CALCULATION COVER SHEET

Prepared For the U.S. Department of Energy,
Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352,
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

1. **Calc. No.** RPP-CALC-56856
Rev. 0

2. **Page** 1
2a. **Total Pages:** 19
3. **Document Media** ☐ Hard Copy ☒ PDF

4. Job/Project Name/Number	5. Calculation Title/Subject	6. Date
T2R29	Estimated Waste Volume Remaining in Single Shell Tank 241-C-112 after Hard Heel Retrieval	4/9/2014

7. Design Agent's Name, Organization, & Phone No.
WB Barton
Process Engineering
376-5118

8. USQ Number ☐ N/A
No. TF-14-0732-D R-Ø
M.V. Shultz 04/22/14
USQ Evaluator Sign/Date
MV SHULTZ

9. PrHA Number ☒ N/A
No.

10. Building/Facility No.	11. System	12. Structure	13. Equipment ID No. (EIN)	14. Safety Designation
241 C Farm	WST	241 C-112	NA	☐ SC ☐ SS ☐ GS ☒ NA

TMP 4/24/14

15. Design Verification (DV) per TFC-ENG-DESIGN-C-52 Required?
☐ Yes ☐ No ☒ N/A
Provide reference to DV as appropriate.

16. Related Documents/ECNs/EDTs
NA

17. TBDs or HOLDS in Calculation? ☐ Yes ☒ No

18. Approval Designator
NA

19. Native File(s) Submitted? ☒ Yes ☐ No

20. Software Used	21. Program Name and Version	22. Software Validation/Verification Document Number	23. Technical Baseline Document
☒ Yes ☐ No	SVF-1770, Rev. 2	RPP-42930 Rev. 3	☐ Yes ☒ No

24. Distribution (Use Distribution Sheet Form # A-6000-135 as required)

Name	MSIN	Name	MSIN
WB Barton	S7-90		
JS Boettger	S7-90		
CS Smalley	S7-90		
KE Carpenter	S7-75		
Peggy M Hamilton	S7-75		
TL Sams	R2-52		
VL Wagner	S7-75		
NW Kirch	R2-58		
MJ Rodgers	R2-58		
JG Reynolds	R2-58		

Release Stamp

DATE:
Apr 24, 2014
HANFORD RELEASE

25. Clearance Review

Cleared For Public Release? Yes ☑ No ☐ | Restricted Use? Yes ☐ No ☑ | Restriction Type:

26. Trademark Disclaimer
Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America.

27. Clearance Review:
APPROVED
By Julia Raymer at 8:11 am, Apr 24, 2014

Signature:______________________ Date:______
(Printed Name and Signature)

CALCULATION COVER SHEET

Prepared For the U.S. Department of Energy,
Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352,
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

1. **Calc. No. RPP-CALC-56856**
   Rev. 0
2. **Page** 2

2a. **Total Pages:** 19

3. **Document Media** ☐ Hard Copy ☒ PDF

28. **Description of Issue/Revision** (Use continuation pages as required)

This document provides the preliminary estimate of the waste remaining in tank 241-C-112 following retrieval completion based on a volume displacement method. It will be superceded by a final official volume estimate when the CCMS estimate work is complete.

29. **Justification for Issue/Revision** (Use continuation pages as required)

Supports PBI submittal for completion of C-112

30. **Key**

(a) Reason for Transmittal		(b) Disposition		
1. Approval	2. Review	1. Approved	3. Reviewed no comment	5. Disapproved
		2. Approved w/comment	4. Reviewed w/comment	

31. **Approvals**

(a) Reason	(b) Disposition	(c) Title	(d) Printed Name and Signature	(e) Date	(f) MSIN
1	1	Design Agent	WB Barton *WB Barton*	4-9-2014	57-90
1	1	Checker	CS Smalley *Colleen S Smalley*	4-9-14	57-90
1	1	Design Authority or DATR No.	JS Boettger *[signature]*	4/9/14	57-90
1	1	Engineering Manager	K. E. Carpenter *[signature]*	4/9/2014	57-75

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TERMS

Abbreviations and Acronyms

AN-101	tank 241-AN-101
C-112	tank 241-C-112
C-Farm	241-C Tank Farm
CAD	computer-aided design
SDDS	Surveillance Data Display System
TWINS	Tank Waste Information Network System

Units

cm	centimeter/centimeters
ft	foot/feet
ft^3	cubic feet
g	gram/grams
gal	gallon
in.	inch/inches

Calculation Checklist

Calculation Title/Subject: *Estimated Waste Volume Remaining in Single Shell Tank 241-C-112 after Hard Heel Retrieval*

