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Revision 0

Single-Shell Tank Structural Integrity Assessment Report

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Single-Shell Tank Structural Integrity Assessment Report

Subcontract No. 64127

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August 30, 2018

INDEPENDENT QUALIFIED REGISTERED PROFESSIONAL ENGINEER (IQRPE) CERTIFICATION OF SINGLE-SHELL TANK STRUCTURAL INTEGRITY ASSESSMENT

As stated in WAC 173-303-810(13)(a):

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Signed and Certified:

Paul M. Giever, S.E.

Date: 8/30/2018

Independent Qualified Registered Professional Engineer (IQRPE)

EXECUTIVE SUMMARY

Integrity assessments are required to determine that the existing single-shell tanks (SST) located at the Hanford Site have structural integrity such that they will not collapse, rupture, or fail. This is a requirement of the Hanford Federal Facility Agreement and Consent Order Tri-Party Agreement (TPA)[1] Change Request M-45-10-01 which established SST Integrity Project interim milestones and targets in January 2011. Interim Milestone M-045-91I established the requirement for this SST structural integrity assessment to be completed with an Independent Qualified Registered Professional Engineer (IQRPE) certification by September 30, 2018.

> *DOE shall provide, to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify. The analysis supporting the certification shall be performed in accordance with the requirements identified for analysis in WAC 173-303-640(2)*[2] *and will include a due diligence review of RPP-10435.*[3] *IQRPE certification of the SST leak integrity is not required. A work plan and schedule for additional integrity assessment activities will be submitted as a change package to cover any time period between the end date of the IQRPE certification and the end date of the mission.*

This integrity assessment is being completed on behalf of the owner, the U.S. Department of Energy (DOE). Washington River Protection Solutions, LLC (WRPS) operates and maintains the SSTs on behalf of the DOE Office of River Protection. The Washington State Department of Ecology (Ecology) has regulatory authority over the Dangerous Waste constituents within the SSTs under WAC 173-303.[4]

This SST Integrity Assessment Report (IAR) addresses regulatory requirements of WAC 173-303-640(2) as applied to this integrity assessment including certification of this integrity assessment report by an IQRPE as required by WAC 173-303-810(13)(a).[5] The purpose of this integrity assessment is to determine if the SSTs are structurally sound such that the entire system is adequately designed, and is structurally adequate and compatible with the waste to ensure that the system will not collapse, rupture, or fail and have structural integrity. This 2018 SST structural integrity assessment is necessary for continued safe storage of waste in the SSTs; as such, this report documents the activities, reviews, analyses, evaluations, and examinations performed to support the IQRPE's assessment of the SSTs.

As part of this 2018 IAR, a due diligence review was done of the 2002 IAR to determine if the 2002 report conclusions were reasonable in 2002 and for continued safe storage.

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[1] Ecology, EPA, and DOE, 2011, *Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Change Package M-45-10-01*, as amended, State of Washington Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

[2] WAC 173-303-640(2), "Assessment of Existing Tank System's Integrity," *Washington Administrative Code*, as amended.

[3] RPP-10435, 2002, *Single-Shell Tank System Integrity Assessment Report*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

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

[5] WAC 173-303-810(13)(a), "Certification," *Washington Administrative Code,* as amended.

This IAR of the SSTs is the second such report. The last 2002 IAR[3] stated the SSTs had adequate collapse margin such that continued safe storage of waste was justified. Due to the fact that the 2002 IAR could not certify the SSTs for leak integrity, the SSTs were declared unfit for use per DOE Letter 02-OMD-036.[6] That letter allowed continued use of the SSTs for interim safe storage of waste. This 2018 IAR uses the results of the 2002 IAR as a fixed, reference baseline for purposes of assessing the SSTs, and uses both structural analyses and structural field evaluations that have been completed for the SSTs during the period from July 1, 2002 to July 31, 2018.

The 2002 IAR had a broader scope than this report. Since the SSTs have been declared unfit for use due to some of the tanks having leaked, leak integrity is not included in the scope of this assessment. In addition to leak integrity assessment, the 2002 report addressed associated ancillary equipment including subordinate tank systems, vaults, transfer pipelines, pump pits, lift stations, catch tanks, unloading stations, and other components used to treat, store, or transfer hazardous waste within the boundary of the SST system. Since these ancillary equipment have been declared unfit for use, this ancillary equipment is not included in this report. So, for this report, the tank systems are strictly the SSTs themselves.

In 1994, TPA Change Number M-45-93-01[7] established Milestone M-45-06 that required complete closure of all the SSTs by September of 2024. By 2010, it was apparent that milestone was not going to be achieved and a new TPA Change Number M-45-09-01[8] established Milestone M-45-70 that required complete waste retrieval of the SSTs by December 31, 2040 or earlier per Milestone M-62-45. TPA Change Number M-45-09-01 also established Milestone M-45-91 that required a panel of technical and recognized experts to perform a SST integrity assurance review. In essence, the Expert Panel performed a due diligence review of the SSTs.

From the Expert Panel, several recommendations were developed that greatly advanced the understanding of the SSTs. This included modern finite element analyses of the tank structures, sidewall core sampling, concrete and rebar testing, regular visual inspections and a reemphasis on the dome deflection surveys.

TPA Milestone M-045-00 currently lists complete closure of SST farms by January 31, 2043. RPP-RPT-60192[9] lists dates as late as fiscal year 2078 for closure. So, the end of mission (i.e., SST closure) appears to be between 2043 and 2078 based on various funding/planning scenarios.

The conclusion of this integrity assessment report is that the SSTs are structurally sound such that they will not collapse, rupture, or fail. There are no findings that the SSTs were not operated or

[6] 02-OMD-036, 2002, Letter, J.E. Rasmussen, Office of River Protection, U.S. Department of Energy, to M.A. Wilson, Washington State Department of Ecology, *Submittal of M-23-24 Single-Shell Tank (SST) System Integrity Assessment Report*, dated June 27.

[7] Ecology, EPA, and DOE, 1994, *Change Number M-45-93-01, Complete Closure of Single-Shell Tank Farms,* State of Washington Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

[8] Ecology, EPA, and DOE, 2010, *Change Number M-45-09-01, Hanford Federal Facility Agreement and Consent Order Milestone Modifications to the M-045-00 Series for Single-Shell Tank Retrieval and Closure of Single-Shell Tanks, Resulting from the 2007-2009 Hanford Negotiations on Changes to the Hanford Federal Facility Agreement and Consent Order (HFFACO), also Known as the Tri-Party Agreement or TPA,* State of Washington Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

[9] RPP-RPT-60192, 2018, *System Plan, Revision 8, Lifecycle Cost Analysis,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

maintained per code or legal or industry standards. WAC 173-303-640(2)[2] states to determine an estimated remaining useful life (ERUL) if practical, but an ERUL could not be determined. There are several recommendations to improve the operation of the SSTs. Most notably, the next integrity assessment should be completed in 16 years from this report. Other recommendations and a work plan of suggested activities for the next integrity assessment are summarized in Section 8.0 of this report.

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Acronyms and Abbreviations

ACI	ACI International
ANSI	American National Standards Institute
AOR	analysis of record
API	American Petroleum Institute
ARH	Atlantic Richfield Hanford Company
ASME	American Society of Mechanical Engineers
BBI	best-basis inventory
bgs	below ground surface
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	State of Washington Department of Ecology
FY	fiscal year
HIHTL	hose-in-hose transfer line
IAR	Integrity Assessment Report
IBC	International Building Code
IQRPE	Independent Qualified Registered Professional Engineer
LFL	lower flammability limit
MARS	mobile arm retrieval system
MCE	maximum considered earthquake
MUST	miscellaneous underground storage tank
NSHMP	National Seismic Hazard Mapping Project
ORP	U.S. Department of Energy, Office of River Protection
PNNL	Pacific Northwest National Laboratory
PSHA	probabilistic seismic hazard analysis
PUREX	plutonium-uranium extraction
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	reduction-oxidation
SME	subject matter expert
SOW	statement of work
SST	single-shell tank
SSTIP	Single-Shell Tank Integrity Project
TOLA	gravity, thermal, and load operating analysis
TPA	Tri-Party Agreement
TSD	treatment, storage, and disposal
TTI	tank-to-tank interaction
USGS	U.S. Geologic Survey
WAC	*Washington Administrative Code*
WRPS	Washington River Protection Solutions, LLC

Units

~	approximately
’	foot
”	inch
%	percent
°C	degrees Celsius
°F	degrees Fahrenheit
Ω-cm	Ohm centimeter
cm	centimeter
ft	foot
ft^3	cubic foot
in.	inch
in^2	square inch
kip	kilopound
ksi	kilopound per square inch
lbf	pound force
mi^2	square mile
mpy	mils per year
pcf	pounds per cubic foot
psf	pounds per square foot
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge

TRADEMARK DISCLOSURE

ACI is a registered trademark of the American Concrete Institute, Farmington Hills, Michigan.

ANSYS is a registered trademark of ANSYS, Inc., Canonsburg, Pennsylvania.

API is a registered trademark of the American Petroleum Institute, Washington, D.C.

ASME is a registered trademark of the American Society of Mechanical Engineers, New York, New York.

IBC is a registered trademark of the International Code Council, Inc., Washington, D.C.

1.0 INTRODUCTION

This Single-Shell Tank (SST) Structural Integrity Assessment Report (IAR) was prepared to determine that the structural integrity of the SSTs meet the requirements of WAC 173-303-640(2), "Assessment of existing tank system's integrity." To this end, this report provides the determination and assessments by an Independent Qualified Registered Professional Engineer (IQRPE) as to the integrity of the SSTs.

The Hanford Site covers an area of 560 mi^2 and is located in south-central Washington State as shown in Figure 1-1. Most of the Hanford Site is a limited-access area under the control of the U.S. Department of Energy (DOE). The SSTs are located in the 200 East and 200 West Areas, shown diagrammatically in Figure 1-2, near the center of the Hanford Site on a relatively flat terrace known as the 200 Area Plateau. Figure 1-3 shows an aerial photo of A Tank Farm.[10]

As an existing tank system (i.e., a system used for storage or treatment of dangerous waste in operation before February 3, 1989), the SSTs must comply with the requirements of WAC-173-303-640(2), "Assessment of existing tank system's integrity." WAC 173-303-640(2) requires periodic integrity assessments of tank systems that store dangerous waste and requires a determination by an IQRPE that the tank system is structurally sound such that the entire system is adequately designed and is structurally adequate and compatible with the waste to ensure that the system will not collapse, rupture, or fail, and has structural integrity.

1.1 BACKGROUND

The SST system is classified by *Resource Conservation and Recovery Act of 1976* (RCRA) regulations, and WAC 173-303-640, "Tank Systems," as an existing interim status treatment, storage, and disposal (TSD) tank system. An assessment of the 100-series and 200-series SSTs' structural integrity is to be completed by September 30, 2018. The assessment is to conform to the requirements described in Interim Milestone M-045-91I of Ecology et al. 1989, *Hanford Federal Facility Agreement and Consent Order* (hereinafter TPA), and the requirements of WAC 173-303-640(2) applicable to the SSTs structural integrity. The assessment must be certified by an IQRPE in accordance with WAC 173-303-810(13)(a), "Certification."

The first SST system IAR was completed in 2002. That assessment is published as RPP-10435, *Single-Shell Tank System Integrity Assessment Report*.

Between 1943 and 1966, a total of 149 underground tanks were constructed in 12 tank farms on the Hanford Site to temporarily store the nuclear waste generated from plutonium production. These tanks, generally referred as SSTs, are underground nuclear waste storage tanks constructed with a single wall, carbon steel liner, backed by a cylindrical reinforced concrete structure. The 12 tank farms are identified as A, AX, B, BX, BY, and C in the 200 East Area and S, SX, T, TX, TY, and U in the 200 West Area. The tanks are classified as Types I through IV per their waste capacities and design features. The four tank types described in Figure 1-4 range in capacity from 55,000 gallons to 1,000,000 gallons. The smallest Type I tanks are 20 ft in diameter while the Type II, III, and IV tanks are nominally 75 ft in diameter (Figure 1-4).

[10] Tank farms and tanks and components are numbered with the prefix '241-'; that prefix is omitted in this report to ease readability.

