No CPF	4.89E-08
N-nitroso-di-n-propylamine	No	0.59	<0.001[c]	10481	0	Dropped[d]	No RfD
Performance objective[e]						1.0E-06[f]	1.0[g]

Notes: See next page

Table 8-3. Estimated Maximum Value for Incremental Lifetime Cancer Risk and Hazard Quotient per Nonradionuclides. (2 sheets)

[a] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, for the basis for the K_d values listed for chromium and nitrate. The K_d values listed for the organic chemical compounds are determined from the chemicals' organic carbon/water partitioning coefficient and an estimate of 0.03% for the Hanford Site sediments fraction of organic content (PNNL-13895, Rev. 1, page 11, paragraph 3).
[b] All exposure scenarios are described in HNF-SD-WM-TI-707.
[c] Simulation predicted contaminant arrives at the fenceline, but at a concentration (0.001 µg/L) that is much below the minimum detection limit for standard analytical methods.
[d] Dropped from the analysis because the simulation predicted concentration (0.001 µg/L) is much below the minimum detection limit for standard analytical methods.
[e] Single Analyte Performance objectives apply to entire WMA, not just a single component of the WMA.
[f] *Washington Administrative Code* (WAC) 173-340-705 (2)(c)(ii), "Dangerous Waste Regulations."
[g] WAC 173-340-705 (2)(c)(i).

Notes:
No CPF = no cancer potency factor available.
No RfD = no reference dose available
DNA = did not arrive at fenceline within the modeling period
Gray shaded cells are nondetects and the inventory used in the risk assessment is calculated at one-half the minimum detection limit.

f. **K_d** is the mobility factor used in the groundwater modeling for the analyte. The smaller the K_d, the more mobile the contaminant; if the K_d is zero, the contaminant moves with the groundwater.

g. **Half-life** is the duration in years for a radionuclide to decay to half its activity. Organic compounds were assumed not to decay (radionuclides only).

h. **ILCR Scenarios** (groundwater) are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Dose Factors for Hanford Tank Waste Performance Assessments*, for the industrial and residential exposure scenarios [including WAC-173-340 Method B (residential)].

i. **Radiological Dose Groundwater** is the estimated drinking water dose for the APF exposure scenario (radionuclides only).

j. **Radiological Dose Beta/Photon** is the drinking water dose for radionuclides using equivalent dose (radionuclides only).

k. **Hazard Quotient Scenarios** are for residential and industrial scenarios described in HNF-SD-WM-TI-707.

8.3 CUMULATIVE ANALYSIS RESULTS FOR TANK C-202 AND WASTE MANAGEMENT AREA C

The cumulative analysis (i.e., sum of the risk metrics) for the SST C-202 residual nominal and 95% UCL risk levels were calculated and are provided in this section.

a. **Nominal Inventory**—best estimate of the residual waste inventory computed using mean sample concentrations, mean sample density, and best estimate of the residual volume.

b. **95% Upper Confidence Level Inventory**—considered the bounding inventory. The 95% UCL of the nominal inventory was calculated based on uncertainties associated with the concentration, volume, and density (for solids) measurements (see Section 7.0).

The effects per performance metric associated with each inventory are given in Table 8-4. Two land use scenarios (industrial and residential) were evaluated for HI and ILCR. All effects for both the nominal and 95% UCL inventories were two to four orders of magnitude below the performance objectives.

8.4 INADVERTENT INTRUDER

DOE recognizes that an inadvertent intruder may be onsite and not be discovered until after exposure has occurred. The radiological dose to an inadvertent intruder is therefore estimated as a part of this risk assessment.

The rural farmer with a dairy cow scenario was considered as the reference case in the SST performance assessment (PA), while the suburban garden and commercial farmer scenarios were sensitivity cases in the SST PA.

Table 8-4. Cumulative Incremental Lifetime Cancer Risk, Hazard Index, and Radiological Drinking Water Dose from Peak Groundwater Concentration Related to Residual Waste Volume in Single-Shell Tank C-202.

Metric[a]	Industrial Receptor		Residential Receptor		Performance Objective[b]
	Nominal	Bounding	Nominal	Bounding	
Radioactive chemicals ILCR (unitless)	1.40E-10[c] (1.40E-10)[c,d]	2.16E-10[c] (2.25E-10)[c,d]	3.42E-09[c] (3.44E-09)[c,d]	5.27E-09[c] (5.34E-09)[c,d]	1.0E-06 to 1.0E-4[e]
Nonradioactive chemicals ILCR (unitless)			Dropped[f]	Dropped[f]	1.0E-5[g]
Hazard Index (unitless)			9.90E-04[c] (1.00E-3)[c,d]	1.08E-03[c] (1.09E-3)[c,d]	1.0[g]
Dose	**Nominal**		**Bounding**		**Dose**
APF (mrem/yr)	1.97E-5[c] (1.97E-5)[c,d]		2.8E-05[c] (3.31E-5)[c,d]		25 mrem/yr[h]
EPA maximum contaminant level (MCL) beta/photon emitters (mrem/yr target organ dose)	4.53E-5[c] (4.53E-5)[c,d]		6.98E-05[c] (7.21E-5)[c,d]		4 mrem/yr[i]
Groundwater Concentration	**Nominal**		**Bounding**		**MCL**
^{99}Tc (pCi/L)	1.0E-2		1.6E-2		900 pCi/L
^{129}I (pCi/L)	<0.001 pCi/L		<0.001 pCi/L		1 pCi/L
^{14}C (pCi/L) (not detected)	<0.001 pCi/L		1.2E-03 pCi/L		2000 pCi/L
Chromium (μg/L)	3.8E-02		4.2E-02		100 μg/L
Uranium (μg/L)	0.0		0.0		30 μg/L

[a] Metric ILCR-rad were evaluated using industrial and residential land use scenarios described in HNF-SD-WM-TI-707. ILCR-nonrad and Hazard Index were evaluated using WAC 173-340-705 (4) Method B (residential).
[b] Performance objectives apply to entire WMA, not just a single component of the WMA.
[c] Analytes with a fenceline concentration of less than either 0.001 pCi/L (radioactive) or 0.001 μg/L (nonradioactive), which is a value that is well below the minimum detection limit for standard analytical methods, are not included in the total.
[d] Total in parenthesis includes nondetects with inventory calculated at one-half the detection limit.
[e] EPA/540/R-99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A, Directive 9200.4-31P.*
[f] Dropped from the analyses because no analyte with a cancer slope factor was predicted to have a concentration >0.001 μg/L which is a value that is well below the minimum detection limit for standard analytical methods.
[g] WAC 173-340-705 (4).
[h] DOE O 435.1, *Radioactive Waste Management.*
[i] 66 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

The dose calculated for each of the intruder scenarios in Table 8-5 are for the nominal and bounding inventories at 100 years and 500 years after closure. At 100 years after closure, the rural pasture, well driller, and commercial farmer are approximately three, 30, and 1,000 times below the performance objectives, respectively. However, the suburban garden scenario is approximately five times the performance objective. At 500 years after closure, all inadvertent intruder scenarios are below the performance objective.

Table 8-5. Intruder Dose Summary for Single-Shell Tank C-202.

Years after Closure	Inventory	Inadvertent Intruder Scenario			
		SST PA Reference Case		SST PA Sensitivity Cases	
		Well Driller (mrem)	Rural Pasture (mrem/yr)	Suburban Garden (mrem/yr)	Commercial Farm (mrem/yr)
100	Nominal	12.9	32.6	489	0.094
	95% UCL	15.4	35.8	539	0.118
500	Nominal	11	3.1	69	0.088
	95% UCL	13	3.7	81	0.1

Notes:
Site closure is assumed to occur on January 1, 2032.
The performance objective for the well driller is 500 mrem. The performance objective for the other scenarios is 100 mrem/yr

8.5 SUMMARY

This risk assessment is summarized in the following:

a. The effects estimated for SST C-202, using the nominal inventory, are three to four orders of magnitude below the performance objectives for the groundwater pathway.

b. The following analytes had the most impact per performance metric (nominal inventory):

1. **ILCR-Rad:** For the nominal inventory, ^{99}Tc contributed 100% of the total for both the industrial land use and residential land use scenarios.

2. **ILCR-Nonrad:** No analytes (either detected or un-detected) with a CPF had a fenceline concentration greater than 1.0E-03 µg/L, which is much lower than minimum detection limit for standard laboratory analytical methods.