Scope of Review: Entire Document

Engineer/Analyst: W.B. Barton *W B Barton* Date: 4-8-2014

Organization Manager: K. E. Carpenter *Kent E. Carpenter* Date: 4/9/2014

Yes	No*	NA*		
[✓]	[ ]	[ ]	a.	The objective/purpose of the calculation is clearly stated and the problem is completely defined by the purpose statement.
[✓]	[ ]	[ ]	b.	Analytical and technical approaches and results are reasonable and appropriate.
[✓]	[ ]	[ ]	c.	Input data are adequately described, referenced to their source, and checked for consistency with original source information.
[✓]	[ ]	[ ]	d.	Necessary assumptions are reasonable, explicitly stated, and supported. Assumptions requiring verification prior to use are clearly stated and identified/tracked using TBD/HOLD numbers.
[✓]	[ ]	[ ]	e.	For both qualitative and quantitative data, uncertainties are recognized and discussed and the data is presented in a manner to minimize design interpretations.
[✓]	[ ]	[ ]	f.	Mathematical derivations were checked, including dimensional consistency of results.
[✓]	[ ]	[ ]	g.	Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring outside information.
[✓]	[ ]	[ ]	h.	Hand and MathCAD® calculations were verified, including review that correct input data are used, formulae correctly interpret intended expressions, correct units are used, and results are reasonable and appropriate.
[✓]	[ ]	[ ]	i.	Software applications used are identified by the program name and version/release number, both on the calculation cover sheet and in the body of the document.
[✓]	[ ]	[ ]	j.	Software input data is identified and/or attached/included, the input data is correct, and consistent with the calculation document.
[✓]	[ ]	[ ]	k.	Software output is consistent with the input and with the results reported in the calculation document.
[✓]	[ ]	[ ]	l.	Software verification and validation are addressed adequately in accordance with TFC-BSM-IRM_HS-C-01. Software verification documentation is noted on the calculation cover sheet and in the body of the document as included in the calculation document or a reference is provided to separate verification documentation.
[✓]	[ ]	[ ]	m.	Spreadsheets used in the calculation are identified, verified, and documented in accordance with TFC-ENG-DESIGN_C-32. Reference to the corresponding spreadsheet verification form is provided on the calculation cover sheet and in the body of the calculation.
[✓]	[ ]	[ ]	n.	Data or results presented in tables and graphs have been checked against original source.
[✓]	[ ]	[ ]	o.	Unit conversions are correct and consistent.
[✓]	[ ]	[ ]	p.	The number of significant digits is appropriate and consistent.
[ ]	[ ]	[✓]	q.	Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references.
[✓]	[ ]	[ ]	r.	Conclusions are consistent with analytical results and applicable limits.
[✓]	[ ]	[ ]	s.	Results and conclusions address all points in the purpose.
[✓]	[ ]	[ ]	t.	Referenced documents are retrievable or otherwise available and the version or revision of each reference is cited.
[✓]	[ ]	[ ]	u.	The document was prepared in accordance with Attachment A, "Calculation Format and Preparation Instructions," of TFC-ENG-DESIGN-C-10.
[✓]	[ ]	[ ]	v.	Impacts on requirements have been assessed and change documentation initiated to incorporate revisions to affected documents, as appropriate.
[✓]	[ ]	[ ]	w.	All checker comments have been dispositioned and the design media matches the calculations.

C. S. Smalley *Colleen S Smalley* 4-9-14

Checker (printed name and signature) Date

* If less than the entire calculation was checked, the scope of the check should be discussed. If any blocks are checked "No" or "NA", an explanation must be provided here or attached

q: No limits/criteria/guidelines were applied to the analysis results.

Title: *Estimated Waste Volume Remaining in Single Shell Tank 241-C-112 after Hard Heel Retrieval*
Engineer/Analyst: WB Barton Wm Blaine Barton **Date:** 4/8/2014
Checker: CS Smalley Colleen S Smalley **Date:** 4/8/2014

1.0 OBJECTIVE/PURPOSE

This calculation documents the preliminary estimated total volume of waste remaining in tank 241-C-112 (C-112) as of January 28, 2014. The estimate of the waste volume is based on a liquid level measurement from C-112, liquid level measurements taken in receiver tank 241-AN-101 (AN-101) before and after the waste transfer from tank C-112, and video observations.

2.0 SUMMARY OF RESULTS AND CONCLUSIONS

The volume of waste remaining in tank C-112 as of January 28, 2014 is estimated to be 1,700 ft^3 (12,700 gal). Section 6.0 presents the methodology, measurement, results calculation, and uncertainty for this volume estimate. Additional video footage and a more precise estimate using the camera computer-aided design (CAD) measurement system per TFC-ENG-FACSUP-CD-22, "Post-Retrieval Tank Waste Volume Determination" will be developed for the retrieval data report and final volume calculation.