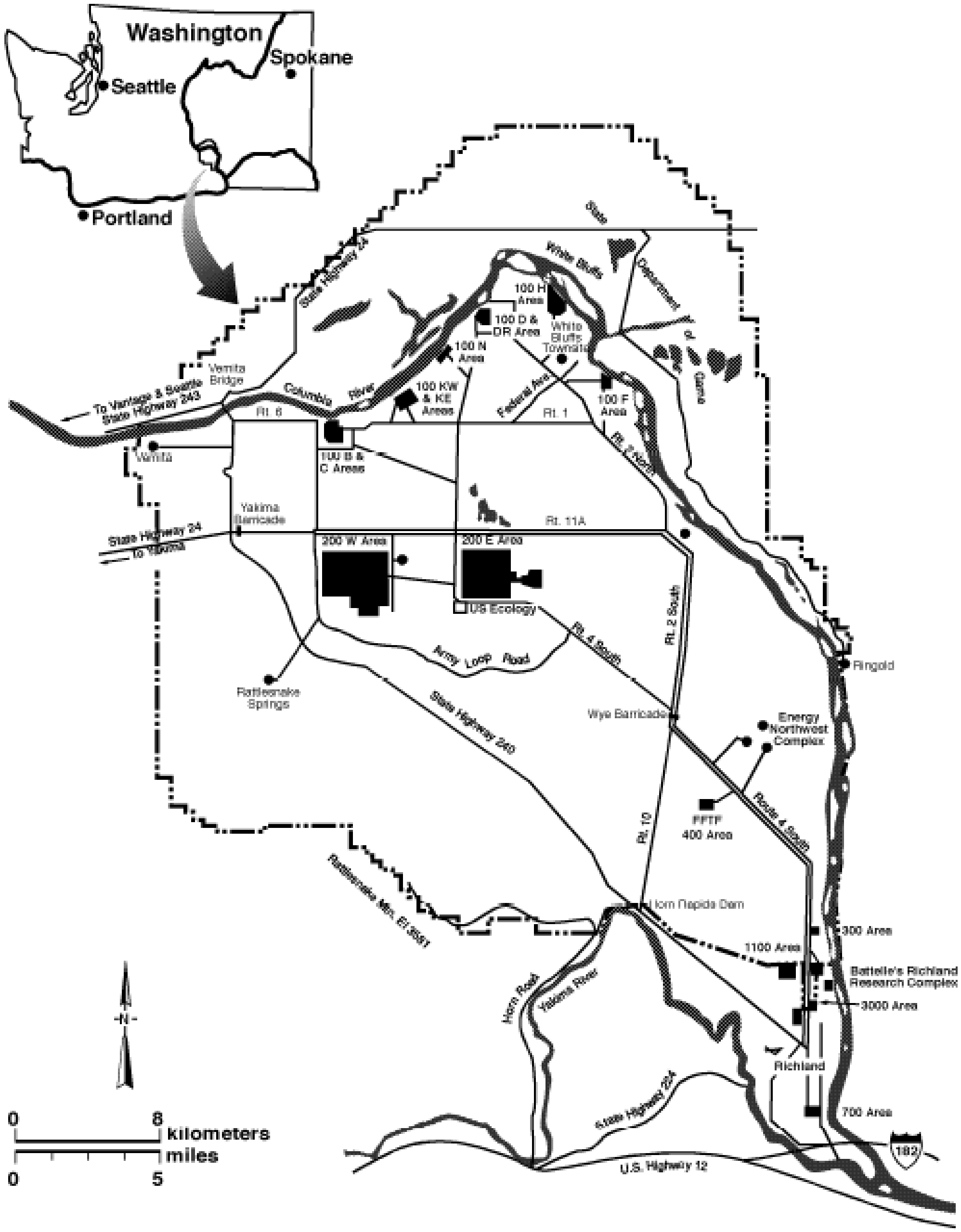


Figure 1-1: Hanford Site Map

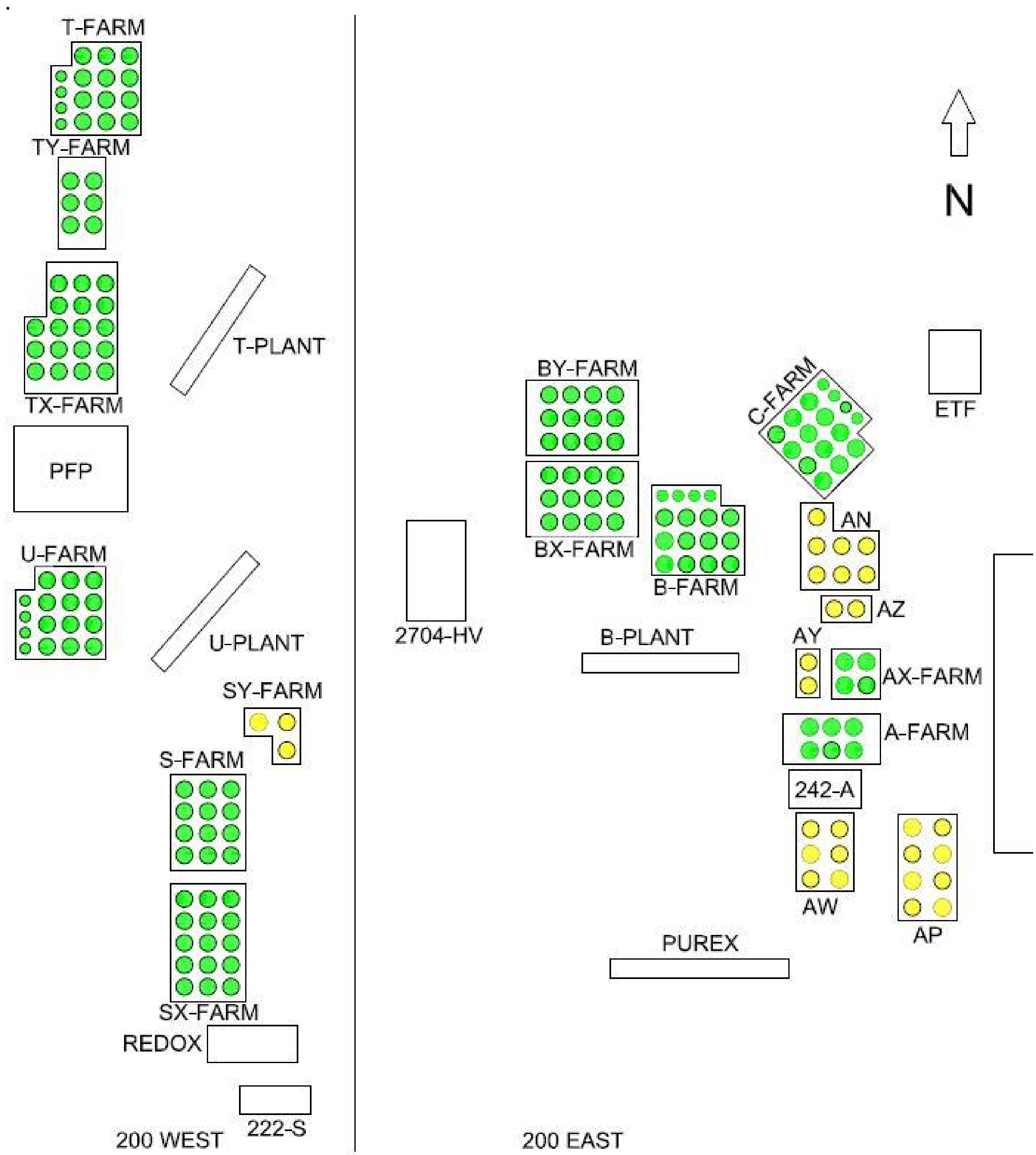


Figure 1-2: Diagrammatic Single-Shell Tank Site Map

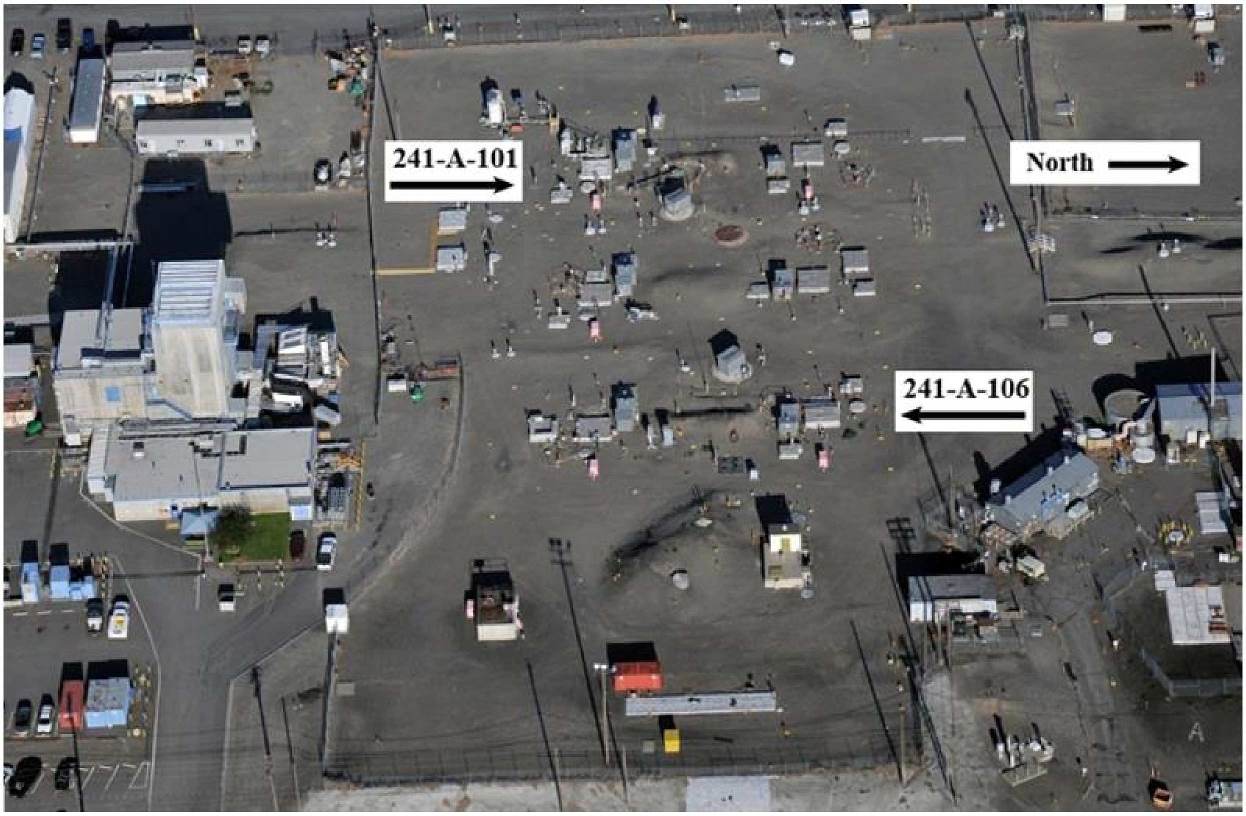


Figure 1-3: Aerial View of a Tank Farm

Type	Farms	Tank Size	Years of Construction	Total
I	B, C, T, and U	200-series, 20-ft Ø, 55,000 gal	1943–1944	16
II	B, C, T, and U BX	100-series, 75 ft Ø, 530,000 gal	1943–1944 1947–1948	60
III	S, BY, TX, and TY	100-series, 75 ft Ø, 758,000 gal	1947–1952	48
IVA	SX	100-series, 75 ft Ø, 1,000,000 gal	1953–1955	15
IVB	A	100-series, 75 ft Ø, 1,000,000 gal	1953–1956	6
IVC	AX	100-series, 75 ft Ø, 1,000,000 gal	1963–1965	4

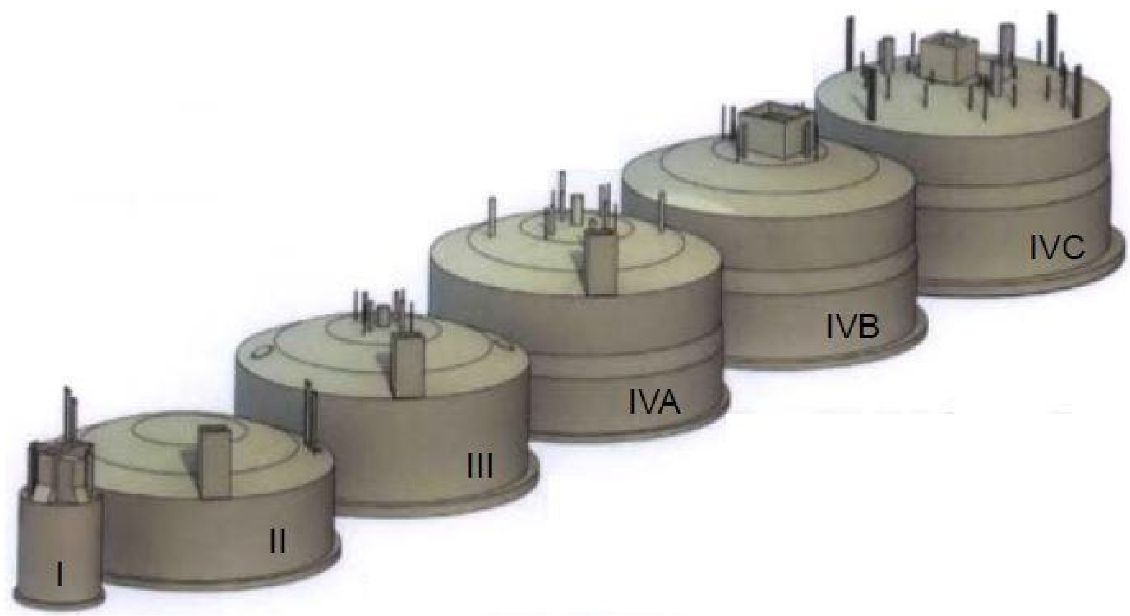


Figure 1-4: Single-Shell Tanks

The 2002 IAR (RPP-10435) concluded that the reinforced concrete tank structures had an adequate collapse margin, justifying continued safe storage of the waste through retrieval and closure. However, given the tank leak history and the condition of the tank liners, long-term leak integrity for the liquids remaining in the tank could not be proven for any of the SSTs. After the 2002 IAR was issued, the DOE Office of River Protection (ORP) declared that the SSTs and their ancillary systems were unfit for use due to the inability to demonstrate leak tightness (DOE Letter 02-OMD-036, "Submittal of M-23-24 Single-Shell Tank (SST) System Integrity Assessment Report").

In 2011, TPA Interim Milestone M-045-91I established the requirement for this SST Structural Integrity Assessment to be completed by September 30, 2018.

TPA Change Request M-45-09-01 added new Milestone M-045-91 to create an SST Expert Panel. TPA Milestone M-045-91 required ORP to:

> "Establish a panel and provide a report on SST integrity assurance review.
>
> DOE has selected and established a panel of technical and nationally recognized experts to focus on data available from of already-retrieved tanks.
>
> The report will contain:
>
> 1) The panel's evaluation of the existing known conditions of the SSTs;
> 2) The Panel's evaluation of the proposed future use of the SSTs;
> 3) The Panel's recommendations for critical modifications and associated schedule aimed at preventing or minimizing further degradation of SST integrity;
> 4) The Panel's recommendations for additional evaluations and program elements that would improve existing understanding of SST integrity.
>
> An agreement change package with interim milestones as necessary to implement the recommendations will be submitted within 90 days of the report."

To this end, DOE formed the panel of subject matter experts from DOE, academia, and recognized industry experts in the fields of structural engineering, stress corrosion cracking, corrosion, waste chemistry, materials, soils and groundwater, and nondestructive analysis. Of most relevance for this report, the structural experts were Robert P. Kennedy, PhD of RPK Structural Mechanics and Anestis S. Veletsos, PhD, Professor Emeritus, at Rice University.

The Expert Panel made 33 recommendations based on the proceedings of two workshops. The panel further identified 10 of the 33 as primary recommendations; these and 6 secondary recommendations formed the basis of what has become the SST Integrity Project (RPP-RPT-43116, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project*; RPP-RPT-45921, *Single-Shell Tank Integrity Expert Panel Report*; RPP-PLAN-45082, *Implementation Plan for the Single-Shell Tank Integrity Project*).

TPA Milestone M-045-91 interim milestones and target dates were created for the key Expert Panel recommendations by TPA Change M-45-10-01, *Establish New M-045-91 Interim Milestones and Target Dates for Single Shell Tanks SST Implementing the Expert Panels Recommendations*, dated December 28, 2010.

The wastes in the SSTs in C Tank Farm and tank S-112 have been retrieved. Therefore, approximately 10% of the SSTs are essentially empty. Since there is some remaining waste even after retrieval, the SSTs require compliance with WAC 173-303-640 until complete closure. Although these tanks are retrieved, they still must meet the WAC 173-303-640 and they are part of this IQRPE IAR.

1.2 PURPOSE

The purpose of this report is to document the activities, reviews, analyses, and evaluations performed by the IQRPE to create this 2018 SST Structural IAR. This is the second IQRPE SST Structural IAR, the first having been completed on June 12, 2002.

WAC 173-303-640(2), includes the following elements for assessment of an existing tank system's integrity:

(2)(a) For each existing tank system, the owner or operator must determine that the tank system is not leaking or is unfit for use. Except as provided in (b) of this subsection, the owner or operator must obtain and keep on file at the facility a written assessment reviewed and certified by an independent, qualified registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that attests to the tank system's integrity by January 12, 1988, for underground tanks that do not meet the requirements of subsection (4) of this section and that cannot be entered for inspection, or by January 12, 1990, for all other tank systems.