3. **HI:** Cr^{+6} and fluoride contributed 99% and 1%, respectively, of the total for WAC-173-340 Method B.

4. **APF:** ^{99}Tc 100% of the total for the APF. Although the model predicted ^{14}C would arrive at the WMA C fenceline, its concentration would not be above 0.001 pCi/L, which is well below the minimum detection limit for standard laboratory analytical methods.

5. **Drinking Water Dose (Target Organ):** ^{99}Tc 100% of the total for the APF. Although the model predicted ^{14}C would arrive at the WMA C fenceline, its concentration would not be above 0.001 pCi/L, which is well below the minimum detection limit for standard laboratory analytical methods.

6. **Intruder Dose:** ^{137}Cs, ^{90}Sr, and plutonium isotopes contribute most of the dose in the first 300 years; after 200 years, plutonium isotopes are responsible for intruder dose.

c. Table 8-6 provides a comparison of the inventory used in DOE/ORP-2005-01 against the inventory for detected analytes calculated using the post-retrieval sample for the nominal inventory and the bounding inventory. For the most part there is good agreement between the HTWOS predicted inventory value and the inventory from the post-retrieval sample and residual volume. The difference in the ratios between HTWOS predicted inventory assumed a dry retrieval method and that there would be no preferential removal of the contaminants.

Table 8-6. Comparison of HTWOS Predicted Inventory used in DOE/ORP-2005-01 and the Nominal Post-Retrieval Inventory.

	Analyte	DOE/ORP-2005-01[a] (HTWOS Predicted)	Nominal Post-Retrieval[a] Inventory	95% UCL Inventory	Ratio Nominal/ HTWOS	Ratio Bounding/ HTWOS
Groundwater	^{14}C (Ci)	2.89E-04	2.57E-04	7.71E-04	N/A	N/A
	^{99}Tc (Ci)	1.13E-02	2.55E-03	3.93E-03	0.226	0.348
	Cr^{+6} (kg)	6.32E+00	9.27E+00	1.02E+01	1.467	1.614
	Fluoride (kg)	2.28E+00	2.31E+00	2.89E+00	1.013	1.268
	Nitrate (kg)	7.77E+01	1.27E+00	1.77E+00	0.016	0.023
	Nitrite (kg)	2.54E+01	4.60E-01	6.77E-01	0.018	0.027
Inadvertent Intruder	^{90}Sr + D (Ci)	2.04E+02	4.74E+02	5.14E+02	2.324	2.520
	^{137}Cs + D (Ci)	1.08E+01	8.72E+00	1.01E+01	0.807	0.935
	^{232}Th (Ci)	1.09E-14	4.20E-06	7.93E-06	3.85E+08	7.28E+08
	^{233}U (Ci)	1.52E-05	1.79E-02	5.36E-02	N/A	N/A
	^{234}U (Ci)	5.17E-02	3.59E-02	4.47E-02	0.694	0.865
	^{235}U + D (Ci)	2.18E-03	1.45E-03	1.78E-03	0.665	0.817
	^{236}U (Ci)	5.49E-04	3.59E-04	5.02E-04	0.654	0.914
	^{238}U + D (Ci)	4.90E-02	3.35E-02	5.31E-02	0.684	1.084
	^{237}Np + D (Ci)	1.17E-03	2.96E-03	3.63E-03	2.530	3.10
	^{238}Pu (Ci)	2.51E-01	3.57E-01	1.07E+00	N/A	N/A
	^{239}Pu (Ci)	7.90E+00	1.45E+01	1.68E+01	1.835	2.127
	^{240}Pu (Ci)	1.71E+00	3.14E+00	3.62E+00	1.836	2.117
	^{241}Pu + D (Ci)	9.03E+00	1.52E+01	1.75E+01	1.683	1.938
	^{241}Am (Ci)	6.67E-01	1.21E+00	1.46E+00	1.814	2.189
	^{242}Cm (Ci)	2.62E-02	1.84E-01	5.52E-01	N/A	N/A
	^{243}Cm (Ci)	1.32E-03	7.35E-03	2.21E-02	N/A	N/A
	^{244}Cm (Ci)	2.99E-02	1.76E-01	5.30E-01	N/A	N/A

[a] Inventories for contaminants having the greatest impact for groundwater or inadvertent intruder pathway.

N/A: Not applicable because the inventory was calculated from the laboratory's minimum detection limit for that analyte.

9.0 ADDITIONAL RETRIEVAL TECHNOLOGIES

This section discusses the feasibility of available retrieval technologies, the feasibility of developing additional retrieval technologies, and the amount of additional waste that could be removed from SST C-202.

The SST C-202 waste retrieval campaign was the second time the VRS, described in Section 2.0, was used to retrieve waste from a Hanford SST. The VRS was first used in SST C-203 (RPP-RPT-26475, *Retrieval Data Report for Single-Shell Tank 241-C-203*). The VRS retrieval satisfied M-45-00 retrieval criteria by retrieving waste from SST C-202 to the limit of the VRS and leaving a residual with a calculated volume of 19.7 ft^3.

9.1 FEASIBILITY AND VIABILITY OF OTHER AVAILABLE WASTE RETRIEVAL TECHNOLOGIES

Several variations of sluicing described in RPP-20577, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106,* and RPP-RPT-27406, *Demonstration Retrieval Data Report for Single-Shell Tank 241-S-112*, were evaluated. These include raw water modified sluicing, modified circulation system, remote water lancing, and ex-tank water heater on a recirculation line. However, RPP-16525, *C-200-Series Tanks Functions and Requirements*, precludes the use of sluicing technologies for tanks designated "assumed leakers" to minimize water additions and mitigate potential leaks during retrieval. As a result, sluicing technologies were not considered further.

The only other available technology reviewed was the mobile retrieval system (MRS). The MRS is currently the preferred technology for 100-Series SSTs designated as assumed leakers. The MRS is similar to the VRS system in many respects but also deploys an in-tank vehicle (ITV). The ITV may have the capacity to move waste to the vacuum head, possibly retrieving more waste from the tank compared to using the VRS alone. However, the existing VRS with its AMS can reach all areas of the tank bottom, so any benefit from deploying the ITV would be negligible. Additionally, existing risers for the 200-series tanks are not large enough to accommodate the MRS system and would require some modification or construction of new risers to allow the use of the MRS. This is deemed impractical due to expected high worker exposure during construction of risers. As a result, MRS was also eliminated from consideration.

9.2 FEASIBILITY OF DEVELOPING NEW TECHNOLOGIES

New technologies are under development that could possibly enhance retrieval performance for future tanks, but these were not available for SST C-202. A brief description of these technologies follows in Sections 9.2.1 through 9.2.5. The technologies discussed are at varying stages of development. Some require substantial investment in research and development while others have already been used elsewhere but would need to be adapted for use at the Hanford Site. Activities needed to deploy these technologies could include engineering, procurement, testing, and construction. More detailed information regarding these technologies is included in RPP-20577.

9.2.1 AEA Technology Power Fluidics™[4]

The power fluidic process for sampling, mixing, and pumping tank waste at the Hanford Site has been evaluated for several years. This fluidic mixing and pumping system was tested by the Hanford Site SST retrieval program to demonstrate potential for dissolution of saltcake waste and mobilization and retrieval of insoluble solids (e.g., sludge waste). Testing results indicated that the fluidic mixing and pumping system did not fully meet objectives and that further development and demonstration would be required. Operation of this system appears to require use of high water volumes, which would preclude its use in an "assumed leaker" such as SST C-202.

9.2.2 Russian Pulsatile Mixer Pumps/Fluidic Retrieval Systems

The Russian Integrated Mining and Chemical Combine fluidic concept for mixing and pumping tank waste is similar to the power fluidics system but has design details different for the pump mechanism and nozzles. While the power fluidics system has no moving parts in the pump, the Russian unit uses a simple check valve mechanism. Both systems use two distinct cycles, fill and discharge, to perform a mixing action. Operation of this system, like the power fluidics system, appears to require use of high water volumes, which would preclude its use in an "assumed leaker" such as SST C-202.

9.2.3 Small Mobile Retrieval Vehicles

The following mobile retrieval systems were assessed:

a. Remotely Operated Vehicle Systems at Oak Ridge—In the 1996-1998 period, Oak Ridge National Laboratory deployed a series of hydraulically powered, remotely operated vehicles. The equipment was redesigned and improved. As redesigned, the equipment was a 4 ft x 5 ft parallelogram-style frame. Folding the frame enabled the device to deploy through a 24-in. tank riser (it is unclear whether this equipment could be deployed through the 24-in. SST C-202 hatchway, which is the largest opening in the tank roof). Many hardware failures occurred during deployment, requiring repair or replacement. The equipment was later used in other tanks in conjunction with a wall-washing tool (the linear scarifying end-effector), a confined sluicing end-effector, and a modified light duty utility arm[5] (MLDUA).