3.0 INTRODUCTION/BACKGROUND

Tank C-112 is a 530,000-gal single-shell tank that is one of twelve 75-ft diameter tanks built in 241-C Tank Farm (C-Farm) from 1944 to 1945. On April 18, 2012, tank C-112 was retrieved to the limit of technology using the modified sluicing technology leaving an estimated 33,600 gal of sludge remaining in the tank (RPP-RPT-52480, *Retrieval Completion Report for Modified Sluicing of Tank 241-C-112*). The estimate was based on volume balance calculations which have historically overestimated the volume of solids remaining after sluicing. The bulk of the remaining waste was comprised mostly of solids (hard heel) that were not mobilized by sluicing. The estimated composition of the remaining waste in tank C-112 was detailed in RPP-RPT-54588, *Tank 241-C-112 Hard Heel Retrieval Flowsheet for the Caustic Soak*. Modeling performed for RPP-RPT-54588 indicated that the dissolution/digestion targets of sodium fluoride phosphate (natrophosphate, $Na_7F[PO_4]_2 \cdot 19H_2O$), gibbsite, and sodium phosphate (trisodium phosphate, $Na_3PO_4 \cdot 12H_2O$) were present in significant quantities, and that other compounds in the solids included insoluble oxides of uranium, iron, and bismuth; fluorapatite ($Ca_5[PO_4]_3F$); and sodium aluminosilicate (cancrinite, $Na_6Ca_2[(CO_3)_2Al_6Si_6O_{24}] \cdot 2H_2O$). Preliminary results from the solid phase characterization of the samples taken at the end of caustic pre-conditioning verify that these compounds are present in the sludge (e-mail from G. A. Cooke to A. M. Templeton et. al., "C-112 Summary of SPC Results," (Cooke, G. A., 2013-12-16).

Based upon the results of heel retrieval operations performed in tanks 241-C-108, 241-C-109, and 241-C-104, and other experiences in C-Farm, caustic pre-conditioning followed by a sluicing process with supernate was selected as the best method for retrieving the remaining heel solids in tank C-112 (RPP-PLAN-55462, *Single-Shell Tanks 241-C-111 and 241-C-112 Hard Heel*

Retrieval Technology Selection). Due to the relatively large quantity of hard heel in tank C-112, a second caustic dissolution step was performed.

Retrieval of the tank C-112 hard heel was conducted between November 18, 2013 and January 31, 2014. The volume of waste remaining after retrieval, as described in this report, was determined using a liquid displacement process and video observations.

4.0 INPUT DATA

The dimensions of tank C-112 are documented in BPF-73550, *Specifications For Construction of Composite Storage Tanks Bldg. No. 241 Hanford Engineer Works Project 9536*, Drawing D-3. The tank diameter is 75 ft. The dish-shaped tank bottom is 12 in. deep, with a radius of 33 ft 8.875 in. and radius of curvature of 569.59 ft. A 4-ft-radius tank knuckle region (rising 47.9 in. from the top of the tank dish) connects the tank dish to the vertical tank wall. Tank C-112 has four stiffener rings located at 4.5-ft intervals with elevations of 5.5 ft, 10 ft, 14.5 ft, and 19 ft above the bottom of the tank. Each stiffener ring extends 5 in. from the wall. The topmost stiffener ring (ring #1) is located at the top of the tank liner and is sloped slightly downward from the wall to the inside edge of the ring.

After supernatant liquids from AN-101 and water were added to tank C-112 for the liquid displacement measurement, the tank C-112 Honeywell Enraf level gauge[1] (hereafter referred to as Enraf) showed a level reading of 21.32[2] inches, with limited solids observed above the liquid surface. The AN-101 Enraf showed a level of 268.18 inches. Liquid was transferred from the tank and Enraf measurements were made in tanks C-112 and AN-101. The measurement in C-112 was to determine the level measured when the Enraf plummet contacted the tank bottom. The measurement in AN-101 was to determine the volume of waste transferred from C-112. These measurements were 11.69 inches and 277.46 inches respectively (see table 6-1).

.

In addition to liquid level measurements, video recordings were made before, during, and after the pump-out of the waste. The video recordings provided information on the location and amount of waste above the starting liquid level. Video was taken of the tank walls and stiffener rings and of the Enraf displacer, to verify that it was hitting the bottom of the tank. Residual waste volumes were estimated from the tank videos for those areas which were not covered by the liquid to arrive at an estimate of the total waste in the tank.

5.0 ASSUMPTIONS

---

[1] Enraf® is a registered trademark of Honeywell International, Inc., Morristown, New Jersey.

[2] All ENRAF data was taken from the Surveillance Data Display System (SDDS), [Level readings from C112-LI-R005-01 and AN101-LI-R004-01], http://toc.rl.gov/rapidweb/SDDS/index.cfm?PageNum=1, for the appropriate date and time.

The following assumptions are used in the waste volume estimate.

- The volume displacement estimates assume that the tank dimensions are as documented in BPF-73550, Drawing D-3. Differences in actual tank dimensions have been observed for other tanks and may significantly impact volume displacement results.

- The tank C-112 Enraf measurement before starting the transfer is assumed to provide the most accurate starting volume for this tank. As noted in the first assumption, accuracy is contingent on the actual tank dimensions. Tank AN-101 Enraf measurements provide the best estimates for the volume of waste transferred. Totalizer measurements provide a second measure of the waste transferred, but generally have higher uncertainty than transfer volumes determined from Enraf measurements.

- The following conversion factors are used in the calculations:

    - 1 ft = 12 in.
    - 1 ft^3 = 7.481 gal
    - 1 m = 3.281 ft

6.0 METHOD OF ANALYSIS AND RESULTS

6.1 WASTE REMAINING IN TANK BOTTOM

6.1.1 Volume Displacement

Volume displacement is a means to estimate remaining volume by removing a known amount from a known starting volume. For tank C-112, enough supernatant liquid and water was added to the tank for final sluicing and liquid displacement measurements to cover all but about 500 gal of solids on the tank bottom(This does not include solids on the stiffener rings and walls). An Enraf measurement at the liquid surface in tank C-112 provided a starting liquid level for the volume displacement. The amount of waste transferred was measured by the change in the liquid level in the receiving tank (tank AN-101).