(2)(b) Tank systems that store or treat materials that become dangerous wastes subsequent to January 12, 1989, must conduct this assessment within twelve months after the date that the waste becomes a dangerous waste.

(2)(c) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following:

(i) Design standard(s), if available, according to which the tank system was constructed;

(ii) Dangerous characteristics of the waste(s) that have been and will be handled;

(iii) Existing corrosion protection measures;

(iv) Documented age of the tank system, if available (otherwise, an estimate of the age); and

(v) Results of a leak test, internal inspection, or other tank system integrity examination such that:

(A) For nonenterable underground tanks, the assessment must include a leak test that is capable of taking into account the effects of temperature variations, tank end deflection, vapor pockets, and high water table effects; and

(B) For other than nonenterable underground tanks and for ancillary equipment, this assessment must include either a leak test, as described above, or other integrity examination, that is certified by an independent, qualified, registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that addresses cracks, leaks, corrosion, and erosion.

Since the scope of this assessment is limited to structural integrity, this report does not address whether the tanks have leak integrity. Additionally, the assessment is limited to the SSTs themselves (i.e., the tank system is just the 149 SSTs). See Section 2.0 for a more extensive list of excluded features. Since the SSTs have been declared unfit for use (DOE Letter 02-OMD-036), no additional assessment of fit for use is required. Based on these limitations, the scope of the IQRPE integrity assessment, per WAC 173-303-640(2), includes the following elements:

(2)(a) Provide a written assessment of the Single-Shell Tanks that is reviewed and certified by an independent, qualified registered professional engineer in accordance with WAC 173-303-810 (13)(a) that attests to the tank system's integrity

(2)(c) Determine the Single-Shell Tanks are adequately designed and have sufficient structural strength and compatibility with the waste to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following:

(i) Design standard(s), if available, according to which the tank system was constructed;

(ii) Dangerous characteristics of the waste(s) that have been and will be handled;

(iii) Existing corrosion protection measures;

(iv) Documented age of the tank system, if available, (otherwise an estimate of the age); and

(v) Results of internal inspection or other tank system integrity examination.

(2)(e) The owner or operator must develop a schedule for conducting integrity assessments over the life of the tank to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The schedule must be based on the results of past integrity assessments, age of the tank system, materials of construction, characteristics of the waste, and any other relevant factors.

Furthermore, the Statement of Work (SOW) specifies additional requirements to meet TPA Interim Milestone M-045-91I. The additional requirements include the following:

- The assessment shall meet the requirements of TPA Interim Milestone M-045-91I: "DOE shall provide, to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify ... and will include a due diligence review of RPP-10435."

1.3 DEFINITIONS

The definitions in WAC 173-303-040, "Definitions," are included by reference and are unchanged. WAC 173-303-040 also states "Any terms … which have not been defined … have their standard, technical meaning." This section is to clarify and define terms, especially to clarify terms from their vernacular or common meanings to their technical meanings.

- **Tank System** – A dangerous waste storage or treatment SST. This definition is slightly modified from the definitions in WAC 173-303-040 since "associated ancillary equipment and containment system" is not included in this assessment. SST ancillary equipment has been declared unfit for use and is not included in this assessment.

Since the scope of this report is for structural aspects and not leak integrity, the ability of the tanks to contain liquids is not in scope. Therefore, the following definitions will be further refined for this report in the context of underground tanks containing waste.

- **Collapse** – For the SSTs to meet the requirement that the tank will not collapse is to mean the tank will not completely cave or fall in from an external or internal force. The collapse may be "abrupt" (e.g., over a very short period of time) or long term (e.g., by creep or other long-term actions). Obviously, a collapse would mean that the SST waste is no longer protected from external forces. As its name implies, a "partial collapse" would be the caving or falling in of a substantial portion of the tank structure.
- **Rupture** – Rupture is the sudden bursting of a portion of the tank due to over-pressurization (e.g., due to a runaway reaction or internal deflagration) that results in damage to the tank structure. A rupture can cause a large hazardous material release and/or other severe consequences. Therefore, a rupture would also mean that the SST waste is no longer protected from external forces.
- **Failure** – Since the purpose of an SST is to contain the tank waste and to protect the waste from internal and external forces, a failure is any mechanism that does not meet this purpose. Therefore, failure is a more general term and would include collapse and rupture. While it would add to the amount of waste, minor amounts of water and/or soil "leaking"

into the tank would also not be a failure. For example, gasoline storage tanks sometimes get nuisance rainwater intrusion and that is not considered a failure. Localized damage of the structure such as spalling, cracking, or rebar corrosion is not a tank failure unless the waste is not contained. Although localized spalling, cracking, rebar corrosion, etc. might be considered structural failures, these are not failures of the tank to protect the tank contents. It will be described later in this document that cutting a permanent hole of up to 55 in. in diameter in some locations of the dome of the tank does not cause a failure of the tank structure. Therefore, failure is defined as structural damage such as spalling, cracking, or rebar corrosion over a fairly large area. Just for conservatism, an area of 48 in. diameter or larger would be an area of concern. This is further discussed in Section 4.9.

In summary, since the purpose of these tanks is to contain waste, any collapse, rupture, or failure must be an event where the tank does not perform its job of protecting the waste. Therefore, localized damage of the structure such as spalling, cracking, or rebar corrosion are not failures. In this context, localized is a 48-in. diameter area.

1.4 METHODOLOGY

The SSTs have been in use for decades and have previously been assessed by an IQRPE. For this current assessment, an emphasis was made in areas where activities and/or time have affected the system's integrity with the objective to ensure parameters are within the appropriate design criteria, and to verify there are adequate programs of inspections. The 2002 IQRPE report will be used as a fixed, referenced baseline. Thus, the 2002 IQRPE recommendations and findings were reviewed as part of this 2018 SST Structural Integrity Assessment.

The IQRPE assessed the SSTs integrity and documented the information reviewed for the SSTs to meet the regulations identified in Section 1.2. This report describes the documents, reviews, evaluations, studies, and other applicable data used by the IQRPE to satisfy the integrity regulations of an existing tank. Subject matter experts (SME) were used as senior technical advisors possessing extensive experience in specific technical fields and who are qualified to review, interpret, and/or clarify specific technical issues. The SMEs worked under the direct supervision of the IQRPE and were assigned and prepared sections of the SST Structural Integrity Assessment in their areas of expertise. The SMEs coordinated their evaluations in areas where there was overlap in the report preparation. Appendix A lists team resumes. Appendix H lists all of the documents reviewed by the SMEs.

As a partial list of key documents assessed, using a graded approach, the IQRPE reviewed the following items from Washington River Protection Solutions, LLC (WRPS) conducted since the 2002 assessment:

- Video examination of various tanks
- Analyses of records (AOR)
- Expert panel reports
- Tank A-106 sidewall coring
- Tank C-107 concrete and rebar testing
- Tank SX-115 core drilling
- Waste characteristics
- Corrosion

- Dome load controls
- Dome deflection surveys.

The compliance matrix, included as Appendix B, was used to ensure that the regulations identified in Section 1.2 were evaluated for compliance. This matrix provides a summary assessment of compliance, including a cross-reference to the reviews, analyses, and documents that demonstrate meeting the requirements.

This SST Structural IAR also includes a review of all relevant IQRPE assessments and references completed since 2002 and through July 31, 2018. The IQRPE reports reviewed are listed in Section 3.0 as Table 3-1.

1.5 CERTIFICATION DISCUSSION

Based on the conclusions of this SST IAR, the IQRPE must choose to either (1) certify the integrity of the SST in its entirety or in part, or (2) not certify the SST. In compliance with WAC 173-303-640 and WAC 173-303-810, "General Permit Conditions," the IQRPE has maintained a direct supervisory role over the development of this IAR. To complete this certification, the IQRPE is required to stamp and sign this report with his Professional Engineer stamp/seal. As such, this report bears the Professional Engineer's stamp and signature of the IQRPE, because it was prepared using qualitative engineering judgment and specifies engineering-related criteria in accordance with the prevailing laws related to Registered Professional Engineers in Washington State.

The certification wording states that the information contained in this integrity report is believed to be "true, accurate, and complete." The nature of this integrity assessment requires that a significant amount of data interpretation and some engineering judgment be applied to obtain meaningful conclusions.

The certification statement word 'complete' means that the data reviewed for the integrity assessment, extracted from the voluminous SST system data, were reasonably sufficient to perform a meaningful integrity evaluation. It also means that in the IQRPE's judgment the information included in this IAR is sufficient for the reader to understand the basis for the conclusions reached in the assessment.

The following certification language from WAC 173-303-810(13)(a) must be used:

> I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

1.6 INTEGRITY ASSESSMENT REPORT DESCRIPTION

This report is divided into sections by topic. As an introduction, these sections can be briefly described as follows:

- Section 2.0 discusses the scope of work provided in the SOW (Requisition #302212) and RPP-PLAN-61510, *Single-Shell Tank Structural Integrity Assessment Plan.* The section outlines both inclusions and exclusions.
- Section 3.0 reviews the 2002 IAR. IQRPE reports between the 2002 IAR and July 31, 2018 are reviewed. A due diligence review of RPP-10435 (the 2002 IQRPE report) and the Expert Panel reports is completed.
- Section 4.0 provides an in-depth assessment of the tanks from a structural perspective.
- Section 5.0 provides an in-depth assessment of waste compatibility to the materials of the SSTs.
- Section 6.0 provides an in-depth discussion of corrosion. This section primarily focuses on the steel liner since that is observable and in contact with the waste. Since the steel liner is not part of the structure, the liner itself is not assessed. But corrosion of the liner could be an indication of the potential of waste to corrode structural features that are in scope.
- Section 7.0 provides a discussion of geotechnical impacts.
- Section 8.0 summarizes this report and provides recommendations.

2.0 SCOPE

To delineate the scope of this assessment, this section describes SSTs that are within the purview of this report, the WAC requirements, the additional requirements from the SOW, and finally, any scope exclusions.

In addition to the WAC 173-303-640 integrity assessment requirements outlined in Section 1.2, the SOW (Requisition #302212) and RPP-PLAN-61510 further define the requirements of this report. Some of these SOW and RPP-PLAN-61510 requirements are additional to the requirements of WAC 173-303-640(2) and some are refinements of those WAC requirements. So, this IAR must include the following elements:

- A site map of the facility showing the location of the tank system. (See Figure 1-1 and Figure 1-2.)
- A sketch of the tank system; locations of specific items inspected should be clearly indicated and cross-referenced in the results of the integrity assessment. See Figure 1-2.
- Results of the structural integrity assessment; the results should clearly state if the SSTs have sufficient structural strength and compatibility with the waste being stored or treated. (For structural, see Section 4.0. For waste compatibility, see Section 5.0. For corrosion, see Section 6.0. For geotechnical and hydrogeological, see Section 7.0.)
- Consideration of the conclusions and uncertainties identified in Section 4.0 of RPP-10435 with respect to the intervening time period between assessments and the expectations for continued waste storage. (See Section 8.0.)
- An estimate of remaining useful life of the SSTs, if practical. (See Section 8.0.)
- A cross-reference matrix to demonstrate how the requirements identified in this section have been met. The matrix will ultimately provide a summary assessment of compliance, including cross-reference to the document(s) that demonstrate meeting the requirements. (See Appendix B.)
- A recommended schedule and work plan for future SST structural integrity assessments, to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The basis for the recommendation must be included in the report in order to determine how changes of circumstances might affect the periodicity of future integrity assessments. Observations, recommendations, and findings (if any) regarding corrections and enhancements necessary for preserving structural integrity of the 100-series and 200-series SSTs must be identified. (See Section 8.0.)
- Exceptions taken to WAC 173-303-640(2) in order to certify to WAC 173-303-810(13)(a) must be identified in the assessment report. (There were none, but see Section 8.0 for conclusions.)
- A statement by an IQRPE certifying the results of the integrity assessment. This certification must be according to WAC 173-303-810(13)(a). The IQRPE's signature and stamp must be placed below the certification statement. (See page ii and Section 1.5.)

Both the SOW (Requisition #302212) and RPP-PLAN-61510 state that the following facilities and equipment are excluded from the 2018 structural integrity assessment:

- Retrieval systems are excluded from the SST structural integrity assessment. Retrieval management of SSTs is established by Appendices H and I of the TPA Action Plan (TPA attachment). Individual retrievals are controlled according to a tank waste retrieval work plan approved by the State of Washington Department of Ecology (Ecology). Following retrieval completion, a retrieval completion certification is submitted to Ecology, and within 12 months of retrieval completion, the retrieval data report is submitted.
- Air ventilation systems used on the SSTs (forced air and passive) are excluded from the assessment. These systems are regulated under the Hanford Site Air Operating Permit and are not used for the storage of RCRA dangerous waste.
- Inactive/not-in-use ancillary equipment including miscellaneous underground storage tanks (MUST), diversion boxes, pump pits, valve pits, process vault tanks and sumps, underground pipelines, hose-in-hose transfer lines (HIHTL) awaiting removal and disposal, and process equipment mounted in tank risers and pits, is excluded from the integrity assessment.
- Inactive/not-in-use equipment as defined by RPP-9937, *Single-Shell Tank System Leak Detection and Monitoring Functions and Requirements Document*, as: "A component with no current and no expected mission in safe storage or transfer of SST system waste. Inactive/not-in-use components may and do contain waste."
- Inactive/not-in-use ancillary equipment structures that may affect the structural loading of the SSTs (e.g., concrete pump pits and sluice pits) will be assessed for effect on structural integrity of the SSTs.

3.0 REVIEW OF INTEGRITY ASSESSMENT AND IQRPE REPORTS

As an integral part of this IAR, a review of the 2002 IAR and the IQRPE reports between 2002 and July 31, 2018 was completed. Since the Expert Panel Reports were in essence a due diligence review of the SSTs following the 2002 IAR, these reports are also reviewed in this section. More details and discussions are provided in Sections 4 through 8 and the appendices.

3.1 SUMMARY OF THE 2002 SINGLE-SHELL TANK STRUCTURAL INTEGRITY ASSESSMENT

The 2002 SST structural IAR was completed in June 2002. The report concluded that the reinforced concrete tank structures had adequate strength such that they would not collapse, rupture, or fail. This justified continued safe storage of the interim-stabilized waste. Unlike this 2018 report, the 2002 report also addressed leak integrity. Since several tanks were assumed leakers at the time of the 2002 report, the 2002 report could not prove that the tanks would not leak liquid waste. The 2002 report also addressed tank liners, transfer lines, and pits that are not included in this 2018 report. In addition to this summary of the 2002 IAR, a due diligence review of the 2002 IAR is done in Section 3.3.