   The MLDUA was used at Oak Ridge to clean seven underground tanks, but shortcomings were observed in its operation. Although lessons learned were documented for both design and operations, the lessons have not been incorporated into any subsequent versions of the MLDUA.

b. Scarab III[6]—The Scarab III vehicles use four rubber-treaded wheels for traction on slick surfaces and four metal wheels for biting into thin layers of waste. The Scarab can climb over 8-in. obstacles and has a manipulator arm. The manipulator gripper end-effector has a payload limit of 5 lb and requires an 18-in.-diameter access. The unit has three on-board cameras for viewing deployment, retrieval, and driving operations. This system

[4] AEA Technology Power Fluidics™ is a registered trademark of AEA Technology, Glengarnock, United Kingdom.
[5] Modified Light Duty Utility Arm is a trademark of SPAR Aerospace, Ltd., Edmonton, Alberta, Canada.
[6] Scarab III is a trademark of R.O.V. Technologies, Inc., Vernon, Vermont.

has been used primarily for sampling at Hanford but has not been demonstrated for retrieval and requires additional development and testing.

c. TMR Associates VAC TRAX[7]—The VAC TRAX is a remote-operated rotating high-pressure water jetting tool that directs ultra-high-pressure water to remove material coverings from a variety of surfaces, e.g., contaminated paint from concrete walls and floors. At higher pressures, the equipment can perform light scabbling or deep scarification of concrete surfaces. The equipment is fully encapsulated with water and debris vacuumed from a manifold through a flexible vacuum hose. The system supplies water up to 36,000 psi through a rotating manifold containing orifices to produce a concentrated stream. However, this system operates in a submerged environment and would be precluded in an "assumed leaker" such as SST C-202.

9.2.4 Tank Wall Washing at West Valley Demonstration Project

The retrieval process was very efficient during early stages of waste removal at the West Valley Demonstration Project. As the process moved from bulk removal to heel and residue retrieval, the number of transfers and associated time per transfer climbed steadily (Hamel and Damerow, *Completing HLW Vitrification at the WVDP; The Approach to Final Retrieval, Flushing, and Characterization*). Riser-mounted arms and positioning systems were developed to provide capability to wash residues from internal tank surfaces. Oxalic acid and mixed organic acids were not used because of concerns for tank integrity. This system may remove additional waste from tank walls, but because only a minimal amount of waste is left on the SST C-202 walls, there is little benefit in removing additional waste compared to the time and cost to test and deploy this system.

9.2.5 Dry Ice Blasting

Decontaminating surfaces using dry ice blasting is a relatively new cleaning process using solid CO_2 pellets. The pellets sublimate (convert directly from a solid blast pellet to a vapor) leaving no residue. This is envisioned as a sandless sandblasting approach to dislodge hard-to-remove residue from the tank surfaces. The dry ice is accelerated by compressed air and requires between 80 psi to 100 psi and 120 ft^3/min to 150 ft^3/min (Lapointe, *Sand-less Sandblasting*). On a fact sheet for alternatives to trichloroethane, EPA identified dry ice blasting with solid pellets as a desirable alternative for cleaning metal surfaces [EPA-905-F-00-026, *Technical Fact Sheet for 1,1,1-Trichloroethane (TCA) Hazards and Alternatives*]. Like tank wall washing, this system may remove additional waste from tank walls, but because only a minimal amount of waste is left on the SST C-202 walls, there is little benefit in removing additional waste compared to the time and cost to test and deploy this system.

9.3 ADDITIONAL WASTE REMOVAL

The SST-C-202 VRS successfully removed waste to the limit of the technology and satisfied requirements set out in HFFACO Milestone M-45-00. Schedules and cost estimates for additional technologies are not included here because no feasible or practical available technologies or developing technologies were identified to retrieve additional waste from the tank.

[7] VAC TRAX is a registered trademark of TMR Associates, Rutherford, New Jersey.

10.0 RECOMMENDATIONS FOR FURTHER ACTION

This section provides recommendations for further actions, identifies lessons learned from the retrieval of SST C-203 which were implemented for SST C-202 retrieval, and discusses opportunities to refine waste retrieval technologies based on lessons learned from the SST C-202 retrieval.

10.1 RECOMMENDATIONS FOR SINGLE-SHELL TANK C-202

As demonstrated by information presented in this RDR, retrieval of SST C-202 is complete. DOE has no recommendation for additional retrieval actions at SST C-202 because M-45-00 retrieval criteria for this tank are satisfied as shown in Sections 5.0 and 6.0 of this RDR.

10.2 IMPROVEMENTS IMPLEMENTED FOR SINGLE-SHELL TANK C-202 RETRIEVAL BASED ON LESSONS LEARNED FROM SINGLE-SHELL TANK C-203 RETRIEVAL

Following retrieval of waste from SST C-203, opportunities to improve future retrieval operations were identified and summarized in RPP-RPT-26475. Based on lessons learned from the SST C-203 retrieval, the following modifications were implemented for SST C-202 retrieval:

a. The SST C-202 retrieval schedule was modified to more accurately reflect the appropriate allocation of time to achieve the retrieval goals. The SST C-202 retrieval schedule was modified based on the results of SST C-203 retrieval.
b. The vacuum line from the AMS head to the vessel/pump was straightened.
c. Line flushes were reduced, based on the specific gravity of the waste, to limit the amount of water used.
d. Communications among waste retrieval system operators were improved.
e. Instrumentation was added to decrease uncertainty of the LDMM calculations.

System improvements incorporated into the SST C-202 waste retrieval system as a result of lessons learned from the tank SST C-203 retrieval included the removal of sharp bends in the vacuum line between the top of the AMS and the slurry tank and a modification of the transfer line flushing frequency. SST C-202 was closer to the slurry tank than tank SST C-203, which resulted in a shorter slurry hose length (75 ft vs. 90 ft).

The shorter hose and modification to the vacuum line between the top of the AMS and the slurry tank resulted in better vacuum and higher airflow rates through the AMS. During the initial batches, the higher flow rate and higher return of air from the vacuum system to the tank resulted in high-pressure (low-vacuum) alarms for the SST C-202 headspace. The exhauster was switched from exhausting both SST C-202 and tank 241-C-204 to exhausting SST C-202 only. This increased the SST C-202 ventilation rate from 225 to 300 scfm, increasing the vacuum in the tank and eliminating the low vacuum problems; it also reduced fogging in the tank headspace, which provided better visual observation.

The greatest improvements to waste retrieval efficiencies came from modifications to the manner in which the waste was retrieved. Operating the AMS with minimal water use and no air injection for pneumatic assist appeared to improve retrieval efficiencies. The lack of air injection results in a higher vacuum at the bottom of the AMS. The AMS head was partially submerged in the waste or periodically raised out of the waste to allow air to flow from the tank headspace into the AMS to provide pneumatic assist. The scarifier was also operated at lower water flow rates. This appeared to mobilize the solids while not pushing them away from the AMS head. Batches took longer to retrieve, but the average waste retrieval per batch increased.

10.3 OPPORTUNITIES FOR IMPROVEMENT OF WASTE RETRIEVAL OPERATIONS AT OTHER SINGLE-SHELL TANKS BASED ON LESSONS LEARNED FROM SINGLE-SHELL TANK C-202

Lessons learned from the retrieval of C-202 were captured in RPP-29413, *Tank 241-C-202 Vacuum Retrieval Lessons Learned: Opportunities for Refinement of Future Retrieval Operations at Other Single-Shell Tanks*. RPP-29413 identifies a summary of opportunities to improve future retrieval operations, as well as specific lessons proposed for implementation as budget and time allows.

Opportunities for improvement for future retrieval operations include physical modifications to equipment (e.g., using hard pipes for drain lines), operational changes (e.g., "sipping" the waste surface rather than submerging the mast head), and work planning (e.g., cautions about extrapolation of Cold Test Facility performance data to planned field activities).