The tank farm tank volume calculator (SVF-1770, *SVF-1770, Rev 2 - Tank Waste Volume Calculator.xlsx*) was used to calculate waste volumes for tank C-112 using the tank C-112 Enraf readings. These volumes were a combination of solids and liquids. Waste volumes transferred to tank AN-101 were determined using the tank AN-101 Enraf to measure the liquid level in the tank before and after transfers from tank C-112. Again the tank volume calculator was used to convert the AN-101 liquid level readings to volume and the difference between the starting and ending volume was the volume transferred. Table 6-1 shows volume displacement results.

The Enraf plummet contacted the tank bottom at 11.69 inches. Based on tank drawings (BPF-73550), the Enraf should have contacted the tank bottom surface at 12.0 inches. This indicates that the distance from the top of the riser to the tank bottom is greater than shown in WHC-SD-WM-CN-078. As a result, a value of 0.31 in. was added to the tank C-112 Enraf readings listed in Table 6-1 to correct the Enraf measurement.

In addition, the Enraf reference level calculation for tank C-112, as shown in WHC-SD-WM-CN-078 Rev. 0-E, *ENRAF Reference Level Calculation*, shows that the Enraf is set up to sense solids having an assumed immersion depth of 0.00 inches. The Enraf works by measuring when a change in weight of the displacer of 15 grams occurs. If the displacer contacts a solid surface the weight change is immediate thus the use of an immersion depth of 0.00 inches. However, if it contacts a liquid surface the weight gradually changes as it is immersed in the liquid until it reaches 15 gram change in weight. An adjustment factor for this immersion is calculated below to account for the depth of the sensor displaced when reading water with a specific gravity of 1.0.

The following equation from HNF-4328, *Test Report for ENRAF Annulus Leak Detector Development* (equation 1, page B-3) was used to determine an immersion depth for the displacer in a liquid with a specific gravity of 1.0.

$$H = 4F_b/(\pi D^2 R_n) \qquad \text{eqn 1}$$

Where:

- H = Immersion depth (cm)
- D = Diameter of displacer = 2 in. or 5.08 cm
- R_n = Density of liquid (g/cm^3)
- F_b = buoyant force (g)

The Enraf installed in tank C-112 is set to measure a 15 g buoyant force (5-LCD-125, "ENRAF Series 854 Initial Installation and Operational Check"). Substituting the above values into equation 1 gives:

$$H = (4)(15\text{ g})/[\pi(5.08\text{ cm})^2(1.0\text{ g/cm}^3)]$$

$$H = 0.74\text{ cm or }0.29\text{ in.}$$

Accounting for both the Enraf offset from the tank bottom and the immersion depth for the displacer, a total of 0.60 in. was added to the measured Enraf level in C-112 to calculate the corrected level in Table 6-1.

Table 6-1. Liquid Displacement Measurements (January 28, 2014).

Incremental Volume Pumped Out	AN-101 Enraf* (in.)	C-112 Enraf measured (in.)	C-112 Enraf Corrected (in.)	AN-101 Volume (gal)	C-112 Volume (gal)	AN-101 Volume Change (gal)
Start	268.18	21.32	21.92	736911	37427	0
Finish	277.46			762440		25529

After the transfer, the volume of remaining waste and equipment in the C-112 tank bottom was estimated to be 11,898 gal (1,590 ft^3) by difference and 500 gal was conservatively estimated to bound the waste above the liquid level (ENRAF reading) by review of the video for a total of 12,398 gal (1,657 ft^3). This was calculated by determining the starting volume in tank C-112 and subtracting the volume transferred to tank AN-101 (37,427-25,529) and adding the estimated waste volume above the liquid level.

6.1.2 Potential Sources of Error in Liquid Displacement Results

One of the key assumptions for the volume displacement calculation to provide correct results is that the tank configuration is the same as the design drawings (see Section 5.0). For the relatively small volume of waste remaining in the tank, a smaller tank radius or bulge or ripples in the tank bottom could introduce errors in the result. Measurements in 241-C-105 and 241-C-107 have shown slightly smaller diameters than the drawing shows. Numerous tanks have shown irregularities in the dish of the tank, usually an upward bulging of a portion of the dish. Both of these conditions lead the volume displacement to overstate the volume of waste remaining in the tank with the effect being larger the smaller the calculated volume of waste remaining. Thus volume displacement provides a conservative estimate of the waste remaining on the floor of the tank.

6.1.3 Video Results

The volume displacement was done on January 28, 2014. Following the volume displacement the tank was rinsed with water to remove as much soluble waste from the liquid as possible and final tank videos were obtained February 3-4, 2014 from both risers 3 and 6. The volume of waste observed appears to be consistent with volume displacement measurements and may be lower.

Figures 6-1 to 6-6 show still photographs of waste remaining on the tank bottom. A drawing of waste residuals using the camera CAD measurement system per TFC-ENG-FACSUP-CD-22 will be developed for the retrieval data report and final residual waste volume calculated.