From a structural design viewpoint, the report stated that the tanks were adequately designed and had a long-term operating history such that the reinforced concrete portions of the tanks are adequate.

The primary concern with waste compatibility is the potential of concrete degradation at tank leak paths. Based on dome surveillance data between leaker tanks and sound (non-leaker) tanks having no notable differences, it was postulated that the leak paths were localized in nature, so any concrete degradation was also localized in nature. So it was concluded that the waste was compatible with the tank structure such that the tanks would not collapse, rupture, or fail.

The report identified some significant structural uncertainties:

- "Due to the limited amount of inspection data, the caustic chemical damage to the tank basemat and footing concrete, in leaking tanks, cannot be defined with high confidence. The conclusion that the concrete damage is local in nature cannot be proven, but is inferred from dome surveillance data and leak investigations.
- The long-term SST structural integrity predictions are based largely upon the relatively benign future operating conditions, when compared to the more aggressive operating conditions of the past. Because operating conditions during future retrieval and closure operations are not fully defined, some uncertainty remains in future tank environments through closure. This statement is especially true for "closure" since SST closure has yet to be defined. As the load conditions associated with future operations become more clearly defined, confirmation will be needed that the loads fall within the existing analysis envelope or additional analyses will be necessary."

These identified significant structural uncertainties are explored in greater detail in Sections 4 to 7 and summarized in Section 8.0.

3.2 PROJECTS REVIEWED BY AN IQRPE AFTER THE 2002 ASSESSMENT

There have been new constructions and/or modifications to the SSTs since 2002. Some of these new constructions and/or modifications to the SSTs required IQRPE assessment and some did not. Additionally, some of the ones that required IQRPE assessment did not affect the SST structure. To ensure that there are no gaps in IQRPE assessments, the new SST construction and modifications since the 2002 IAR were reviewed. Table 3-1 lists the IQRPE assessments that affected the tank structure completed since the 2002 IAR. The conclusion is that new constructions and modifications to the SSTs have been appropriately assessed by an IQRPE and the associated reports appear complete.

3.3 DUE DILIGENCE REVIEW OF RPP-10435

As required by TPA Interim Milestone M-045-91I:

> *DOE shall provide, to Ecology, an IQRPE certification … and will include a due diligence review of RPP-10435.*

As such, this RPP-10435 due diligence review will assess whether:

- Assumptions are identified and justified
- The report is sufficiently detailed such that a person technically qualified in the subject can review and understand the report and verify the adequacy of the results without recourse to the originator
- Conclusions were reasonable at the time of the report in 2002
- Conclusions were reasonable for continued safe storage of waste to 2018 or another date.

As part of this due diligence review, this review will also look for things which should have been considered or were omitted. This section will first examine the appendixes that provide most of the background and analysis that are later summarized in Chapter 4 of RPP-10435.

RPP-10435, Appendix A, Single-Shell Design Details

Appendix A does a very complete job of defining the original details about the original designs, design standards used for the tank system construction, dangerous characteristics of the wastes that have been contained, existing corrosion protection measures and the age of the tank system.

The conclusions of Appendix A are as follows:

1. "Design standards used for SSTs were considered "good practice" when the tanks were designed and constructed and were adequate for the intended use of the tanks." (pg A-3)
2. "Post-design analyses were used to set safe operating limits for the older tanks." (pg A-3)
3. "Higher temperature operation…damaged some of the carbon steel liners…Thus the SST designs did not adequately provide for thermal expansion compatibility between the carbon steel liners and the reinforced concrete tanks. The high temperatures resulted in strength reduction in the reinforced concrete tanks." (pg A-3) (This assumption was a good assumption based on the data that was available in 2002. Based on more recent concrete compression testing, the concrete exceeds design strengths.)

Table 3-1: IQRPE Assessments Completed Since 2002

Document Number	Date of Publication	Tank Involved	Title	Comments
RPP-56892 Rev. 0	4/23/2014	C-107	Independent Qualified Registered Professional Engineer Installation Integrity Assessment Report for C-107 MARS-S Slurry Pump Replacement - IQRPE Installation Integrity Assessment Report No. IA-259835-01.	Installation intergrity assessment for the procurement , fabrication, installation and testing of the C-107 MAR-S slurry pump equipment.
RPP-57176	4/23/2014	C-107	Fit For Use Letter - C-107 MARS-S Slurry Pump replacement - IQRPE Installation Integrity Assessment, per Requirements of WAC 173-303-640.	Fit for use letter for the procurement , fabrication, installation and testing of the C-107 MAR-S slurry pump equipment.
RPP-58044 Rev. 0	4/1/2015	C-105	IQRPE Fabrication Installation Integrity Assessment Report for MARS V-Spares for C-105	Fabrication assessment for MARS-V replacement equipment for the C-105 retrieval project.
RPP-RPT-49457 Rev. 0	5/2/2011	C-107	Mobile Arm Retrieval System Project Bulk Retrieval Option Independent Design and Fabrication Integrity Assessment Report (MARS_S for C-107, MARS-V for C-105)	Fabrication assessment for Mobile Arm Retrieval System (MARS) equipment.
RPP-RPT-50145 Rev. 0	7/11/2011	C-107	Integrity Assessment for the C-107 Larger Riser	Documentation for the assessment of the design and installation of equipment installed in C-107.
RPP-RPT-50204 Rev. 0	9/13/2011	C-107	Independent Integrity Assessment Report for Tank 241-C-107 Waste Retrieval System Project.	Integrity assessment of the design, fabrication, installation and testing of the 241-C-107 modified sluicing waste retrieval system.
RPP-RPT-54764, Rev. 0	3/28/2013	A-106	Independent Qualified Registered Professional Engineer (IQRPE) Report for Single-Shell Tank 241-A-106 Sidewall Coring Project	241-A-106 SST was selected for sampling based on its status as a sound non-leaking tank, and because it has the highest thermal history of all the SSTs.
RPP-RPT-56390 Rev. 0	4/29/2014	C-105	IQRPE Integrity Assessment Report for C-105 Waste Retrieval Project Phase 2	Integrity assessment of the design, fabrication, installation and testing of the 241-C-105 Phase 2 waste retrieval system.

4. "Hazardous waste characteristics of the waste currently stored in the SSTs are within the specified limits." (pg A-3)
5. "Currently stored waste does not compromise the structural integrity of the tanks." (pg A-3)
6. "The tank domes have been inspected and show some visible evidence of aging; however, there is no evidence of corrosion degradation that significantly impacts the structural capacities of the domes. Given the past operations history and the relatively benign conditions in the current vapor zones, no increase is expected in the current slow rate of ongoing degradation." (pg A-3 through A-4).
7. AX Tanks had a design corrosion service life of 25 years. Since the most recently constructed AX Tanks reached their end-of-life in 1990, "the earliest SST's are much further beyond their end-of-life."

RPP-10435, Appendix B, Integrity Assessment Details of the Single-Shell Tank System Transfer Lines and Pits

Since transfer lines and pits are not in the scope of this IAR, no review of this section was completed.

RPP-10435, Appendix C, Single-Shell Tank System Operating History

RPP-10435 discussed the process history at the Hanford Site as it related to waste generation and disposal in different tank farms, but actual waste characteristics by tank were not documented. This assessment provides an analysis of the best-basis inventory (BBI) to document the estimated concentrations for all chemical constituents that contribute to corrosion mechanisms.

RPP-10435, Appendix D, Single-Shell Tank Leak Summary

Although tank leaks are not part of this IAR, tank leaks are reviewed to the extent that they could indicate failures of the tank structure.

1. Interim stabilization has reduced the leak potential and there is no reason to expect large leaks through SST liners will occur because of:
   a. Elimination of high-heat waste,
   b. Removal of pumpable liquids, and
   c. Reduction of waste corrosive properties.
2. Tanks that were operated outside of their design temperature limits or pH less than 10 may have a higher potential for leaking.
3. There is no reason to expect failures of liners to occur that would cause large leaks in interim stabilized tanks.

RPP-10435, Appendix E, Single-Shell Tank Integrity Examinations

As outlined below, the 2002 IQRPE made sound conclusions with the limited data available:

1. "In-tank surveillance indicates that the overall structural condition of the visible concrete in the SSTs is sound." (pg E-3)

2. "Visual surveillance indicates minor imperfections are present in the dome concrete." (pg E-3) Some were construction imperfections. None affect structural stability.
3. Visual evidence and dome deflection surveys indicate that no evidence of failure of the walls or footing have occurred that affects structural stability.
4. In tanks C-104 and C-106, local concrete damage around the 36-in. risers was visible, but this does not affect dome structural stability.
5. Patterns on a 1996 videotape of tank AX-104 may indicate concrete degradation but no reinforcing was observed. Photos from 1983 do not show these lines in the concrete.
6. Dome elevation surveys for the 100-series tanks were reviewed. The authors felt that elevations surveys for the 200-series tanks were not necessary.
7. Degradation of concrete near the bottom of the tanks may still be occurring but cannot be observed by current methods of inspection.

RPP-10435, Appendix F, Single-Shell Tank Material Compatibility

RPP-10345 concluded the design, as related to corrosion and waste compatibility, was still valid and predictions of future effects could not be made. It noted that two potential failure modes related to corrosion or concrete degradation were:

- Corrosion of the rebar, and
- Caustic waste exposure to the concrete.

These potential failure modes were considered conservative based on the discussion throughout the report that little corrosion was noted except in the vapor phase, and was generally localized, and the effect of waste on the concrete appeared to be minimal. Admittedly, however, part of the reason for the conservative conclusions was the unknown plans for the future use of the tanks. Overall RPP-10435 did a commendable review of the existing information.

RPP-10435 also relied on the conclusion that the tank liners were in good condition other than localized spots, where waste may come into contact with the reinforced concrete. With the number of leaking tanks, the effect of waste in direct contact with the reinforced concrete (without regard to the steel liner) should have been considered.

RPP-10435, Appendix G, Single-Shell Tank Structural Analyses

This section comprehensively discusses the structural analyses done prior to 2002. The conclusions of Appendix G are as follows:

1. "The structural analyses that have been performed on the SSTs over the years have all reached the same general conclusion that the tanks are not in danger of collapse for the conditions experienced by the SSTs. Rigorous analyses including the effects of material aging, thermal loading, temperature effects on concrete properties, and concrete creep have concluded that the tank design is adequate for the loading environment that exists on the tanks."
2. Analyses performed on the 20-ft diameter tanks found them to be structurally adequate for soil overburden, hydrostatic and seismic loading in 1983. No additional analysis is necessary since these tanks are out of service and did not see high waste temperature.

3. From an ACI code viewpoint, the critical areas of concrete structure performance are the footing and the tank dome. Loads over the dome have the greatest influence on the stresses.
4. Post-design seismic evaluations have indicated that the SSTs are adequate for current site seismic requirements.
5. The dome deflection surveys provide an indication that the foundations have not failed.

RPP-10435, Appendix H, Single-Shell Tank Facility List

This table is adequate.

RPP-10435, Chapter 4, Conclusions

The IQRPE agrees with the conclusions of RPP-10435, which are as follows:

- There is strong evidence that the reinforced concrete portion of the SSTs was adequately designed.
- The primary issue emerging from the waste compatibility evaluation is the potential for concrete degradation adjacent to tank leak paths. Based on no visual evidence of distress in the domes, it is assumed that the leak paths are not adversely affecting the structural stability of the tanks.
- This report indicated the importance of both the dome deflection surveys and visual inspection for cracking of the haunch.
- The long-term SST structural integrity predictions are based largely upon the relatively benign future operating conditions, when compared to the more aggressive operating conditions of the past.

Uncertainties

Uncertainties which still exist are as follows:

- Limited amount of inspection data of the tank basemat and footing concrete make it impossible to determine the exact extent of structural damage. It is assumed that leaking is localized and is not large enough to adversely affect the structure.

Continued Waste Storage After 2002

RPP-10435 did not set a time frame recommendation for the next integrity assessment or how long waste could continue to be stored. At the time of the 2002 IAR, TPA Milestone M-45-06 required complete closure of all the SSTs by September of 2024. Retrieval was scheduled to be completed around 2018, before full closure in 2024. Since there is some remaining waste even after retrieval, the SSTs require compliance with WAC 173-303-640 until complete closure. So, end of mission for waste storage would have been around 2024. In fact, retrieval of tank C-106 was in progress in 2002. With anticipated SST closure in 2024 and retrieval started in 2002, it would have appeared that tanks would be emptied over that period of time. As each tank is retrieved, the risk to the environment of a tank collapse is reduced because there would be fewer tanks containing large volumes of waste. As such, as tanks are emptied the significance of reassessment is reduced.

Although not stated in the 2002 IAR, with the end of mission only 22 years away (less for most tank waste), safe storage of the waste through 2024 probably would have seemed very reasonable considering the large collapse margin discussed in the 2002 report. Likewise, the need for another integrity assessment would have probably seemed unnecessary.

Review Summary

Summary of RPP-10435 due diligence:

- Assumptions were identified and justified
- The report is sufficiently detailed
- Conclusions were reasonable at the time of the report in 2002
- Although not discussed in the report, the conclusions would have supported continued safe storage of waste through 2018 based on retrieval concluding in 2018 and full closure in 2024.

Overall RPP-10435 was a very thorough report and did a commendable review of the available information.

3.4 SINGLE-SHELL TANK INTEGRITY EXPERT PANEL

In 2009, an Expert Panel was assembled to determine what needed to be done to utilize the SSTs until they could be emptied and removed from service. Part of the impetus for this panel was as follows:

- All of the SSTs had exceeded their commonly understood design life.
- Several of the SSTs had either been confirmed to be leaking or are assumed to be leaking.
- There is not enough available additional unused storage in the Hanford Site double-shell tanks (DST) to hold all the SST waste, and methods had not been developed by 2009 to remove all the tank waste. A series of SST Integrity Expert Panel Workshops were held to determine what needed to be done to utilize the SSTs until they could be emptied and removed.

The Expert Panel was made up of people proficient in their various fields (e.g., structural engineering, stress corrosion cracking, corrosion, waste chemistry, materials, soils and groundwater, and non-destructive analysis). The first two workshops were held January 26 to 29, 2009 and April 29 to May 1, 2009 and focused on the following (RPP-RPT-43116, pg 4):

- Confirmation of tank structural integrity
- Assessment of the likelihood of future tank liner degradation
- Leak identification and prevention
- Mitigation and containment migration.

The structural integrity recommendations that were the outcome of these first two workshops are as follows:

- **Recommendation SI-1, Perform Modern Structural Analyses** – The Panel recommends performing modern structural analyses (including seismic) on representative samples of SSTs. Such analyses are necessary to understand the structural integrity of the SSTs during a seismic event. The analysis will be useful in answering the following questions: How much rebar must remain to achieve adequate structural integrity under a major seismic event? What is the level of confidence that at least this amount of rebar cross-sectional area exists and will remain present for the operating life of the tanks (e.g., 20 to 50 additional years)? What is the minimum required concrete strength?