Lessons learned from C-202 retrieval that are proposed for implementation in future retrievals, as budget and time allow, are the following:

a. Replace vacuum-skid-seal-water-separator-water radiator with a higher capacity unit. The current unit is undersized and results in poor vacuum pump performance, frequent delays to dump hot water from separator, and fogging in the tank.

b. Replace AMS mast with modified 241-U-200 mast. The 241-U-200 mast has additional venturi to enhance vertical lift for specific gravities in the 2.0 to 4.0 range.

c. Add Loctite®[8] to vacuum pump motor couplers or provide a more positive mechanical connection. This will minimize the chance of decoupling as a result of the force created by the cycling of the pumps, most of which is due to breaking vacuum to clear a clogged screen. Also consider a software modification that will allow the mast to be vented to atmosphere without turning off the vacuum pumps.

d. Test the C-204 line length with simulant that contains large granular particles to mimic waste encountered in tanks SST C-203 and SST C-202 to determine its effect on retrieval performance.

e. Develop a more robust supplemental light for the video camera. Consider the multi-lamp unit deployed in tank 241-S-112.

The application of lessons learned to future retrievals will be at the discretion of the retrieval project manager.

[8] Loctite® is a registered trademark of Henkel Corporation, Gulph Mills, Pennsylvania.

11.0 REFERENCES

10 CFR 830, "Nuclear Safety Management," Subpart B, "Safety Basis Requirements," *Code of Federal Regulations,* as amended.

66 FR 76708, 2000, "National Primary Drinking Water Regulations; Radionuclides; Final Rule," *Federal Register*, Vol. 65, pp. 76707-76753 (December 7).

AIR 03-704, NOC ID 579, 2003, *Approval of Notice of Construction for 241-C-200 Series Tanks Retrieval*, Washington State Department of Health, Olympia, Washington.

ATL-MP-1011, 2006, *ATL Quality Assurance Project Plan for 222-S Laboratory*, Advanced Technologies and Laboratories, Inc., Richland, Washington

CVI-73550, 1943, Drawing D-20, *Typical Sections for 20 ft Tanks,* and Drawing D-23, *Structural Steel Lining for 20 ft Tanks,* Richland, Washington.

DOE O 435.1, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE/ORP-2005-01, 2005, *Single-Shell Tank Performance Assessment*, partial predecisional draft, U.S. Department of Energy, Office of River Protection, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, State of Washington Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

EPA/540/1-89/002, 1989, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final*, U.S. Environmental Protection Agency, Washington D.C.

EPA/540/R-99/006, 1999, *Radiation Risk Assessment at CERCLA Sites: Q & A*, Directive 9200.4-31P, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington D.C.

EPA 905F-00026, 2000, *Technical Fact Sheet for 1,1,1-Trichloroethane (TCA) Hazards and Alternatives,* U.S. Environmental Protection Agency, Region 5, Chicago, Illinois.

H-2-73354, 1986, *Piping Waste Tank Isolation 241-C-203*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

H-14-106126-3, 2004, *C-201 Tank/Riser P & I D*, Drawing H-14-106126, Sheet 3, Rev. 7, U.S. Department of Energy, Office of River Protection, Richland, Washington.

H-14-106126-4, 2004, *C-202 Tank/Riser P & I D*, Drawing H-14-106126, Sheet 4, Rev. 7, U.S. Department of Energy, Office of River Protection, Richland, Washington.

H-14-106126-5, 2004, *C-203 Tank/Riser P & I D*, Drawing H-14-106126, Sheet 5, Rev. 9, U.S. Department of Energy, Office of River Protection, Richland, Washington.

H-14-106126-6, 2004, *C-204 Tank/Riser P & I D*, Drawing H-14-106126, Sheet 6, Rev. 7, U.S. Department of Energy, Office of River Protection, Richland, Washington.

Hamel, W. F., Jr., and F. W. Damerow, 2001, "Completing HLW Vitrification at the WVDP; The Approach to Final Retrieval, Flushing, and Characterization," in *Proc. Int. Conf. WM'01*, Tucson, Arizona.

HNF-EP-0182, 2005, *Waste Tank Summary Report for Month Ending September 30, 2005*, Rev. 210, CH2M HILL Hanford Company, Inc., Richland, Washington.

HNF-SD-WM-TI-707, 2004, *Exposure Scenarios and Unit Dose Factors for Hanford Tank Waste Performance Assessments*, Rev. 4, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-SD-WM-TSR-006, 2003, *Tank Farms Technical Safety Requirements*, Rev. 4-F, CH2M HILL Hanford Group, Inc., Richland, Washington.

Lapointe, J., 2004, "Sand-less Sandblasting," *Pollution Engineering Magazine*, February.

PNNL-13895, 2003, *Hanford Contaminant Distribution Database and User's Guide*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

RPP-6924, 2000, *Statistical Methods for Estimating the Uncertainty in the Best-Basis Inventories*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7625, 2004, *Best Basis Inventory Process Requirements*, Rev. 5, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-12711, 2004, *Temporary Waste Transfer Line Management Program Plan,* Rev. 3A, Cogema Engineering, Richland, Washington.

RPP-13019, 2003, *Determination of Hanford Waste Tank Volumes*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-15408, 2003, *Origin of Wastes in C-200-Series Single-Shell Tanks*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-16525, 2004, *C-200-Series Tanks Retrieval Functions and Requirements*, Rev. 6, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-16945, 2005, *Process Control Plan for the 241-C-200 Series Waste Retrieval System*, Rev. 6, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-17190, 2004, *Safety Evaluation of the Waste Retrieval System Vacuum System for 241-C Tank Farms 200-Series Tanks*, Rev. 4, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-17507, 2003, *Waiver of Temperature Requirements During Retrieval of 241-C-200 Series Tanks,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-20577, 2004, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-23403, 2005, *Single-Shell Tank Component Closure Data Quality Objectives,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-27512, 2005, *Post-Retrieval Waste Volume Determination for Single-Shell Tank 241-C-202,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-29413, 2006, *Tank 241-C-202 Vacuum Retrieval Lessons Learned: Opportunities for Refinement of Future Retrieval Operations at Other Single-Shell Tanks,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-CALC-26943 2005, *Tank 241-C-202 Retrieval: Calculation of Initial Waste Volume,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-CALC-27512, 2005, *Post-Retrieval Waste Volume Determination for Single-Shell Tank 241-C-202*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-CALC-27555, 2005, *Leak Detection Monitoring Calculation for Single-Shell Tank 241-C-202*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-23680, 2005, *Sampling and Analysis Plan for Residual Waste Solids in the C-200 Series Tanks*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-23827, 2005, *Sampling and Analysis Plan for Single-Shell Tank Component Closure*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-22891, 2004, *Revised Methodology to Calculating Residual Waste Volume at 95% Confidence Interval,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-26475, 2006, *Retrieval Data Report for Single-Shell Tank 241-C-203*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-26925, 2005, *Final Report for Tank 241-C-202 Post-Retrieval Solid Finger Trap Grab Samples*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-27406, 2005, *Demonstration Retrieval Data Report for Single-Shell Tank 241-S-112*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-29202, 2006, *Tank 241-C-202 Residual Waste Inventory Estimates for Component Closure Risk Assessment*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, as amended, U.S. Environmental Protection Agency, Washington, D.C.

Tank Waste Information Network System (TWINS), [Best-Basis Calculation Detail Report], available at http://twins.pnl.gov/data/datamenu.htm .

TFC-ENG-CHEM-P-47, 2005, *Single-Shell Tank Retrieval Completion Evaluation*, Rev. A-1, CH2M HILL Hanford Group, Inc., Richland, Washington.

TFC-ESHQ-ENV_FS-C-01, 2005, *Environmental Notification*, Rev. B-3, CH2M HILL Hanford Group, Inc., Richland, Washington.

TFC-OPS-OPER-C-24, 2005, *Occurrence Reporting and Processing of Operations Information*, Rev. B-3, CH2M HILL Hanford Group, Inc., Richland, Washington.

TO-220-106, 2005, *Transfer From 241-C-200 Series Tanks to 241-AN-106*, Rev. A-14, CH2M HILL Hanford Group, Inc., Richland, Washington.

WAC 173-340, "Model Toxics Control Act – Cleanup," *Washington Administrative Code,* as amended.