Figure 6-1. Tank 241-C-112 Panorama View.

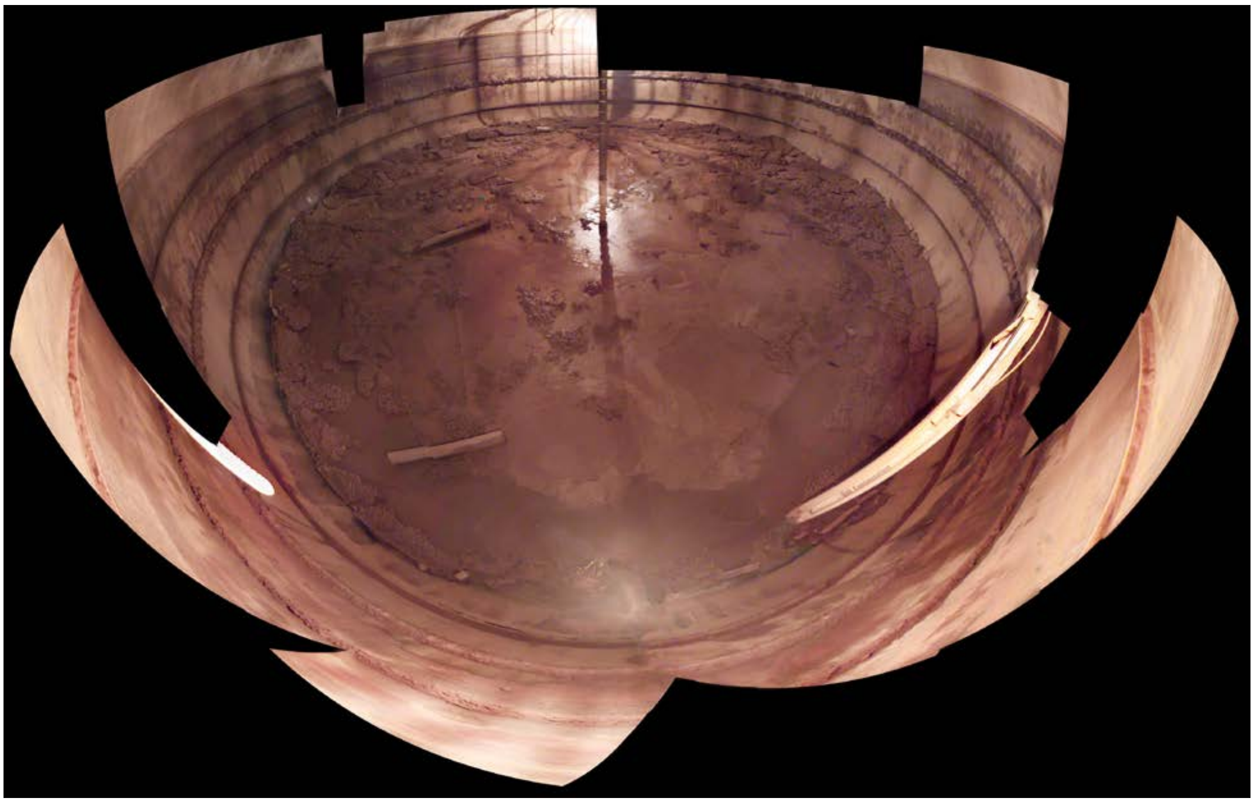


Figure 6-2. Tank 241-C-112 from Riser 6.

Figure 6-3. Tank 241-C-112 Enraf Plummet from Riser 6.

Subsequent video clearly shows that the tank bottom was clear under the plummet when it was raised.

Figure 6-4. Tank 241-C-112 from Riser 3.