- **Recommendation SI-2, Perform Dome Deflection Surveys** – The Panel recommends continuation of the current Dome Deflection Survey Program. The program should be augmented to obtain dome deflection data near the haunch of the domes. The dome surveys are important, as any future potential for dome collapse would be preceded by excessive downward dome deflection. The haunch data is important to determine whether dome deflections are due to downward displacement of the dome or of the footing under the sidewall.
- **Recommendation SI-3, Obtain and Test Sidewall Core** – The Expert Panel recommends obtaining and testing a vertical core from the entire depth of the sidewalls for two tanks that have leaked and had been operated at high temperatures for extended periods. Such cores will provide important data about the structural condition of concrete and rebar in the sidewalls.
- **Recommendation SI-4, Perform Non-Destructive Evaluation of Concrete** – The Expert Panel emphasizes the importance of the hierarchical aspect of this recommendation. Initially, the Expert Panel recommends the application of two technologies: (1) visual inspection of domes to identify cracks in excess of 1/16 in. wide, rust stains on the concrete, or spalling of the concrete, and (2) utilization of a ‘thumper’ truck to determine the modulus of the dome concrete. The modulus correlates with concrete strength and controls the degree of deformation that will occur under loading.

Further development and deployment of non-destructive evaluation technologies such as guided wave propagation should occur in the event initial SST Integrity Project (SSTIP) activities (e.g., visual inspection, modeling, vertical core results) indicate potential concrete degradation.

- **Recommendation SI-5, Test Dome Concrete and Rebar ‘Plugs’** – Current plans call for the cutting of holes in the SST domes to facilitate the use of retrieval equipment. The Expert Panel recommends the following tests on concrete and rebar ‘plugs’ removed from domes during cutting: (1) concrete compression and bend tests and (2) rebar diameter measurement and tensile tests. These tests will provide an opportunity to obtain data on the condition of the dome concrete and rebar.
- **Recommendation SI-6, Develop Engineering Mechanics Document** – The Expert Panel recommends the development and up-to-date maintenance of a living document containing the best current understanding of engineering mechanics properties of each tank. Such a document is an important reference in understanding both the current and future structural integrity of the SSTs, and will be useful in defining input information for future tank evaluation.
- **Recommendation SI-7, Test Effects of Waste Exposure on Structural Integrity** – The Expert Panel recommends measuring the physical and mechanical properties of concrete exposed for more than 28 days to simulated waste. Based on these measurements, the effects of waste/concrete/rebar reactions and temperature on the structural integrity of the tank walls should be estimated. These tests will assist in determining whether liquid waste that has leaked through the steel liner and the concrete walls could have damaged the concrete and rebar.

- **Recommendation SI-8, Study the Deployment of Corrosion Potential Mapping** – The Expert Panel recommends studying the feasibility of performing corrosion potential measurements to assess the condition of rebar in the SSTs. "If potential mapping can be successfully deployed it has the potential to detect active corrosion" (RPP-RPT-43116, pg v).

In addition to those recommendations, recommendation MCM-1 is also applicable to this report:

- **Recommendation MCM-1, Install Surface Barrier Over SST Farms** – The Expert Panel recommends design and implementation of a surface barrier to reduce recharge at the SSTs. Sources of water (e.g., leaking pipes, vaults) that could contribute to subsurface water deep percolation should also be identified and controlled. New control/barrier measures should be prioritized based on the risk associated with past and/or future releases at each tank farm.

After reviewing the report from the first two Expert Panel meetings, ORP requested additional commentary from the Panel. The areas of additional commentary were: (1) evaluation of the existing known conditions of the SSTs, (2) evaluation of the proposed future use of the SSTs, (3) recommendations for critical modifications and associated schedule aimed at preventing or minimizing further degradation of SST integrity, and (4) recommendations for additional evaluations and program elements that would improve existing understanding of the SSTs integrity (RPP-RPT-45921).

The Expert Panel met January 20 and 21, 2010 to discuss and provide the commentary that was requested by ORP. In response to these questions, the original recommendations were evaluated and additional recommendations were generated. Several new recommendations were made regarding which tanks would be the most likely tanks to continue to store waste. Looking at the structural integrity of the tanks, it was determined that the first five structural integrity recommendations from the first two meetings were the most important. To those five, three additional structural integrity recommendations were developed (RPP-RPT-45921, pg 19):

- **Recommendation SI-9** – AORs of SSTs should be performed. This recommendation goes beyond the AORs in Recommendation SI-1. This recommendation was to take into account the corrosion of the reinforcing in the lower third of the tank walls. The goal of these analyses is to determine how much rebar is necessary to maintain the SSTs structural integrity.
- **Recommendation SI-10** – If waste exposure tests indicate concrete integrity has been degraded, additional evaluations should be performed to determine the corrosion behavior or rebar steel exposed to waste and/or simulants.
- **Recommendation SI-11** – If structural integrity issues are identified, the Panel recommends WRPS develop and implement a mitigation strategy. Recommendation SI-8 would be appropriate where evidence exists from testing and analysis that the leaked waste is capable of promoting accelerated corrosion of the rebar steel.

The fourth SST Integrity Project Expert Panel Meeting was held on February 23, 2011 (RPP-RPT-49272, *Fourth Single-Shell Tank Integrity Project Expert Panel Meeting*). During this meeting, the Panel reviewed the TPA (Milestone M-45-91) and RPP-PLAN-45082. The Panel approved the WRPS approach and the recommendations were prioritized into a Phase I and Phase II activities. Due to their priority, the Phase I activities were those to be completed prior to

July 2014. After Phase I activities were completed, Phase II activities were to be re-evaluated in 2014 (RPP-RPT-49272, pg 1).

The fifth and final SST Integrity Project Expert Panel Meeting was held August 28 and 29, 2014. This meeting was focused primarily on updating the Panel on progress in response to the past recommendations (RPP-ASMT-59981, *Fifth Single-Shell Tank Integrity Project Expert Panel Meeting August 28-29, 2014*, pg 1). In this report, it was re-iterated to continue the dome deflection surveys and visual inspection of the domes. If degradation is observed, the frequency of dome deflection surveys should be increased. The initial AORs have been completed. If degradation is observed, additional AORs to determine at what point of degradation the tank would fail. The sidewall test core from tank A-106 has been evaluated. A second full wall height test core is a "higher priority" than performing additional AORs (RPP-ASMT-59981).

This Expert Panel recommendations and the resulting analyses and testing and studies have been extremely informative for this IAR.

4.0 STRUCTURAL ASSESSMENT

4.1 INTRODUCTION

The 149 SSTs were constructed of reinforced concrete for Hanford Site nuclear waste storage between 1943 and 1965. The tanks were grouped together into tank farms and are located in the 200 East and 200 West Areas. Figure 1-1 shows the general layout of the tank farms. Figure 4-1 shows the B Tank Farm under construction.

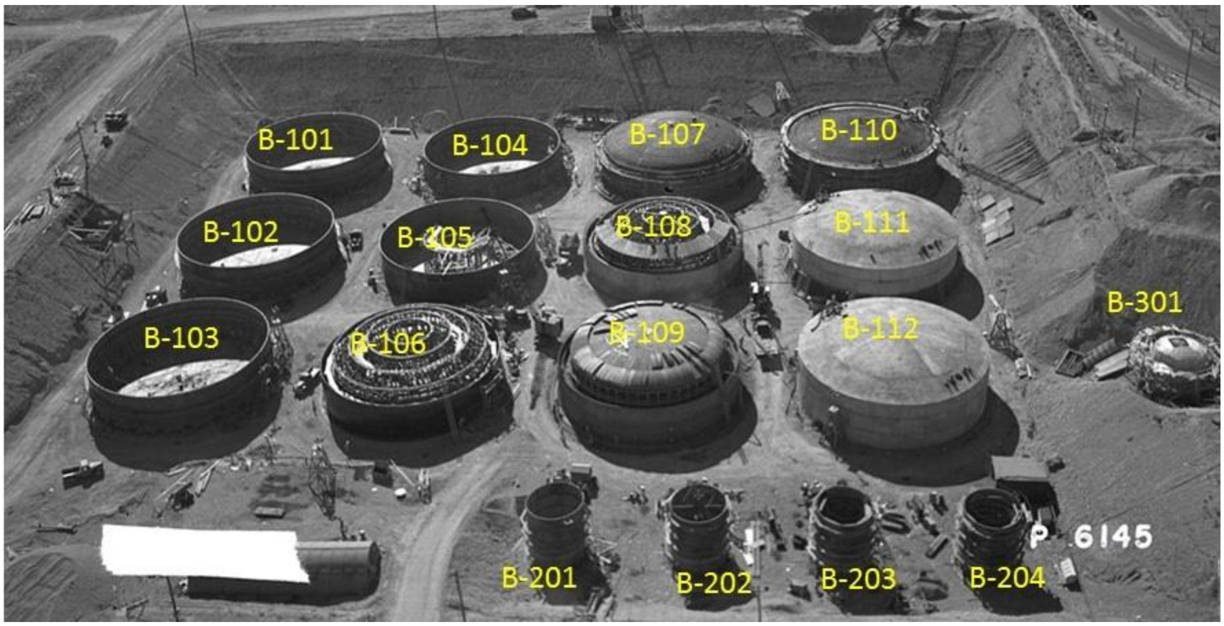


Figure 4-1: Typical Single-Shell Tank Farm Construction B Tank Farm (RPP-PLAN-60765)

The first tanks to be constructed consisted of Type I tanks and Type II tanks. Type I tanks are 55,000 gallons, 200-series tanks. A cross-section of a typical Type I tank is shown in Figure 4-2.

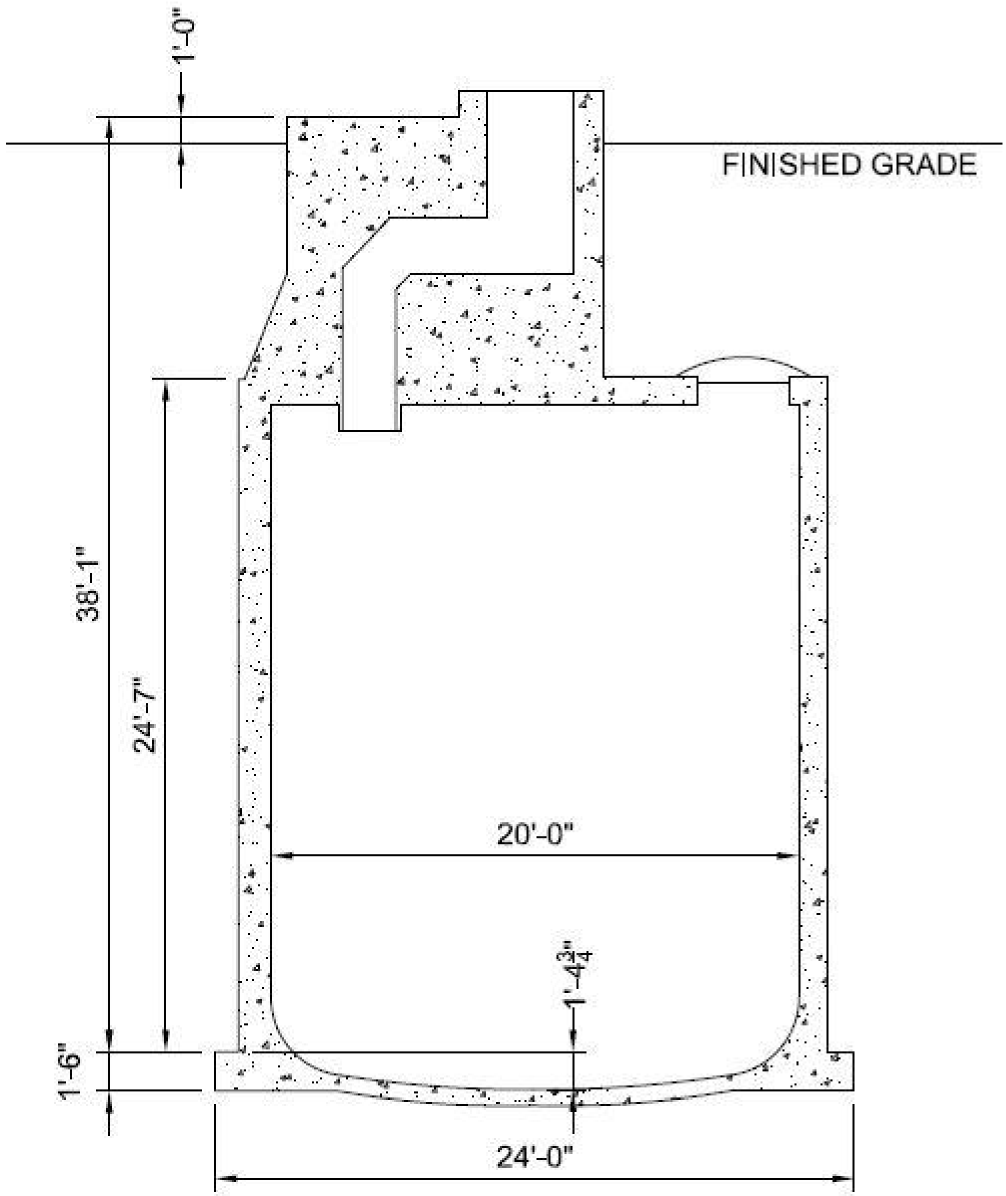


Figure 4-2: Tank Type I Cross-Section (BPF-73550)

At the same time as the Type I tanks, the 530,000 gallons Type II, 100-series first-generation tanks were constructed. A cross-section of a Type II tank is shown in Figure 4-3. These tanks were constructed concurrently with four Type I tanks and 12 Type II tanks in the B, C, T, and U Tank Farms between 1943 and 1944. An additional farm, BX Tank Farm, contains 12 Type II tanks that were constructed between 1946 and 1947. Even though the actual diameter of 100-series tanks varied, all 100-series tanks are referred to as 75-ft diameter tanks having a nominal capacity of 2,750 gallons per inch above the transition from the tank bottom to the sidewall.