WHC-SD-WM-ER-349, 1994, *Historical Tank Content Estimate for the Northeast Quadrant of the Hanford 200 East Area*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

SINGLE-SHELL TANK 241-C-202 RESIDUAL WASTE CONCENTRATIONS AND INVENTORIES

Table A-1. Mean Concentrations and Relative Standard Deviations of Constituents Analyzed in the SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS	< Detection Limit	Mean	Units	RSD (%)
1,1,1-Trichloroethane	71-55-6	<	8.60E-03	µg/g	100
1,1,2,2-Tetrachloroethane	79-34-5	<	6.25E-03	µg/g	100
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	9.72E-03	µg/g	100
1,1,2-Trichloroethane	79-00-5	<	6.25E-03	µg/g	100
1,1-Dichloroethene	75-35-4	<	9.90E-03	µg/g	100
1,2,4-Trichlorobenzene	120-82-1	<	9.82E-03	µg/g	100
1,2-Dichlorobenzene	95-50-1	<	4.67E+02	µg/g	100
1,2-Dichloroethane	107-06-2	<	6.15E-03	µg/g	100
1,4-Dichlorobenzene	106-46-7	<	2.90E+02	µg/g	100
1-Butanol	71-36-3	<	1.21E+03	µg/g	100
2,4,5-Trichlorophenol	95-95-4	<	2.70E+02	µg/g	100
2,4,6-Trichlorophenol	88-06-2	<	2.77E+02	µg/g	100
2,4-Dinitrotoluene	121-14-2	<	3.13E+02	µg/g	100
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	8.30E+02	µg/g	100
2-Butanone	78-93-3		6.35E-02	µg/g	39
2-Chlorophenol	95-57-8	<	2.87E+02	µg/g	100
2-Ethoxyethanol	110-80-5	<	6.47E+02	µg/g	100
2-Methylphenol	95-48-7	<	2.97E+02	µg/g	100
2-Nitrophenol	88-75-5	<	2.63E+02	µg/g	100
2-Nitropropane	79-46-9	<	1.50E-02	µg/g	100
4-Chloro-3-methylphenol	59-50-7	<	2.93E+02	µg/g	100
4-Nitrophenol	100-02-7	<	2.73E+02	µg/g	100
Acenaphthene	83-32-9	<	3.00E+02	µg/g	100
Acetate	71-50-1		9.51E+01	µg/g	19
Acetone	67-64-1		2.17E-01	µg/g	29
Aluminum	7429-90-5		8.85E+03	µg/g	2
Americium-241	14596-10-2		1.24E+00	µCi/g	9
Ammonium Ion by IC	14798-03-9		5.69E+01	µg/g	19
Antimony	7440-36-0	<	9.48E+01	µg/g	100
Antimony-125	14234-35-6	<	7.15E-01	µCi/g	100
Aroclor 1016 (dry weight)	12674-11-2	<	2.07E-01	µg/g	100
Aroclor 1221 (dry weight)	11104-28-2	<	6.48E-02	µg/g	100

Table A-1. Mean Concentrations and Relative Standard Deviations of Constituents Analyzed in the SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS	< Detection Limit	Mean	Units	RSD (%)
Aroclor 1232 (dry weight)	11141-16-5	<	1.17E+00	µg/g	100
Aroclor 1242 (dry weight)	53469-21-9	<	2.07E-01	µg/g	100
Aroclor 1248 (dry weight)	12672-29-6	<	6.68E-02	µg/g	100
Aroclor 1254 (dry weight)	11097-69-1	<	3.92E-02	µg/g	100
Aroclor 1260 (dry weight)	11096-82-5	<	2.85E-01	µg/g	100
Arsenic	7440-38-2	<	9.48E+01	µg/g	100
Barium	7440-39-3		1.76E+02	µg/g	1
Benzene	71-43-2	<	6.02E-03	µg/g	100
Beryllium	7440-41-7	<	1.52E+01	µg/g	100
Bismuth	7440-69-9		6.61E+02	µg/g	31
Boron	7440-42-8	<	2.84E+01	µg/g	100
Bromide	24959-67-9	<	5.71E+01	µg/g	100
Bulk Density	NA		1.75E+00	g/mL	1
Butylbenzylphthalate	85-68-7	<	6.00E+02	µg/g	100
Cadmium	7440-43-9		1.83E+01	µg/g	32
Calcium	7440-70-2		7.42E+03	µg/g	3
Carbon disulfide	75-15-0	<	8.90E-03	µg/g	100
Carbon tetrachloride	56-23-5	<	1.10E-02	µg/g	100
Carbon-14	14762-75-5	<	5.25E-04	µCi/g	100
Cerium	7440-45-1	<	1.33E+02	µg/g	100
Cesium-137	10045-97-3		8.92E+00	µCi/g	7
Chloride	16887-00-6		2.99E+02	µg/g	52
Chlorobenzene	108-90-7	<	7.42E-03	µg/g	100
Chloroform	67-66-3	<	9.10E-03	µg/g	100
Chromium	7440-47-3		9.48E+03	µg/g	2
Cobalt	7440-48-4		8.02E+01	µg/g	6
Cobalt-60	10198-40-0	<	2.68E-01	µCi/g	100
Copper	7440-50-8		3.20E+02	µg/g	6
Cresol	1319-77-3	<	5.67E+02	µg/g	100
Cresol (m)	108-39-4	<	2.87E+02	µg/g	100
Cresol (p)	106-44-5	<	2.87E+02	µg/g	100
Curium-242	15510-73-3	<	3.76E-01	µCi/g	100
Curium-243/244	NA	<	3.76E-01	µCi/g	100
Cyanide	57-12-5		4.13E+00	µg/g	8

Table A-1. Mean Concentrations and Relative Standard Deviations of Constituents Analyzed in the SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS	< Detection Limit	Mean	Units	RSD (%)
Cyclohexanone	108-94-1	<	1.95E+03	µg/g	100
Di-n-butylphthalate	84-74-2	<	1.95E+03	µg/g	100
Di-n-octylphthalate	117-84-0	<	3.47E+02	µg/g	100
Ethyl acetate	141-78-6	<	9.32E-03	µg/g	100
Ethyl ether	60-29-7	<	8.50E-03	µg/g	100
Ethylbenzene	100-41-4	<	1.50E-02	µg/g	100
Europium	7440-53-1		5.20E+01	µg/g	8
Europium-152	14683-23-9	<	1.17E+00	µCi/g	100
Europium-154	15585-10-1	<	8.18E-01	µCi/g	100
Europium-155	14391-16-3	<	4.49E-01	µCi/g	100
Fluoranthene	206-44-0	<	3.10E+02	µg/g	100
Fluoride	16984-48-8		2.36E+03	µg/g	12
Formate	12311-97-6		6.73E+01	µg/g	22
Glycolate	666-14-8	<	3.74E+01	µg/g	100
Hexachlorobutadiene	87-68-3	<	3.13E+02	µg/g	100
Hexachloroethane	67-72-1	<	5.65E-03	µg/g	100
Hexone	108-10-1		2.27E-02	µg/g	8
Iodine-129	15046-84-1		7.66E-06	µCi/g	15
Iron	7439-89-6		9.08E+04	µg/g	6
Isobutanol	78-83-1	<	1.59E+03	µg/g	100
Lanthanum	7439-91-0	<	1.14E+01	µg/g	100
Lead	7439-92-1		6.09E+03	µg/g	3
Lithium	7439-93-2	<	1.52E+01	µg/g	100
Magnesium	7439-95-4		1.39E+03	µg/g	4
Manganese	7439-96-5		1.76E+04	µg/g	3
Mercury	7439-97-6		2.99E+02	µg/g	7
Methylenechloride	75-09-2	<	7.35E-03	µg/g	100
Molybdenum	7439-98-7	<	1.90E+01	µg/g	100
Morpholine, 4-nitroso-	59-89-2	<	6.53E+02	µg/g	100
Naphthalene	91-20-3	<	2.97E+02	µg/g	100
Neodymium	7440-00-8	<	7.58E+01	µg/g	100
Neptunium-237	13994-20-2		4.30E+00	µg/g	10
Nickel	7440-02-0		7.60E+03	µg/g	3
Nickel-63	13981-37-8		2.30E-01	µCi/g	9