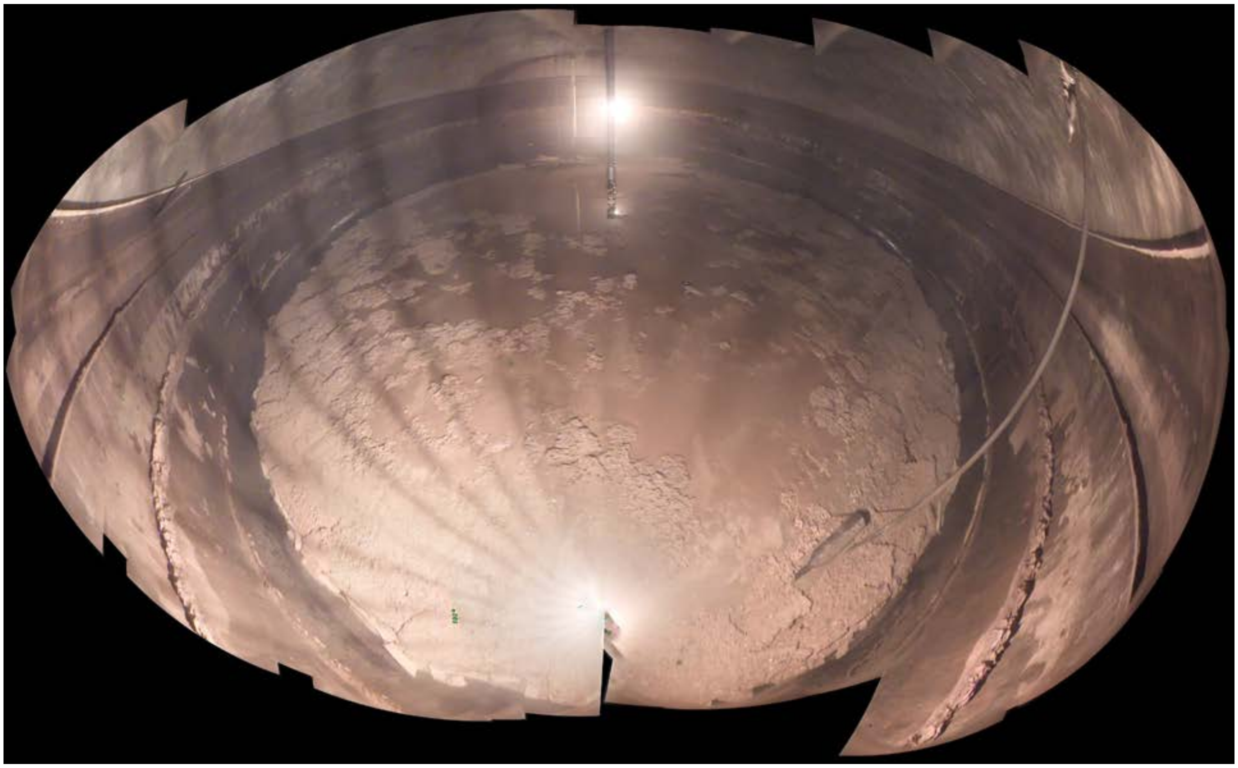
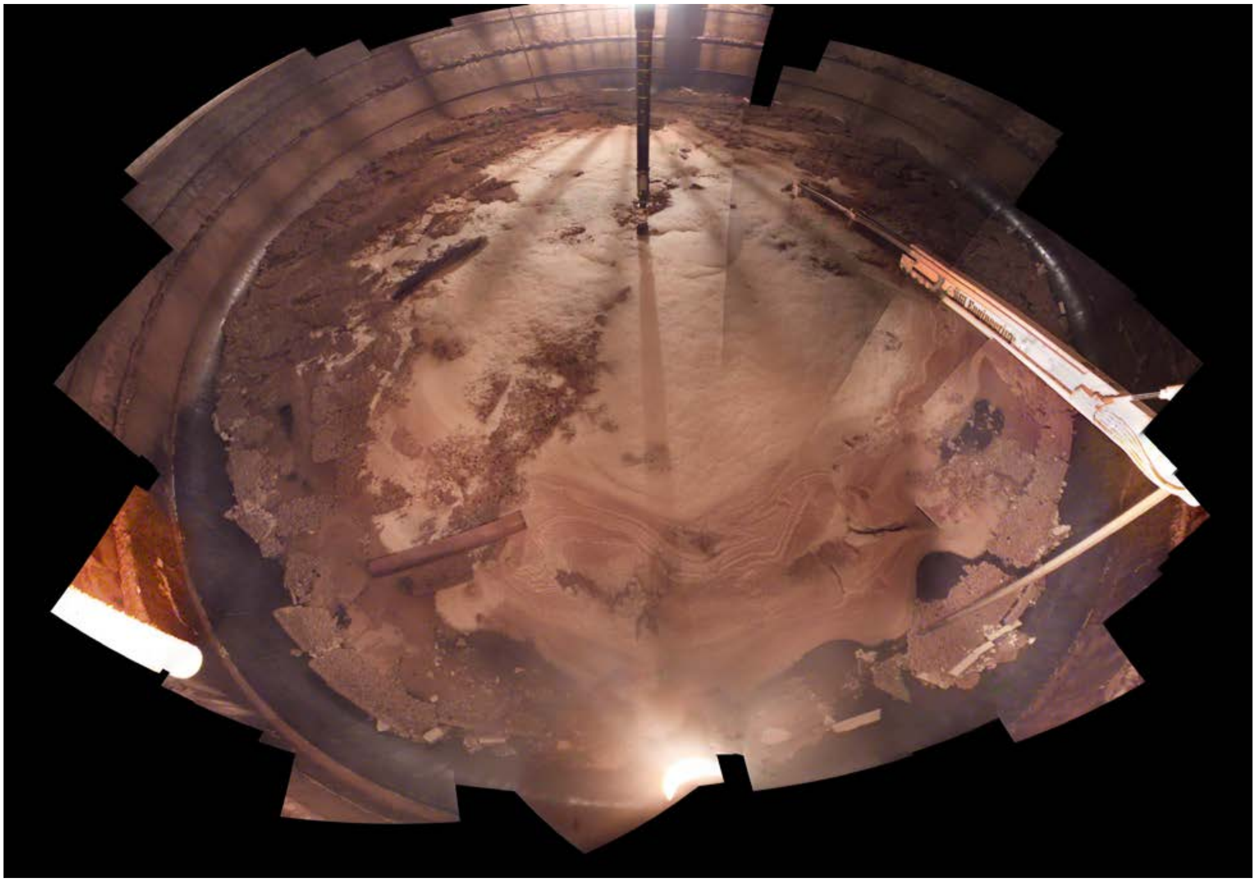


Figure 6-5. Tank 241-C-112 Tank Stiffener Rings and Wall.