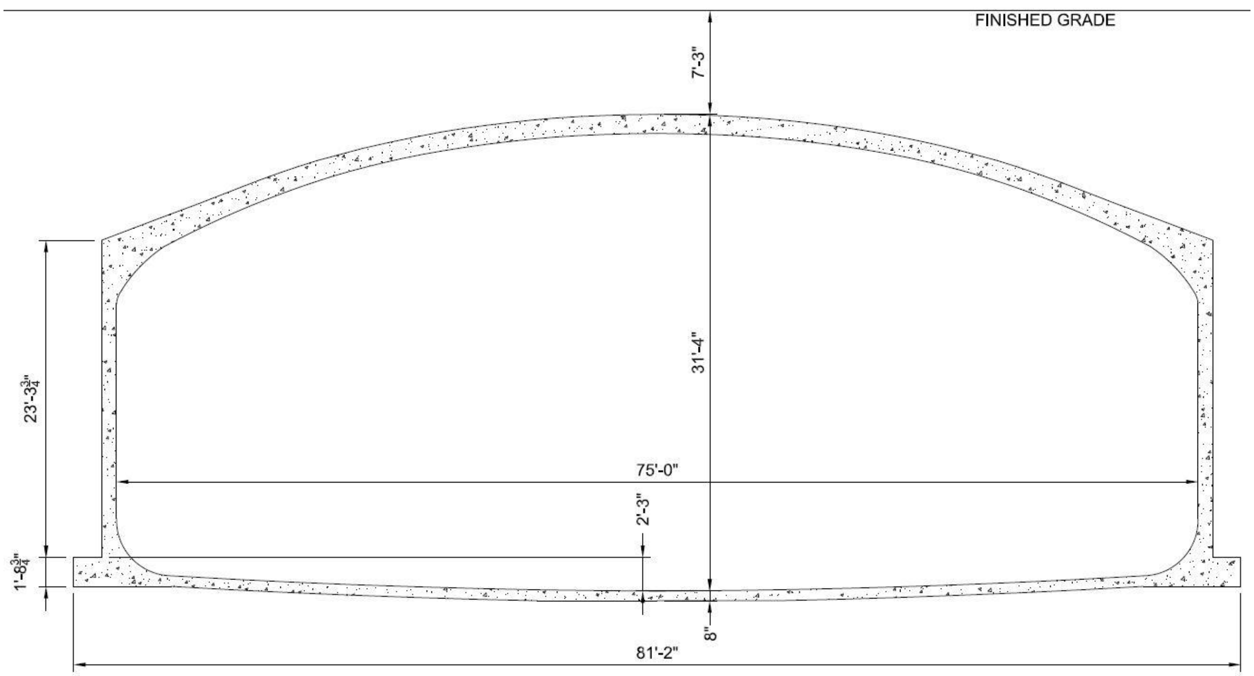


Figure 4-3: Tank Type II Cross-Section (BPF-73550)

As time went on, more storage capacity was required. Larger and larger tanks were constructed to contain the waste. The Type III tanks were the second generation of 100-series tanks, contain 750,000 gallons of waste each, and are located in TX Tank Farm (12 tanks constructed 1947 to 1948), BY Tank Farm (12 tanks constructed 1948 through 1949), S Tank Farm (12 tanks constructed 1950 to 1951), and TY Tank Farm (six tanks constructed 1951 to 1952). A cross-section of a typical Type III tank is shown in Figure 4-4. Again, for the purposes of this assessment, all 100-series tanks are referred to as 75-ft diameter tanks.

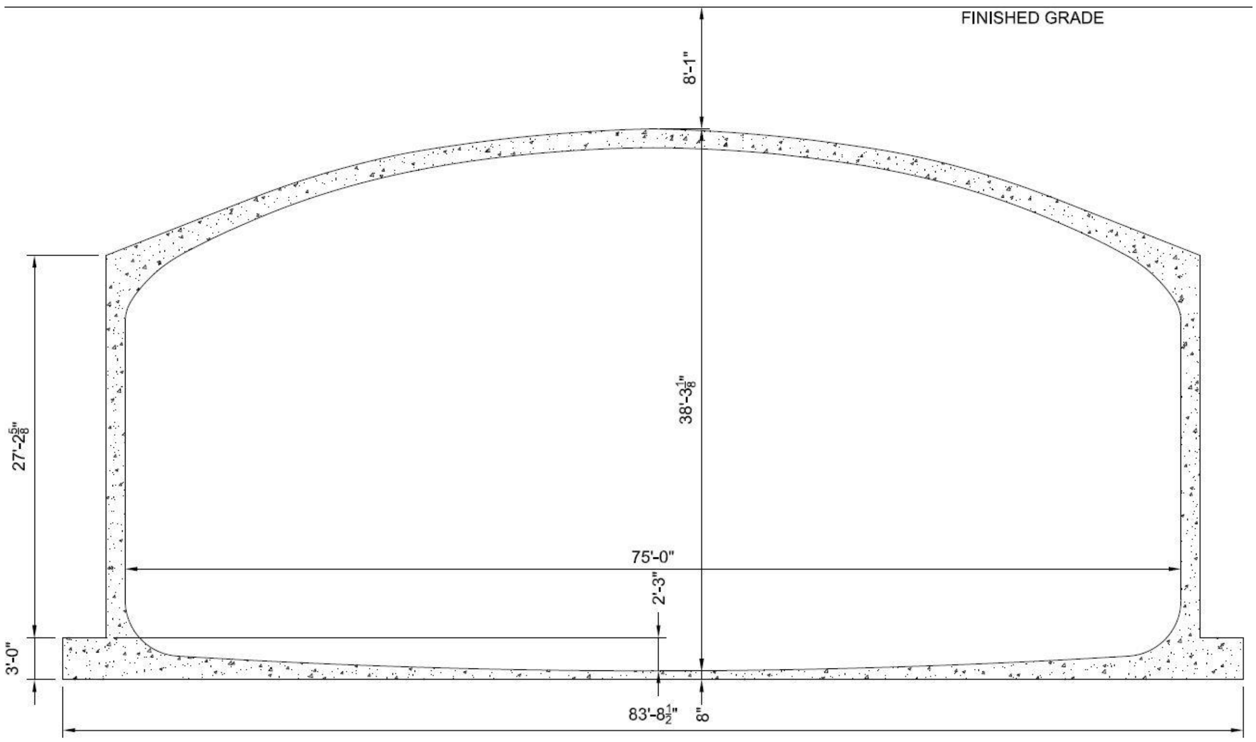


Figure 4-4: Tank Type III Cross-Section (H-2-1783)

The Type IV tanks are the third generation of 100-series tanks. These tanks contain 1,000,000 gallons of waste each. Type IV-A tanks are located in SX Tank Farm (15 tanks constructed 1953 to 1955). A cross-section is shown in Figure 4-5. Type IV-B tanks are located in A Tank Farm (six tanks constructed 1953 to 1955). A cross-section is shown in Figure 4-6. Type IV-C tanks are located in AX Tank Farm (four tanks constructed 1963 to 1965). A cross-section is shown in Figure 4-7. Again, for the purposes of this assessment, all 100-series tanks are referred to as 75-ft diameter tanks.

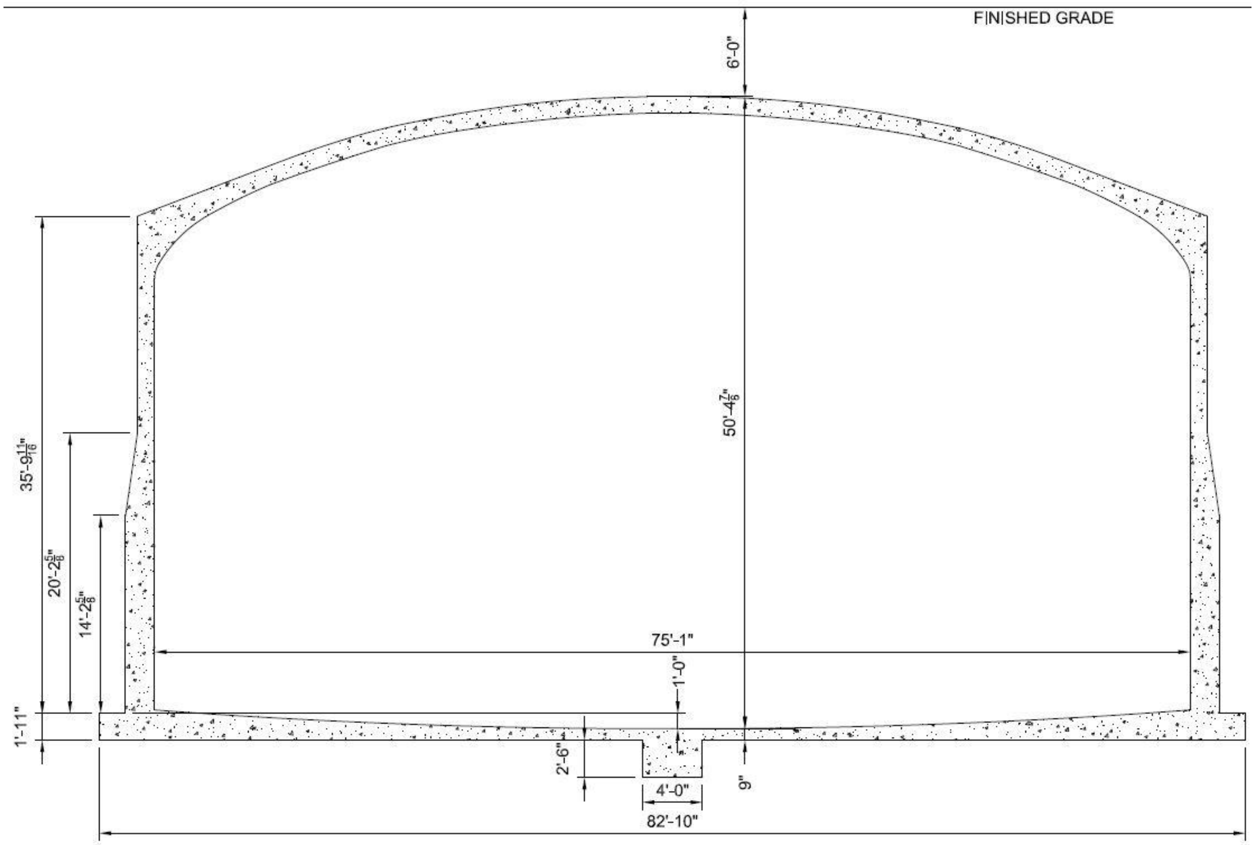


Figure 4-5: Tank Type IV-A Cross-Section SX Tank Farm (H-2-39511)

A cross-section is shown in Figure 4-6. Type IV-C tanks are located in AX Tank Farm (four tanks constructed 1963 to 1965).

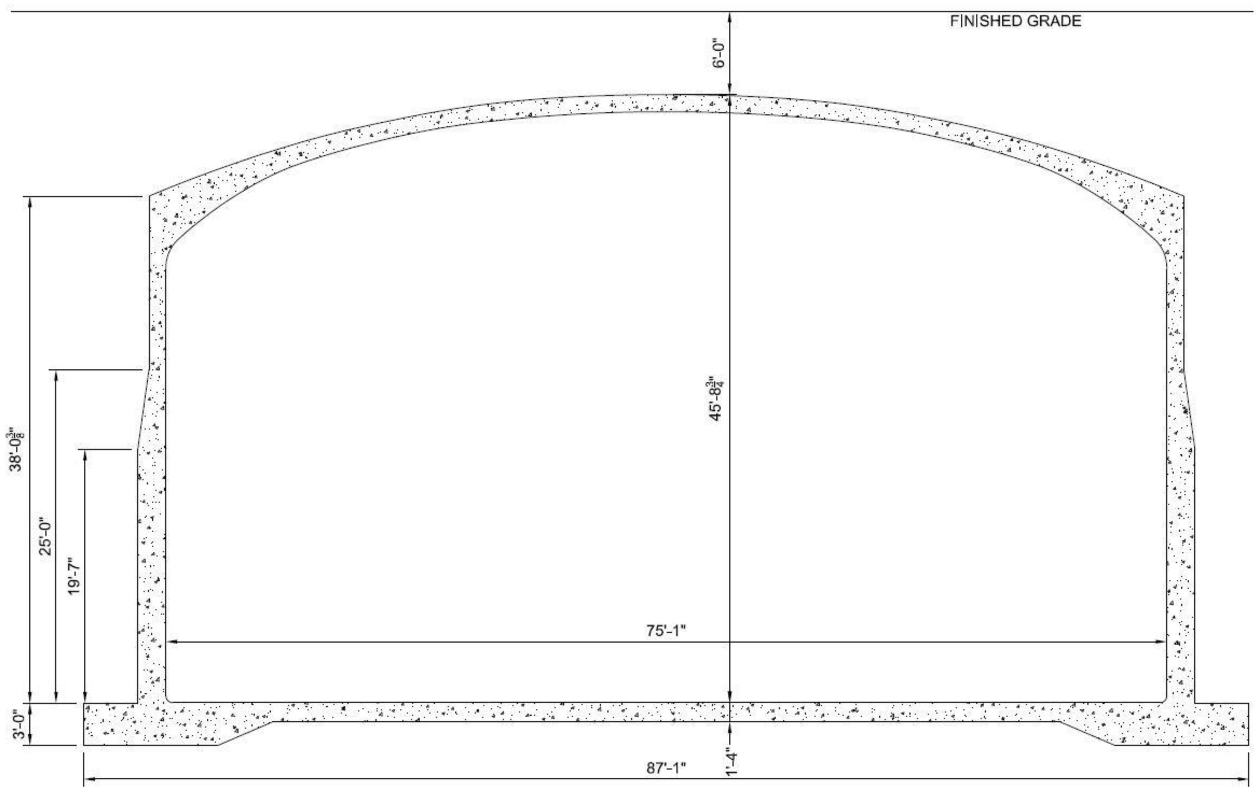


Figure 4-6: Tank Type IV-B Cross-Section A Tank Farm (H-2-55911)

A cross-section is shown in Figure 4-7. Again, for the purposes of this assessment, all 100-series tanks are referred to as 75-ft diameter tanks.