Table A-1. Mean Concentrations and Relative Standard Deviations of Constituents Analyzed in the SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS	< Detection Limit	Mean	Units	RSD (%)
Niobium	7440-03-1	<	9.48E+01	µg/g	100
Nitrate	14797-55-8		1.30E+03	µg/g	19
Nitrite	14797-65-0		4.71E+02	µg/g	23
Nitrobenzene	98-95-3	<	3.13E+02	µg/g	100
N-Nitroso-di-n-propylamine	621-64-7	<	2.77E+02	µg/g	100
Oxalate	338-70-5		3.92E+04	µg/g	59
Palladium	7440-05-3	<	2.17E+02	µg/g	100
Pentachlorophenol	87-86-5	<	2.32E+02	µg/g	100
Percent Water	NA		2.44E+01	%	10
Phenol	108-95-2	<	2.87E+02	µg/g	100
Phosphorus	7723-14-0		1.21E+04	µg/g	2
Plutonium-238	13981-16-3	<	7.31E-01	µCi/g	100
Plutonium-239/240	NA		1.81E+01	µCi/g	6
Potassium	7440-09-7	<	9.48E+02	µg/g	100
Praseodymium	7440-10-0		6.50E+02	µg/g	16
Pyrene	129-00-0	<	2.97E+02	µg/g	100
Pyridine	110-86-1	<	2.73E+02	µg/g	100
Rhodium	7440-16-6	<	4.35E+02	µg/g	100
Rubidium	7440-17-7	<	6.52E+03	µg/g	100
Ruthenium	7440-18-8	<	1.14E+02	µg/g	100
Samarium	7440-19-9	<	3.79E+01	µg/g	100
Selenium	7782-49-2	<	9.48E+01	µg/g	100
Selenium-79	15758-45-9	<	1.28E-04	µCi/g	100
Silicon	7440-21-3		8.97E+03	µg/g	7
Silver	7440-22-4	<	1.30E+01	µg/g	100
Sodium	7440-23-5		4.78E+04	µg/g	12
Strontium	7440-24-6		1.27E+03	µg/g	2
Strontium-89/90	10098-97-2		4.85E+02	µCi/g	1
Sulfide	18496-25-8	<	1.08E+01	µg/g	100
Sulfur	7704-34-9		1.40E+02	µg/g	2
Tantalum	7440-25-7	<	7.59E+01	µg/g	100
Technetium-99	14133-76-7		1.54E-01	µg/g	27
Tellurium	13494-80-9	<	1.52E+02	µg/g	100
Tetrachloroethene	127-18-4	<	7.85E-03	µg/g	100

Table A-1. Mean Concentrations and Relative Standard Deviations of Constituents Analyzed in the SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS	< Detection Limit	Mean	Units	RSD (%)
Thallium	7440-28-0	<	2.56E+02	µg/g	100
Thorium	7440-29-1		5.46E+02	µg/g	14
Thorium-230	14269-63-7	<	3.79E+00	µg/g	100
Thorium-232	NA		3.90E+01	µg/g	44
Tin	7440-31-5		3.93E+02	µg/g	53
Titanium	7440-32-6		5.94E+02	µg/g	5
Toluene	108-88-3	<	7.02E-03	µg/g	100
Trans-1,3-Dichloropropene	10061-02-6	<	6.12E-03	µg/g	100
Tributyl phosphate	126-73-8		5.53E+03	µg/g	4
Trichloroethene	79-01-6	<	1.20E-02	µg/g	100
Trichlorofluoromethane	75-69-4	<	8.97E-03	µg/g	100
Tritium	15086-10-9	<	7.21E-03	µCi/g	100
Tungsten	7440-33-7	<	1.22E+02	µg/g	100
Uranium	7440-61-1		1.21E+05	µg/g	16
Uranium-233	13968-55-3	<	3.79E+00	µg/g	100
Uranium-234	13966-29-5		5.91E+00	µg/g	12
Uranium-235	15117-96-1		6.85E+02	µg/g	11
Uranium-236	13982-70-2		5.68E+00	µg/g	19
Uranium-238	NA		1.02E+05	µg/g	10
Vanadium	7440-62-2	<	1.14E+01	µg/g	100
Vinyl chloride	75-01-4	<	4.25E-03	µg/g	100
Xylene (m)	108-38-3	<	1.70E-02	µg/g	100
Xylene (o)	95-47-6	<	1.70E-02	µg/g	100
Xylene (p)	106-42-3	<	5.32E-03	µg/g	100
Xylenes (total)	1330-20-7	<	2.20E-02	µg/g	100
Yttrium	7440-65-5	<	9.48E+00	µg/g	100
Zinc	7440-66-6		5.14E+02	µg/g	5
Zirconium	7440-67-7		9.85E+01	µg/g	6

CAS = Chemical Abstracts Service Registry Number.
< = Below.
RSD = Relative Standard Deviation, representing the uncertainty of the concentration estimate.

Table A-2. Average Inventory for SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory	Inventory Units
1,1,1-Trichloroethane	71-55-6	<	8.41E-06	kg
1,1,2,2-Tetrachloroethane	79-34-5	<	6.11E-06	kg
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	9.50E-06	kg
1,1,2-Trichloroethane	79-00-5	<	6.11E-06	kg
1,1-Dichloroethene	75-35-4	<	9.68E-06	kg
1,2,4-Trichlorobenzene	120-82-1	<	9.60E-06	kg
1,2-Dichlorobenzene	95-50-1	<	4.56E-01	kg
1,2-Dichloroethane	107-06-2	<	6.01E-06	kg
1,4-Dichlorobenzene	106-46-7	<	2.84E-01	kg
1-Butanol	71-36-3	<	1.18E+00	kg
2,4,5-Trichlorophenol	95-95-4	<	2.64E-01	kg
2,4,6-Trichlorophenol	88-06-2	<	2.71E-01	kg
2,4-Dinitrotoluene	121-14-2	<	3.06E-01	kg
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	8.12E-01	kg
2-Butanone	78-93-3		6.21E-05	kg
2-Chlorophenol	95-57-8	<	2.80E-01	kg
2-Ethoxyethanol	110-80-5	<	6.32E-01	kg
2-Methylphenol	95-48-7	<	2.90E-01	kg
2-Nitrophenol	88-75-5	<	2.58E-01	kg
2-Nitropropane	79-46-9	<	1.47E-05	kg
4-Chloro-3-methylphenol	59-50-7	<	2.87E-01	kg
4-Nitrophenol	100-02-7	<	2.67E-01	kg
Acenaphthene	83-32-9	<	2.93E-01	kg
Acetate	71-50-1		9.30E-02	kg
Acetone	67-64-1		2.13E-04	kg
Aluminum	7429-90-5		8.65E+00	kg
Americium-241	14596-10-2		1.21E+00	Ci
Ammonium Ion by IC	14798-03-9		5.57E-02	kg
Antimony	7440-36-0	<	9.27E-02	kg
Antimony-125	14234-35-6	<	6.99E-01	Ci
Aroclors (total PCB)	1336-36-3	<	2.90E-05	kg
Arsenic	7440-38-2	<	9.27E-02	kg
Barium	7440-39-3		1.72E-01	kg
Benzene	71-43-2	<	5.88E-06	kg

Table A-2. Average Inventory for SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory	Inventory Units
Beryllium	7440-41-7	<	1.48E-02	kg
Bismuth	7440-69-9		6.46E-01	kg
Boron	7440-42-8	<	2.78E-02	kg
Bromide	24959-67-9	<	5.59E-02	kg
Butylbenzylphthalate	85-68-7	<	5.87E-01	kg
Cadmium	7440-43-9		1.79E-02	kg
Calcium	7440-70-2		7.26E+00	kg
Carbon disulfide	75-15-0	<	8.70E-06	kg
Carbon tetrachloride	56-23-5	<	1.08E-05	kg
Carbon-14	14762-75-5	<	5.14E-04	Ci
Cerium	7440-45-1	<	1.30E-01	kg
Cesium-137	10045-97-3		8.72E+00	Ci
Chloride	16887-00-6		2.93E-01	kg
Chlorobenzene	108-90-7	<	7.25E-06	kg
Chloroform	67-66-3	<	8.90E-06	kg
Chromium	7440-47-3		9.27E+00	kg
Cobalt	7440-48-4		7.84E-02	kg
Cobalt-60	10198-40-0	<	2.62E-01	Ci
Copper	7440-50-8		3.13E-01	kg
Cresol	1319-77-3	<	5.54E-01	kg
Cresol (m)	108-39-4	<	2.80E-01	kg
Cresol (p)	106-44-5	<	2.80E-01	kg
Curium-242	15510-73-3	<	3.68E-01	Ci
Curium-243	15757-87-6	<	1.47E-02	Ci
Curium-244	13981-15-2	<	3.53E-01	Ci
Cyanide	57-12-5		4.04E-03	kg
Cyclohexanone	108-94-1	<	1.91E+00	kg
Di-n-butylphthalate	84-74-2	<	1.91E+00	kg
Di-n-octylphthalate	117-84-0	<	3.39E-01	kg
Ethyl acetate	141-78-6	<	9.11E-06	kg
Ethyl ether	60-29-7	<	8.31E-06	kg
Ethylbenzene	100-41-4	<	1.47E-05	kg
Europium	7440-53-1		5.08E-02	kg
Europium-152	14683-23-9	<	1.14E+00	Ci