Figure 6-6. Tank 241-C-112 Composite.



6.2 WASTE ON STIFFENER RINGS

The volume of waste on the stiffener rings was calculated by estimating the average depth of the waste on each of the stiffener rings and multiplying by the surface area of each of the rings (97.6 ft^2). The average depths of waste on the stiffener rings were estimated based on video observation and comparisons with video estimates before and after the retrieval. Figures 6-1, 6-5, and 6-6 show photographs of the rings after completing retrieval. Only ring 3 shows a significant amount of waste on the ring. In general the tank rings were clean compared to previous C-Farm tanks retrieved. Table 6-2 shows the estimated depth and volume of waste remaining on each of the stiffener rings.

Table 6-2. Waste Estimates for Stiffener Rings.

Stiffener Ring #	Average Waste Depth	Waste Volume (ft^3)
1 (top)	0.25 in.	2.03
2	0.25 in.	2.03
3	3.5 in.	28.5
4 (above knuckle)	0.25	2.03
Total		34.6 (259 gal)

The waste volume for each ring was estimated using:

$$V = \pi(R^2 - r^2)h \qquad \text{eqn. 2}$$

Where:

R = outer radius of stiffener ring
= 75 ft/2
= 37.5 ft

r = inner radius of stiffener ring
= 37.5 ft – 5 in./12 in./ft

h = average thickness of waste on the stiffener ring as estimated from the photograph by the author.

Stiffener ring #1:

$$V_1 = \pi(R^2 - r^2)h_1$$

Where:

h_1 = 0.25 in.

$V_1 = \pi[(37.5 \text{ ft})^2 - (37.5 \text{ ft} - 5 \text{ in.}/12 \text{ in./ft})^2](0.25 \text{ in.}/12 \text{ in./ft})$

$= 2.03 \text{ ft}^3$ (15.2 gal)

Stiffener ring #2:

$$V_2 = \pi(R^2 - r^2)h_2$$

Where:

h_2 = 0.25 in.

$V_2 = \pi[(37.5 \text{ ft})^2 - (37.5 \text{ ft} - 5 \text{ in.}/12 \text{ in./ft})^2] (0.25 \text{ in.}/12 \text{ in./ft})$

$= 2.03 \text{ ft}^3$ (15.2 gal)

Stiffener ring #3:

$$V_3 = \pi(R^2 - r^2)h_3$$

Where:

h_3 = 3.5 in.
$V_3 = \pi[(37.5 \text{ ft})^2-(37.5 \text{ ft} - 5 \text{ in./12 in./ft})^2]\ (3.5 \text{ in./12 in./ft})$
$= 28.5 \text{ ft}^3$ (213 gal)

Stiffener ring #4:

$$V_4 = \pi(R^2-r^2)h_4$$

Where:

h_4 = 0.25 in.
$V_4 = \pi[(37.5 \text{ ft})^2-(37.5 \text{ ft} - 5 \text{ in./12 in./ft})^2]\ (0.25 \text{ in./12 in./ft})$
$= 2.03 \text{ ft}^3$ (15.2 gal)

Total Waste Volume on Stiffener Rings:
The total volume of waste on the stiffener rings is:

$V = V_1 + V_2 + V_3 + V_4$
$= 2.03 \text{ ft}^3 + 2.03 \text{ ft}^3 + 28.5 \text{ ft}^3 + 2.03 \text{ ft}^3$
$= 34.6 \text{ ft}^3$ = 259 gal

6.3 WASTE ON TANK WALLS

The waste on the walls was also determined by estimating an average depth and multiplying by the surface area between each stiffener ring. Figure 6-5 shows photographs of the tank walls. The tank walls appear to be mostly clean, but some waste was observed on the tank walls between the stiffener rings. Because of the thin layer of waste on the tank walls, a uniform, nonporous layer is assumed. The waste volume was calculated as follows, assuming a thickness of ~0.0625 in. on half the tank wall between stiffener rings #1 and #2, rings #2 and #3, and rings #3 and #4.

R = tank radius
= 37.5 ft
h = distance between stiffener rings
= 4.5 ft
t = waste thickness between stiffener rings
= 0.0625 in. = 0.00521 ft
c = coverage factor
= 0.5

Wall between stiffener rings:

V = Volume of waste between stiffener rings
$= 2\pi Rhtc$ eqn. 3
$= 2\pi\ (37.5 \text{ ft})(4.5 \text{ ft})(0.00521 \text{ ft})(0.5)$

$= 2.76\ ft^3$ per wall segment

Total Waste Volume on Wall

Total Volume $= V\ (3)$
$= 8.3\ ft^3$ (62 gal)

6.4 TOTAL WASTE IN TANK

Summing the waste volumes on the tank bottom, stiffener rings and walls, the total volume of waste remaining in tank C-112 is estimated to be less than:

$$V = 1{,}657\ ft^3 + 34.6\ ft^3 + 8.3\ ft^3 = 1700\ ft^3\ (12700\ gal).$$

Sources of uncertainty in the estimate of the volume of waste remaining in tank C-112 are waste characteristics and Enraf measurement adjustment.