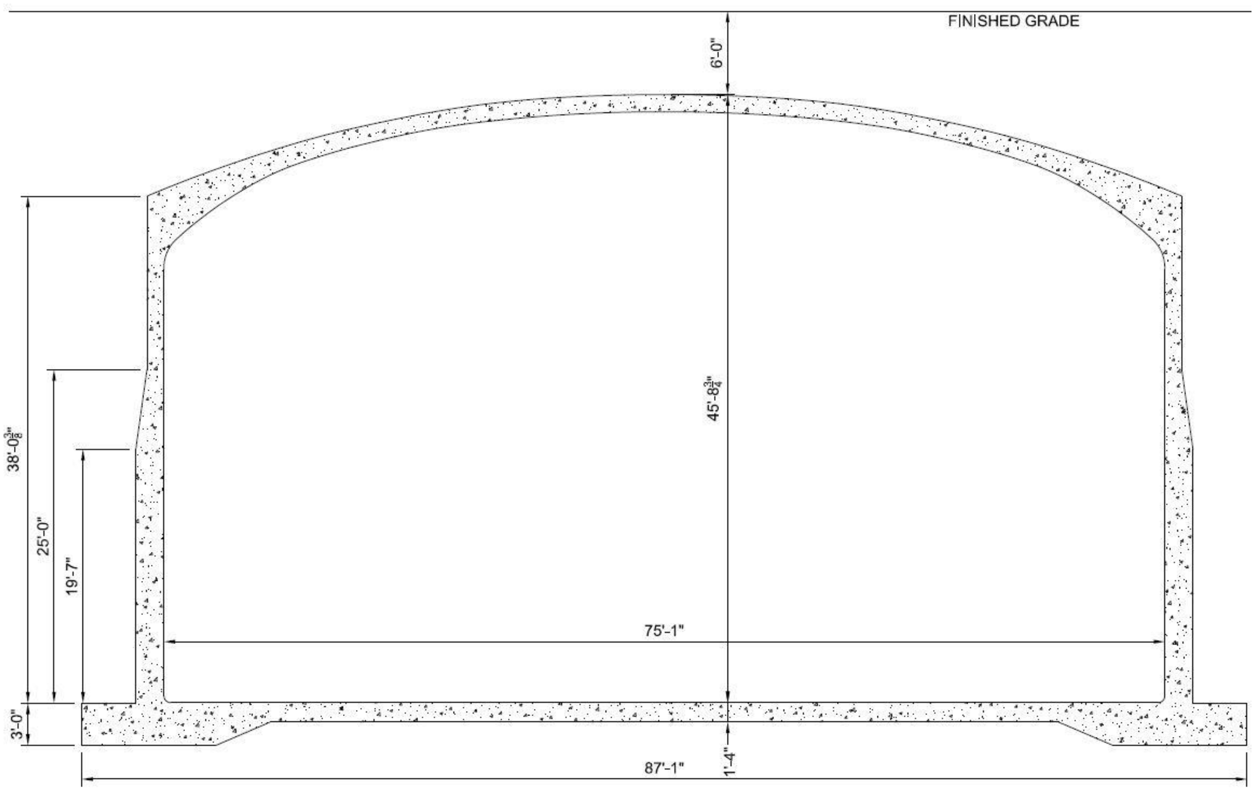


Figure 4-7: Tank Type IV-C Cross-Section AX Tank Farm (H-2-44562)

The pumpable liquid waste was removed from the tanks from 1976 to 2005 to agreed end point criteria (RPP-PLAN-61510 and HNF-EP-0182). This is referred to as interim stabilization. C Tank Farm tanks and tank S-112 have been retrieved. See Table 4-1 through Table 4-6 for the age of the tanks, the time in service, and retrieval waste status.

Table 4-1: Tank Age Type 1, Tank Farms B, C, T, and U

Tank Farm	Tank Type	Tank	Tank Age as of 2018 (years)	Construction [2]	First Year In-Service [2]	Year Out of Service [2]	Years of Service	Year Interim Stabilized	Year Retrieval Complete
B	Type I	201	74	1943-1944	1952	1971	19	1981 [1]	
		202	74		1952	1977	25	1985 [3]	
		203	74		1952	1977	25	1984 [1]	
		204	74		1952	1977	25	1984 [1]	
C	Type I	201	74		1947	1977	30	1982 [1]	2006 [1]
		202	74		1947	1977	30	1981 [1]	2005 [1]
		203	74		1947	1977	30	1982 [1]	2005 [1]
		204	74		1947	1977	30	1982 [1]	2006 [1]
T	Type I	201	74		1952	1976	24	1981 [3]	
		202	74		1952	1976	24	1981 [3]	
		203	74		1952	1976	24	1991 [A3]	
		204	74		1952	1976	24	1981 [3]	
U	Type I	201	74		1956	1977	21	1979 [3]	
		202	74		1956	1977	21	1979 [3]	
		203	74		1956	1977	21	1979 [3]	
		204	74		1954	1977	23	1979 [3]	

Notes:
[A] Date the Interim Stabilization documentation was completed.

References:
[1] HNF-EP-0182
[2] RPP-10435
[3] HNF-SD-RE-TI-178

Table 4-2: Tank Age Type II, Tank Farms B, C, and BX

Tank Farm	Tank Type	Tank	Tank Age as of 2018 (years)	Construction [2]	First Year In-Service [2]	Year Out of Service [2]	Years of Service	Year Interim Stabilized	Year Retrieval Complete
B	Type II	101	74	1943-1944	1945	1974	29	1991 [D1]	
		102	74		1945	1978	33	1985 [3]	
		103	74		1945	1977	32	1985 [1]	
		104	74		1946	1972	26	1985 [3]	
		105	74		1947	1977	30	1984 [1]	
		106	74		1947	1977	30	1985 [3]	
		107	74		1945	1969	24	1985 [1]	
		108	74		1945	1977	32	1985 [3]	
		109	74		1946	1977	31	1985 [3]	
		110	74		1945	1971	26	1985 [1]	
		111	74		1946	1976	30	1985 [1]	
		112	74		1946	1977	31	1985 [1]	
C	Type II	101	74	1943-1944	1946	1970	24	1983 [1]	2013 [A1]
		102	74		1946	1976	30	1995 [3]	2015 [A1]
		103	74		1946	1979	33	2003 [3]	2006 [1]
		104	74		1946	1980	34	1985 [3]	2012 [1]
		105	74		1947	1979	32	1995 [1]	2018 [4]
		106	74		1947	1979	32	N/A	2003 [1]
		107	74		1946	1978	32	1995 [3]	2014 [B1]
		108	74		1947	1976	29	1984 [3]	2012 [C1]
		109	74		1948	1976	28	1983 [3]	2012 [C1]
		110	74		1964	1976	12	1995 [3]	2013 [1]
		111	74		1946	1978	32	1984 [1]	2016 [1]
		112	74		1946	1978	32	1990 [3]	2014 [1]
BX	Type II	101	71	1946-1947	1948	1972	24	1978 [1]	
		102	71		1948	1971	23	1978 [1]	
		103	71		1948	1977	29	1983 [3]	
		104	71		1949	1980	31	1989 [3]	
		105	71		1949	1980	31	1986 [3]	
		106	71		1949	1971	22	1995 [3]	
		107	71		1948	1977	29	1990 [3]	
		108	71		1949	1974	25	1979 [1]	
		109	71		1950	1974	24	1990 [3]	
		110	71		1949	1977	28	1985 [1]	
		111	71		1950	1977	27	1995 [1]	
		112	71		1951	1977	26	1990 [3]	

Notes:
[A] Retrieved to limit of first and second retrieval technologies.
[B] Retrieved to limit of third retrieval technologies.
[C] Retrieved to limit of modified sluicing retrieval technologies.
[D] Date the Interim Stabilization documentation was completed.

References:
[1] HNF-EP-0182
[2] RPP-10435
[3] HNF-SD-RE-TI-178
[4] RPP-IQRPE-50028

Table 4-3: Tank Age Type II, Tank Farms T and U

Tank Farm	Tank Type	Tank	Tank Age as of 2018 (years)	Construction [2]	First Year In-Service [2]	Year Out of Service [2]	Years of Service	Year Interim Stabilized	Year Retrieval Complete
T	Type II	101	74	1943-1944	1945	1979	34	1993 [1]	
		102	74		1945	1976	31	1981 [3]	
		103	74		1945	1974	29	1983 [1]	
		104	74		1946	1974	28	1999 [3]	
		105	74		1946	1976	30	1987 [3]	
		106	74		1947	1973	26	1981 [1]	
		107	74		1945	1976	31	1996 [1]	
		108	74		1945	1974	29	1978 [1]	
		109	74		1945	1974	29	1984 [1]	
		110	74		1945	1976	31	2000 [3]	
		111	74		1945	1974	29	1995 [1]	
		112	74		1946	1977	31	1981 [3]	
U	Type II	101	74	1943-1944	1946	1960	14	1979 [1]	
		102	74		1946	1979	33	2002 [3]	
		103	74		1947	1978	31	2000 [3]	
		104	74		1947	1951	4	1978 [3]	
		105	74		1947	1978	31	2001 [3]	
		106	74		1948	1977	29	2001 [3]	
		107	74		1948	1980	32	2003 [3]	
		108	74		1949	1979	30	2004 [3]	
		109	74		1949	1978	29	2002 [3]	
		110	74		1946	1975	29	1984 [3]	
		111	74		1947	1980	33	2003 [3]	
		112	74		1947	1970	23	1984 [A3]	

Notes:
[A] Date the Interim Stabilization documentation was completed.

References:
[1] HNF-EP-0182
[2] RPP-10435
[3] HNF-SD-RE-TI-178

Table 4-4: Tank Age Type III, Tank Farms BY and S

Tank Farm	Tank Type	Tank	Tank Age as of 2018 (years)	Construction [2]	First Year In-Service [2]	Year Out of Service [2]	Years of Service	Year Interim Stabilized	Year Retrieval Complete
BY	Type III	101	69	1948-1949	1950	1971	21	1984 [3]	
		102	69		1950	1977	27	1995 [3]	
		103	69		1950	1973	23	1997 [1]	
		104	69		1950	1977	27	1985 [3]	
		105	69		1951	1974	23	2003 [1]	
		106	69		1953	1977	24	2005 [3]	
		107	69		1950	1974	24	1979 [1]	
		108	69		1951	1972	21	1985 [1]	
		109	69		1953	1979	26	1997 [3]	
		110	69		1951	1979	28	1985 [3]	
		111	69		1951	1977	26	1985 [3]	
		112	69		1951	1978	27	1984 [3]	
S	Type III	101	67	1950-1951	1953	1980	27	2004 [1]	
		102	67		1953	1980	27	2010 [1]	
		103	67		1953	1980	27	2000 [1]	
		104	67		1953	1968	15	1984 [1]	
		105	67		1953	1974	21	1988 [A1]	
		106	67		1952	1979	27	2001 [1]	
		107	67		1952	1980	28	2004 [1]	
		108	67		1952	1979	27	1996 [1]	
		109	67		1952	1979	27	2001 [1]	
		110	67		1952	1979	27	1997 [1]	
		111	67		1952	1972	20	2005 [1]	
		112	67		1952	1974	22	2005 [1]	2007 [1]

Notes:
[A] Date the Interim Stabilization documentation was completed.

References:
[1] HNF-EP-0182
[2] RPP-10435
[3] HNF-SD-RE-TI-178

Table 4-5: Tank Age Type III, Tank Farms TX and TY

Tank Farm	Tank Type	Tank	Tank Age as of 2018 (years)	Construction [2]	First Year In-Service [2]	Year Out of Service [2]	Years of Service	Year Interim Stabilized	Year Retrieval Complete
TX	Type III	101	70	1947-1948	1949	1980	31	1984 [3]	
		102	70		1950	1977	27	1983 [3]	
		103	70		1950	1980	30	1983 [3]	
		104	70		1950	1977	27	1984 [A3]	
		105	70		1952	1977	25	1983 [1]	
		106	70		1952	1977	25	1983 [3]	
		107	70		1952	1977	25	1984 [A3]	
		108	70		1952	1977	25	1983 [3]	
		109	70		1949	1977	28	1983 [1]	
		110	70		1949	1977	28	1983 [3]	
		111	70		1950	1977	27	1983 [3]	
		112	70		1950	1974	24	1983 [3]	
		113	70		1952	1971	19	1983 [1]	
		114	70		1952	1971	19	1983 [1]	
		115	70		1952	1977	25	1983 [1]	
		116	70		1952	1969	17	1983 [1]	
		117	70		1952	1969	17	1983 [1]	
		118	70		1952	1980	28	1983 [3]	
TY	Type III	101	66	1951-1952	1953	1973	20	1983 [1]	
		102	66		1953	1979	26	1984 [A3]	
		103	66		1953	1976	23	1983 [3]	
		104	66		1953	1974	21	1983 [1]	
		105	66		1953	1960	7	1983 [3]	
		106	66		1953	1977	24	1978 [1]	

Notes:
[A] Date the Interim Stabilization documentation was completed.

References:
[1] HNF-EP-0182
[2] RPP-10435
[3] HNF-SD-RE-TI-178

Table 4-6: Tank Age Type IV, Tank Farms SX, A, and AX

Tank Farm	Tank Type	Tank	Tank Age as of 2018 (years)	Construction [2]	First Year In-Service [2]	Year Out of Service [2]	Years of Service	Year Interim Stabilized	Year Retrieval Complete
SX	Type IV-A	101	64	1953-1955	1954	1980	26	2003 [3]	
		102	64		1954	1980	26	2004 [3]	
		103	64		1954	1980	26	2003 [3]	
		104	64		1955	1980	25	2000 [1]	
		105	64		1955	1980	25	2002 [3]	
		106	64		1954	1980	26	2000 [3]	
		107	63		1956	1964	8	1979 [1]	
		108	63		1955	1962	7	1979 [1]	
		109	63		1955	1965	10	1992 [3]	
		110	63		1959	1976	17	1979 [1]	
		111	63		1956	1974	18	1979 [1]	
		112	63		1956	1969	13	1979 [1]	
		113	63		1958	1958	0	1978 [1]	
		114	63		1957	1972	15	1979 [1]	
		115	63		1958	1965	7	1978 [1]	
A	Type IV-B	101	62	1953-1956	1956	1980	24	2004 [3]	
		102	62		1956	1980	24	1989 [3]	
		103	62		1956	1980	24	1988 [1]	
		104	62		1957	1975	18	1978 [1]	
		105	62		1957	1963	6	1979 [1]	
		106	62		1957	1980	23	1982 [3]	
AX	Type IV-C	101	53	1963-1965	1965	1980	15	2003 [3]	
		102	53		1965	1980	15	1988 [1]	
		103	53		1965	1980	15	1987 [1]	
		104	53		1965	1974	9	1981 [1]	

References:
[1] HNF-EP-0182
[2] RPP-10435
[3] HNF-SD-RE-TI-178

4.2 DESIGN STANDARDS

The SSTs are reinforced concrete slab/foundation, walls, and dome. The structural steel liners were constructed as a barrier between the concrete structure and the waste. Since the steel liners are considered non-structural, the structural integrity of the tank only relies on the reinforced concrete structure. The design standards at the time of construction for the reinforced concrete and the protective barriers are listed in Table 4-7.