Table A-2. Average Inventory for SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory	Inventory Units
Europium-154	15585-10-1	<	8.00E-01	Ci
Europium-155	14391-16-3	<	4.39E-01	Ci
Fluoranthene	206-44-0	<	3.03E-01	kg
Fluoride	16984-48-8		2.31E+00	kg
Formate	12311-97-6		6.58E-02	kg
Glycolate	666-14-8	<	3.66E-02	kg
Hexachlorobutadiene	87-68-3	<	3.06E-01	kg
Hexachloroethane	67-72-1	<	5.53E-06	kg
Hexone	108-10-1		2.22E-05	kg
Iodine-129	15046-84-1		7.49E-06	Ci
Iron	7439-89-6		8.88E+01	kg
Isobutanol	78-83-1	<	1.55E+00	kg
Lanthanum	7439-91-0	<	1.11E-02	kg
Lead	7439-92-1		5.96E+00	kg
Lithium	7439-93-2	<	1.48E-02	kg
Magnesium	7439-95-4		1.36E+00	kg
Manganese	7439-96-5		1.72E+01	kg
Mercury	7439-97-6		2.93E-01	kg
Methylenechloride	75-09-2	<	7.19E-06	kg
Molybdenum	7439-98-7	<	1.85E-02	kg
Morpholine, 4-nitroso-	59-89-2	<	6.39E-01	kg
Naphthalene	91-20-3	<	2.90E-01	kg
Neodymium	7440-00-8	<	7.41E-02	kg
Neptunium-237	13994-20-2		2.96E-03	Ci
Nickel	7440-02-0		7.43E+00	kg
Nickel-63	13981-37-8		2.25E-01	Ci
Niobium	7440-03-1	<	9.27E-02	kg
Nitrate	14797-55-8		1.27E+00	kg
Nitrite	14797-65-0		4.60E-01	kg
Nitrobenzene	98-95-3	<	3.06E-01	kg
N-Nitroso-di-n-propylamine	621-64-7	<	2.71E-01	kg
Oxalate	338-70-5		3.83E+01	kg
Palladium	7440-05-3	<	2.13E-01	kg
Pentachlorophenol	87-86-5	<	2.27E-01	kg

Table A-2. Average Inventory for SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory	Inventory Units
Phenol	108-95-2	<	2.80E-01	kg
Phosphate	14265-44-2		3.62E+01	kg
Plutonium-238	13981-16-3	<	7.14E-01	Ci
Plutonium-239	15117-48-3		1.45E+01	Ci
Plutonium-240	14119-33-6		3.14E+00	Ci
Plutonium-241	14119-32-5		1.52E+01	Ci
Potassium	7440-09-7	<	9.27E-01	kg
Praseodymium	7440-10-0		6.36E-01	kg
Pyrene	129-00-0	<	2.90E-01	kg
Pyridine	110-86-1	<	2.67E-01	kg
Rhodium	7440-16-6	<	4.25E-01	kg
Rubidium	7440-17-7	<	6.38E+00	kg
Ruthenium	7440-18-8	<	1.11E-01	kg
Samarium	7440-19-9	<	3.71E-02	kg
Selenium	7782-49-2	<	9.27E-02	kg
Selenium-79	15758-45-9	<	1.25E-04	Ci
Silicon	7440-21-3		8.77E+00	kg
Silver	7440-22-4	<	1.28E-02	kg
Sodium	7440-23-5		4.67E+01	kg
Strontium	7440-24-6		1.24E+00	kg
Strontium-89/90	10098-97-2		4.74E+02	Ci
Sulfide	18496-25-8	<	1.05E-02	kg
Sulfate	14808-79-8		4.09E-01	kg
Tantalum	7440-25-7	<	7.42E-02	kg
Technetium-99	14133-76-7		2.55E-03	Ci
Tellurium	13494-80-9	<	1.48E-01	kg
Tetrachloroethene	127-18-4	<	7.68E-06	kg
Thallium	7440-28-0	<	2.50E-01	kg
Thorium	7440-29-1		5.34E-01	kg
Thorium-228	14274-82-9		6.96E-06	Ci
Thorium-230	14269-63-7	<	7.64E-02	Ci
Thorium-232	NA		4.20E-06	Ci
Tin	7440-31-5		3.84E-01	kg
Titanium	7440-32-6		5.81E-01	kg

Table A-2. Average Inventory for SST C-202 Residual Waste. (5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory	Inventory Units
Toluene	108-88-3	<	6.86E-06	kg
Trans-1,3-Dichloropropene	10061-02-6	<	5.98E-06	kg
Tributyl phosphate	126-73-8		5.41E+00	kg
Trichloroethene	79-01-6	<	1.17E-05	kg
Trichlorofluoromethane	75-69-4	<	8.77E-06	kg
Tritium	15086-10-9	<	7.05E-03	Ci
Tungsten	7440-33-7	<	1.20E-01	kg
Uranium	7440-61-1		1.19E+02	kg
Uranium-233	13968-55-3	<	3.57E-02	Ci
Uranium-234	13966-29-5		3.59E-02	Ci
Uranium-235	15117-96-1		1.45E-03	Ci
Uranium-236	13982-70-2		3.59E-04	Ci
Uranium-238	NA		3.35E-02	Ci
Vanadium	7440-62-2	<	1.11E-02	kg
Vinyl chloride	75-01-4	<	4.16E-06	kg
Xylene (m)	108-38-3	<	1.66E-05	kg
Xylene (o)	95-47-6	<	1.66E-05	kg
Xylene (p)	106-42-3	<	5.20E-06	kg
Xylenes (total)	1330-20-7	<	2.15E-05	kg
Yttrium	7440-65-5	<	9.27E-03	kg
Zinc	7440-66-6		5.03E-01	kg
Zirconium	7440-67-7		9.64E-02	kg

CAS = Chemical Abstracts Service Registry Number
< = Below

Table A-3. 95% Upper Confidence Level Inventory for SST C-202 Residual Waste.
(5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory at 95% UL	Inventory Units
1,1,1-Trichloroethane	71-55-6	<	2.52E-05	kg
1,1,2,2-Tetrachloroethane	79-34-5	<	1.83E-05	kg
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	2.85E-05	kg
1,1,2-Trichloroethane	79-00-5	<	1.83E-05	kg
1,1-Dichloroethene	75-35-4	<	2.91E-05	kg
1,2,4-Trichlorobenzene	120-82-1	<	2.88E-05	kg
1,2-Dichlorobenzene	95-50-1	<	1.37E+00	kg
1,2-Dichloroethane	107-06-2	<	1.81E-05	kg
1,4-Dichlorobenzene	106-46-7	<	8.51E-01	kg
1-Butanol	71-36-3	<	3.54E+00	kg
2,4,5-Trichlorophenol	95-95-4	<	7.93E-01	kg
2,4,6-Trichlorophenol	88-06-2	<	8.12E-01	kg
2,4-Dinitrotoluene	121-14-2	<	9.20E-01	kg
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	2.44E+00	kg
2-Butanone	78-93-3		1.10E-04	kg
2-Chlorophenol	95-57-8	<	8.41E-01	kg
2-Ethoxyethanol	110-80-5	<	1.90E+00	kg
2-Methylphenol	95-48-7	<	8.71E-01	kg
2-Nitrophenol	88-75-5	<	7.73E-01	kg
2-Nitropropane	79-46-9	<	4.40E-05	kg
4-Chloro-3-methylphenol	59-50-7	<	8.61E-01	kg
4-Nitrophenol	100-02-7	<	8.02E-01	kg
Acenaphthene	83-32-9	<	8.81E-01	kg
Acetate	71-50-1		1.28E-01	kg
Acetone	67-64-1		3.36E-04	kg
Aluminum	7429-90-5		9.46E+00	kg
Americium-241	14596-10-2		1.46E+00	Ci
Ammonium Ion by IC	14798-03-9		7.76E-02	kg
Antimony	7440-36-0	<	2.78E-01	kg
Antimony-125	14234-35-6	<	2.10E+00	Ci
Aroclors (Total PCB)	1336-36-3	<	8.69E-05	kg