- Visual observation of the waste remaining in tank C-112 suggests that the waste is comprised of a nearly monolithic layer rather than of sludge-like material.

  The Enraf measurement of the tank bottom indicated that the distance from the top of the riser to the tank bottom may be slightly greater than expected. The calculation of the waste remaining in the tank used an adjustment for this difference. An adjustment was not made to the initial tank waste volume of 104,000 gal prior to bulk retrieval, which was also based on waste level measurements.

The results of this calculation indicate that ~21,000 gal of waste has been retrieved while the volume balance (SVF-2867, *C-112 volume balance (Final).xlsx*), which calculates the volume retrieved from the increase in the volume of tank AN-101, indicates that ~3000 gallons of waste was retrieved. This difference can be a result of factors such as water evaporation, void space in the solids, and uncertainty in the initial volume.

- Evaporation is not accounted for in the volume balance. Water exiting the system via the off-gas will not be received in tank AN-101 and the volume balance is biased low. Evaporation rates during sluicing are not known but are expected to be higher than when the tank is not being retrieved due to the high droplet surface area available for evaporation as supernatant liquid is sprayed into the tank.

- There is an uncertainty associated with the tank C-112 initial volume. The Best-Basis Inventory states that the relative standard deviation of the tank C-112 volume at the restart of retrieval is 35% (Tank Waste Information Network System (TWINS), Queried 04/04/14, [Best-Basis Calculation Detail, Tank 241-C-112], https://twins.labworks.org/twinsdata/Forms/About.aspx.)

- Factors such as uncertainties in flow measurements; potential gas retention in tank solids; and solids dissolution or non-ideal mixing behavior explain some of the difference between the results of this calculation and the results of the volume balance. However, these factors do not contribute to uncertainty in this calculation. The results of this calculation are not dependent on these factors.

7.0 USE OF COMPUTER SOFTWARE

The conversion of liquid level measurements to waste volumes was performed using Excel®[3] spreadsheet SVF-1770, which is described in RPP-42930, *Spreadsheet Description Document for Tank Waste Volume Calculator.xlsx*. No other computer software or spreadsheets were required for the calculation. The tables presented were generated in Excel for ease of visualization of the data.

8.0 CONCLUSIONS

The preliminary remaining waste volume for tank C-112 is estimated as follows:

Tank bottom	= 1,657 ft^3
Stiffener Rings	= ~35 ft^3
Tank Walls	= ~8 ft^3
Total	= 1,700 ft^3 (12,700 gal).

Additional video footage and a more precise estimate using the camera CAD measurement system per TFC-ENG-FACSUP-CD-22 will be developed for the retrieval data report and final volume calculation.

9.0 REFERENCES

5-LCD-125, Rev. I-0, "ENRAF Series 854 Initial Installation and Operational Check," Washington River Protection Solutions, LLC, Richland, Washington.

BPF-73550, 1944, *Specifications For Construction of Composite Storage Tanks Bldg. No. 241 Hanford Engineer Works Project 9536*, Drawing D-3, Rev. 2, Richland, Washington.

Cooke, G. A., 2013-12-16, "C-112 Summary of SPC Results," (e-mail to A. M. Templeton et. al.), Washington River Protection Solutions, LLC, Richland, Washington.

[3] Excel is a registered trademark of Microsoft Corp., Redmond, Washington.

HNF-4328, 1999, *Test Report for ENRAF Annulus Leak Detector Development*, Rev. 0, Lockheed Martin Hanford Corporation, Richland, Washington.

RPP-42930, 2012, *Spreadsheet Description Document for Tank Waste Volume Calculator.xlsx*, Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-55462, 2013, *Single-Shell Tanks 241-C-111 and 241-C-112 Hard Heel Retrieval Technology Selection*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-52480, 2012, *Retrieval Completion Report for Modified Sluicing of Tank 241-C-112*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54588, 2013, *Tank 241-C-112 Hard Heel Retrieval Flowsheet for the Caustic Soak*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

Surveillance Data Display System (SDDS), [Level readings from C112-LI-R005-01 and AN101-LI-R004-01], http://toc.rl.gov/rapidweb/SDDS/index.cfm?PageNum=1.

SVF-1770, 2012, *SVF-1770, Rev 2 - Tank Waste Volume Calculator.xlsx*, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

SVF-2867, 2014, *C-112 volume balance (Final).xlsx*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ENG-FACSUP-CD-22, Rev. B-3, "Post-Retrieval Tank Waste Volume Determination," Washington River Protection Solutions, LLC, Richland, Washington.

Tank Waste Information Network System (TWINS), Queried 04/04/14, [Best-Basis Calculation Detail, Tank 241-C-112], https://twins.labworks.org/twinsdata/Forms/About.aspx.

WHC-SD-WM-CN-078, 2013, *ENRAF Reference Level Calculation*, Rev. 0-AL, Washington River Protection Solutions, LLC, Richland, Washington.