Table A-3. 95% Upper Confidence Level Inventory for SST C-202 Residual Waste.
(5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory at 95% UL	Inventory Units
Arsenic	7440-38-2	<	2.78E-01	kg
Barium	7440-39-3		1.87E-01	kg
Benzene	71-43-2	<	1.77E-05	kg
Beryllium	7440-41-7	<	4.45E-02	kg
Bismuth	7440-69-9		1.05E+00	kg
Boron	7440-42-8	<	8.35E-02	kg
Bromide	24959-67-9	<	1.68E-01	kg
Butylbenzylphthalate	85-68-7	<	1.76E+00	kg
Cadmium	7440-43-9		2.93E-02	kg
Calcium	7440-70-2		8.03E+00	kg
Carbon disulfide	75-15-0	<	2.61E-05	kg
Carbon tetrachloride	56-23-5	<	3.23E-05	kg
Carbon-14	14762-75-5	<	1.54E-03	Ci
Cerium	7440-45-1	<	3.89E-01	kg
Cesium-137	10045-97-3		1.01E+01	Ci
Chloride	16887-00-6		5.99E-01	kg
Chlorobenzene	108-90-7	<	2.18E-05	kg
Chloroform	67-66-3	<	2.67E-05	kg
Chromium	7440-47-3		1.02E+01	kg
Cobalt	7440-48-4		9.03E-02	kg
Cobalt-60	10198-40-0	<	7.86E-01	Ci
Copper	7440-50-8		3.57E-01	kg
Cresol	1319-77-3	<	1.66E+00	kg
Cresol (m)	108-39-4	<	8.41E-01	kg
Cresol (p)	106-44-5	<	8.41E-01	kg
Curium-242	15510-73-3	<	1.10E+00	Ci
Curium-243	15757-87-6	<	4.41E-02	Ci
Curium-244	13981-15-2	<	1.06E+00	Ci
Cyanide	57-12-5		4.80E-03	kg
Cyclohexanone	108-94-1	<	5.72E+00	kg
Di-n-butylphthalate	84-74-2	<	5.73E+00	kg
Di-n-octylphthalate	117-84-0	<	1.02E+00	kg
Ethyl acetate	141-78-6	<	2.73E-05	kg
Ethyl ether	60-29-7	<	2.50E-05	kg

Table A-3. 95% Upper Confidence Level Inventory for SST C-202 Residual Waste.
(5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory at 95% UL	Inventory Units
Ethylbenzene	100-41-4	<	4.40E-05	kg
Europium	7440-53-1		6.02E-02	kg
Europium-152	14683-23-9	<	3.42E+00	Ci
Europium-154	15585-10-1	<	2.40E+00	Ci
Europium-155	14391-16-3	<	1.32E+00	Ci
Fluoranthene	206-44-0	<	9.10E-01	kg
Fluoride	16984-48-8		2.89E+00	kg
Formate	12311-97-6		9.54E-02	kg
Glycolate	666-14-8	<	1.10E-01	kg
Hexachlorobutadiene	87-68-3	<	9.20E-01	kg
Hexachloroethane	67-72-1	<	1.66E-05	kg
Hexone	108-10-1		2.62E-05	kg
Iodine-129	15046-84-1		9.88E-06	Ci
Iron	7439-89-6		1.02E+02	kg
Isobutanol	78-83-1	<	4.66E+00	kg
Lanthanum	7439-91-0	<	3.34E-02	kg
Lead	7439-92-1		6.57E+00	kg
Lithium	7439-93-2	<	4.45E-02	kg
Magnesium	7439-95-4		1.52E+00	kg
Manganese	7439-96-5		1.90E+01	kg
Mercury	7439-97-6		3.41E-01	kg
Methylenechloride	75-09-2	<	2.16E-05	kg
Molybdenum	7439-98-7	<	5.56E-02	kg
Morpholine, 4-nitroso-	59-89-2	<	1.92E+00	kg
Naphthalene	91-20-3	<	8.71E-01	kg
Neodymium	7440-00-8	<	2.23E-01	kg
Neptunium-237	13994-20-2		3.63E-03	Ci
Nickel	7440-02-0		8.23E+00	kg
Nickel-63	13981-37-8		2.68E-01	Ci
Niobium	7440-03-1	<	2.78E-01	kg
Nitrate	14797-55-8		1.77E+00	kg
Nitrite	14797-65-0		6.77E-01	kg
Nitrobenzene	98-95-3	<	9.20E-01	kg
N-Nitroso-di-n-propylamine	621-64-7	<	8.12E-01	kg

Table A-3. 95% Upper Confidence Level Inventory for SST C-202 Residual Waste.
(5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory at 95% UL	Inventory Units
Oxalate	338-70-5		8.34E+01	kg
Palladium	7440-05-3	<	6.38E-01	kg
Pentachlorophenol	87-86-5	<	6.80E-01	kg
Phenol	108-95-2	<	8.41E-01	kg
Phosphate	14265-44-2		3.94E+01	kg
Plutonium-238	13981-16-3	<	2.14E+00	Ci
Plutonium-239	15117-48-3		1.68E+01	Ci
Plutonium-240	14119-33-6		3.62E+00	Ci
Plutonium-241	14119-32-5		1.75E+01	Ci
Potassium	7440-09-7	<	2.78E+00	kg
Praseodymium	7440-10-0		8.49E-01	kg
Pyrene	129-00-0	<	8.71E-01	kg
Pyridine	110-86-1	<	8.02E-01	kg
Rhodium	7440-16-6	<	1.28E+00	kg
Rubidium	7440-17-7	<	1.91E+01	kg
Ruthenium	7440-18-8	<	3.34E-01	kg
Samarium	7440-19-9	<	1.11E-01	kg
Selenium	7782-49-2	<	2.78E-01	kg
Selenium-79	15758-45-9	<	3.77E-04	Ci
Silicon	7440-21-3		1.02E+01	kg
Silver	7440-22-4	<	3.83E-02	kg
Sodium	7440-23-5		5.85E+01	kg
Strontium	7440-24-6		1.35E+00	kg
Strontium-89/90	10098-97-2		5.14E+02	Ci
Sulfide	18496-25-8	<	3.16E-02	kg
Sulfate	14808-79-8		4.47E-01	kg
Tantalum	7440-25-7	<	2.23E-01	kg
Technetium-99	14133-76-7		3.93E-03	Ci
Tellurium	13494-80-9	<	4.45E-01	kg
Tetrachloroethene	127-18-4	<	2.30E-05	kg
Thallium	7440-28-0	<	7.50E-01	kg
Thorium	7440-29-1		6.93E-01	kg
Thorium-228	14274-82-9		1.16E-05	Ci
Thorium-230	14269-63-7	<	2.29E-01	Ci

Table A-3. 95% Upper Confidence Level Inventory for SST C-202 Residual Waste.
(5 sheets)

Constituent Name	CAS Number	< Detection Limit	Inventory at 95% UL	Inventory Units
Thorium-232	NA		7.93E-06	Ci
Tin	7440-31-5		7.91E-01	kg
Titanium	7440-32-6		6.53E-01	kg
Toluene	108-88-3	<	2.06E-05	kg
Trans-1,3-Dichloropropene	10061-02-6	<	1.80E-05	kg
Tributyl phosphate	126-73-8		6.03E+00	kg
Trichloroethene	79-01-6	<	3.52E-05	kg
Trichlorofluoromethane	75-69-4	<	2.63E-05	kg
Tritium	15086-10-9	<	2.12E-02	Ci
Tungsten	7440-33-7	<	3.59E-01	kg
Uranium	7440-61-1		1.58E+02	kg
Uranium-233	13968-55-3	<	1.07E-01	Ci
Uranium-234	13966-29-5		4.47E-02	Ci
Uranium-235	15117-96-1		1.78E-03	Ci
Uranium-236	13982-70-2		5.02E-04	Ci
Uranium-238	NA		4.08E-02	Ci
Vanadium	7440-62-2	<	3.34E-02	kg
Vinyl chloride	75-01-4	<	1.25E-05	kg
Xylene (m)	108-38-3	<	4.99E-05	kg
Xylene (o)	95-47-6	<	4.99E-05	kg
Xylene (p)	106-42-3	<	1.56E-05	kg
Xylenes (total)	1330-20-7	<	6.46E-05	kg
Yttrium	7440-65-5	<	2.78E-02	kg
Zinc	7440-66-6		5.72E-01	kg
Zirconium	7440-67-7		1.10E-01	kg

CAS = Chemical Abstracts Service Registry Number
< = Below