Table 4-7: Tank Design Standards (2 sheets)

<table>
<tr><th rowspan="2">Item</th><th colspan="7">Single-Shell Tanks</th></tr>
<tr><th>Type I
(241-B, C, T, U)</th><th colspan="2">Type II
(241-B, BX, C, T, U)</th><th colspan="2">Type III
(241-BY, S, TX, TY)</th><th colspan="2">Type IV
(241-A, AX, SX)</th></tr>
<tr><td>Design Codes</td><td>PCA ST-57 Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete (ASTM 1940)</td><td colspan="2">PCA ST-57, PCA ST-55 Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete (ASTM 1940)</td><td colspan="2">PCA ST-55
PCA ST-57</td><td colspan="2">PCA ST-55
PCA ST-57
ACI 318-51</td></tr>
<tr><td rowspan="4">Construction Specifications</td><td rowspan="4">Spec. No. 1946
BPF-73550</td><td rowspan="2">BX</td><td rowspan="2">General Electric 1946</td><td>BY</td><td>HW-3783</td><td>SX</td><td>HW-4957</td></tr>
<tr><td>S</td><td>HW-3937</td><td rowspan="2">A</td><td rowspan="2">HW-5614</td></tr>
<tr><td rowspan="2">All Others</td><td rowspan="2">Spec. No. 1946
BPF-73550</td><td>TY</td><td>HW-4696</td></tr>
<tr><td>TX</td><td>General Electric 1946, HW-3061</td><td>AX</td><td>HWS-8237</td></tr>
<tr><td rowspan="2">Concrete Compressive Strength</td><td rowspan="2">3000 PSI</td><td rowspan="2" colspan="2">3000 PSI</td><td rowspan="2" colspan="2">3000 PSI</td><td>SX/A</td><td>3000 PSI</td></tr>
<tr><td>AX</td><td>4000 PSI</td></tr>
<tr><td>Maximum Concrete Aggregate Size</td><td>1 1/2 in.</td><td colspan="2">1 1/2 in.</td><td colspan="2">1 1/2 in.</td><td colspan="2">1 1/2 in.</td></tr>
<tr><td rowspan="2">Reinforcing Steel</td><td rowspan="2">ASTM A15-39
Intermediate Grade
Fy = 40 ksi</td><td rowspan="2" colspan="2">ASTM A15-39
Intermediate Grade
Fy = 40 ksi</td><td rowspan="2" colspan="2">ASTM A15-39
ASTM A16-35
Intermediate Grade
Fy = 40 ksi</td><td>SX/A</td><td>ASTM A15-50T
ASTM A305-50T
Intermediate Grade
Fy = 40 ksi</td></tr>
<tr><td>AX</td><td>HW-4769-S
ASTM A15-58T
ASTM A185-61T
Fy = 40 ksi</td></tr>
</table>

Table 4-7: Tank Design Standards (2 sheets)

Item	Single-Shell Tanks				
	Type I (241-B, C, T, U)	Type II (241-B, BX, C, T, U)	Type III (241-BY, S, TX, TY)	Type IV (241-A, AX, SX)	
Internal Corrosive Protection Dome	Magnesium Zinc Fluorosillicate 3 Coats (min)	Magnesium Zinc Fluorosillicate 3 Coats (min)	Magnesium Zinc Fluorosillicate 3 Coats (min)	SX	Magnesium Zinc Fluorosillicate 3 coats (min)
				A/AX	N/A
Internal Corrosive Protection Walls	2 coats (inside) Dulux Searchrome Primer No. 67710	2 coats (inside) Dulux Searchrome Primer No. 67710	2 coats (inside) Dulux Searchrome Primer No. 67710	SX A	1 coat Red Lead Primer
				AX	2 coats Red Lead Primer
Internal Corrosive Protection Base	2 coats Dulux Searchrome Primer No. 67710	2 coats Dulux Searchrome Primer No. 67710	2 coats Dulux Searchrome Primer No. 67710	SX A	1 coat Red Lead Primer
				AX	2 coats Red Lead Primer
External Waterproofing	3-Ply Asphaltic Fabric Coating Asphalt - ASTM D449-37T Fabric Fed Spec. HHC-581 Dome Only	3-Ply Asphaltic Fabric Coating Asphalt - ASTM D449-37T Fabric Fed Spec. HHC-581 Dome Only	3-Ply Asphaltic Fabric Coating Asphalt - ASTM D449-37T Fabric Fed Spec. HHC-581 Dome Only	A	2-Ply Asphaltic Primer ASTM D41-41 Asphalt - ASTM D449-49 Type C "Glasfab" by Owens Corning Dome Only
				AX/SX	N/A

Reference:
RPP-10435

The tank dimensions are shown in Figure 4-2 through Table 4-13. Table 4-8 through Table 4-13 show the typical reinforcing of the tanks.

Table 4-8: Type I Tank Reinforcing (BPF-73550)

	Dome			Wall			Footing			Haunch	
	Vertical		Circ.	Vertical		Circ.	Horizontal		Circ.	Circ.*	Ties
	Int.	Ext.		Int.	Ext.		Top	Bottom			
Rebar Size (in)	3/4"	N/A	1/2"	3/4"	3/4"	5/8"	5/8"	5/8"	5/8"	N/A	N/A
Typ. Spacing (in)	12" OC	N/A	12" OC	12" OC	12" OC	Varies	12" OC	12" OC	Varies	N/A	N/A
Design Concrete Cover (Clearance) (in)	2" *	N/A	N/A	2" *	2" *	N/A	2" *	2" *	N/A	N/A	N/A

Note: * Dimension not shown on reference drawing, value shown is an assumed value.

Table 4-9: Type II Tank Reinforcing (BPF-73550)

	Dome			Wall			Footing			Haunch	
	Vertical		Circ.	Vertical		Circ.	Horizontal		Circ.	Circ.*	Ties
	Int.	Ext.		Int.	Ext.		Top	Bottom			
Rebar Size (in)	3/4"	3/4"	3/4"	3/4"	3/4"	7/8"	1/2"	3/4"	(12) 1"	(11)3/4"	5/8"
Typ. Spacing (in)	12" OC	12" OC	12" OC	12" OC	12" OC	Varies	24" OC	8" OC	Varies	12" OC	24" OC
Design Concrete Cover (Clearance) (in)	2" **	2" **	2"	3"	3"	N/A	4"	4"	N/A	2" **	N/A

Note: * Bar size and quantity is for the exterior row of circumference rebar, there are twelve (12) columns of circumference bars within the haunch (size and quantity varies).

** Dimension not shown on reference drawing, value shown is an assumed value.

Table 4-10: Type III Tank Reinforcing (H-2-1785, H-2-1786)

	Dome			Wall			Footing			Haunch	
	Vertical		Circ.	Vertical		Circ.	Horizontal		Circ.	Circ.*	Ties
	Int.	Ext.		Int.	Ext.		Top	Bottom			
Rebar Size (in)	3/4"	3/4"	3/4"	5/8"	5/8"	1/2	1/2"	1/2"	(5) #5	(10) 3/4"	5/8"
Typ. Spacing (in)	12" OC	12" OC	12" OC	12" OC	12" OC	Varies	24" OC	12" OC	24" OC	12" OC	24" OC
Design Concrete Cover (Clearance) (in)	3"	3"	3"	2"	3-1/4"	N/A	3-1/2"	4-1/8"	3-1/2"	2-1/2"	N/A

Note: * Bar size and quantity is for the exterior row of circumference rebar, there are sixteen (16) columns of circumference bars within the haunch (size and quantity varies).

Table 4-11: Type IV-A Tank Reinforcing (H-2-39512, H-2-39513)

	Dome			Wall			Footing			Haunch	
	Vertical		Circ.	Vertical		Circ.	Horizontal		Circ.	Circ.*	Ties
	Int.	Ext.		Int.	Ext.		Top	Bottom			
Rebar Size (in)	3/4"	3/4"	#6	3/4"	3/4"	#8	3/4"	5/8"	#6	(11) #11	(7) #5
Typ. Spacing (in)	12" OC	12" OC	12" OC	16" OC	16" OC	Varies	8" OC	12" OC	8" OC	EQ Spaced	24" OC
Design Concrete Cover (Clearance) (in)	3"	3"	3"	3-5/8"	3-5/8"	N/A	2-1/2"	3-1/2"	3-1/2"	2-3/8"	N/A

Note: * Bar size and quantity is for the exterior row of circumference rebar, there are sixteen (16) columns of circumference bars within the haunch (size and quantity varies).

Table 4-12: Type IV-B Tank Reinforcing (H-2-55912, H-2-55913)

	Dome			Wall			Footing			Haunch	
	Vertical		Circ.	Vertical		Circ.	Horizontal		Circ.	Circ.*	Ties
	Int.	Ext.		Int.	Ext.		Top	Bottom			
Rebar Size (in)	3/4"	3/4"	3/4"	3/4"	3/4"	#8	3/4"	5/8"	#5	(9) #11	5/8"
Typ. Spacing (in)	12" OC	12" OC	12" OC	16" OC	16" OC	Varies	8" OC	12" OC	12" OC	EQ Spaced	24" OC
Design Concrete Cover (Clearance) (in)	3"	3"	2-3/4"	3-5/8"	3-5/8"	N/A	2-1/2"	3-1/2"	4"	N/A	N/A

Note: * Bar size and quantity is for the exterior row of circumference rebar, there are fifteen (15) columns of circumference bars within the haunch (size and quantity varies).

Table 4-13: Type IV-C Tank Reinforcing (H-2-44562)

	Dome			Wall			Footing			Haunch	
	Vertical		Circ.	Vertical		Circ.	Horizontal		Circ.	Circ.*	Ties
	Int.	Ext.		Int.	Ext.		Top	Bottom			
Rebar Size (in)	3/4"	3/4"	#6	1"	1"	#8	3/4"	5/8"	#6	(11)3/4"	3/4"
Typ. Spacing (in)	12" OC	12" OC	N/A	18" OC	18" OC	18" OC	12" OC	12" OC	12" OC	12" OC	6" OC
Design Concrete Cover (Clearance) (in)	3"	3"	N/A	1-1/2"	2"	N/A	3-1/2"	2"	N/A	3"	3-3/4"

Note: * Bar size and quantity is for the exterior row of circumference rebar, there are twelve (12) columns of circumference bars within the haunch (size and quantity varies).

Figure 4-8 through Figure 4-23 show photographs taken during the construction of the concrete SST structures. These photographs show a typical construction sequence used in the tank construction. Figure 4-24 to Figure 4-28 show voids in the concrete created during construction. These are reported to be severe conditions and not typical of tank construction conditions.

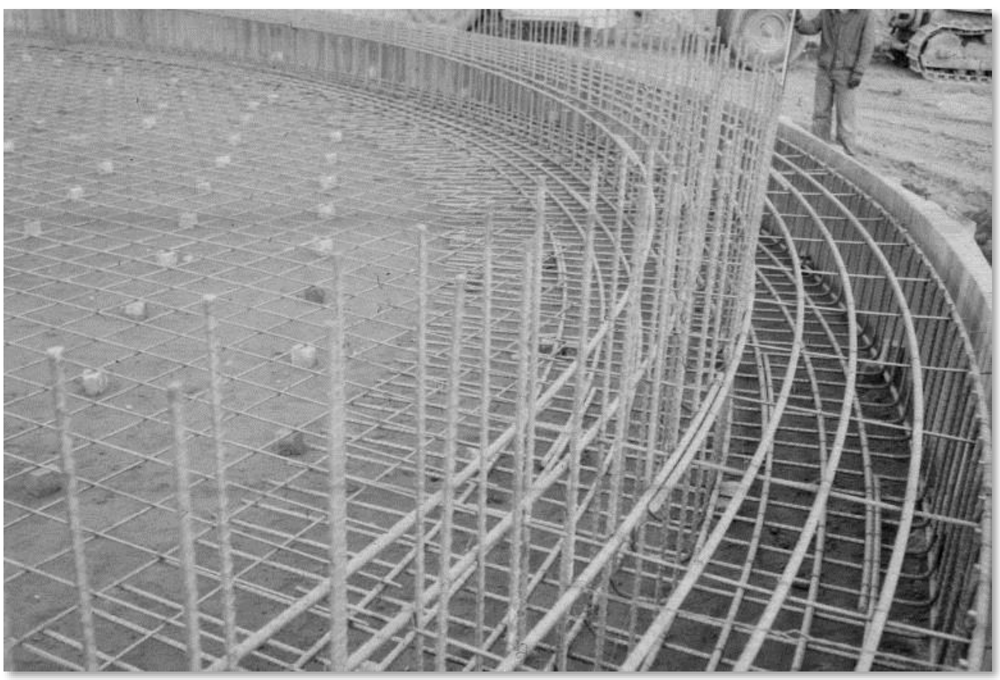


Figure 4-8: Placement of Reinforcing Steel in Base Showing Wall Dowels in TX Tank Farm (RPP-PLAN-61510)

Figure 4-9: Pouring of Concrete in Base Slab Showing Wall Dowels Around the Perimeter (RPP-PLAN-61510)

Figure 4-10: Base Slab Construction (RPP-PLAN-61510)

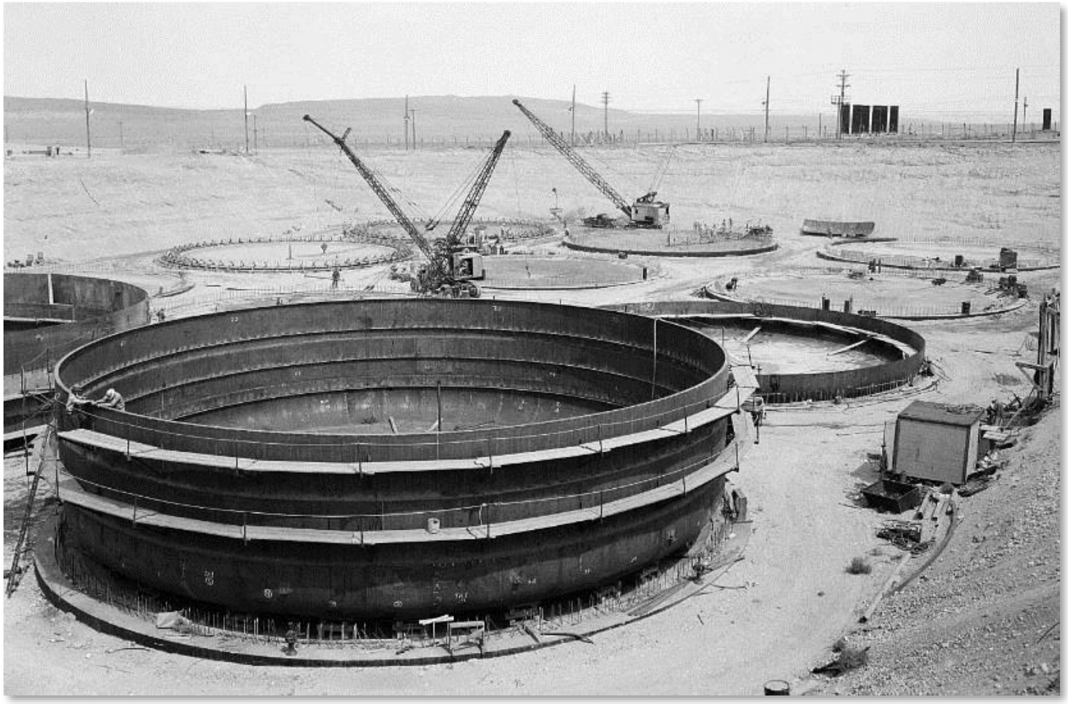


Figure 4-11: Construction of Steel Liners (RPP-PLAN-61510)

Figure 4-12: Base of Liner with View of Sloping (Dish-Shaped) Base Slab (RPP-PLAN-61510)

Figure 4-13: Transition from Tank Base to Vertical Wall BX Tank Farm (RPP-PLAN-60765)

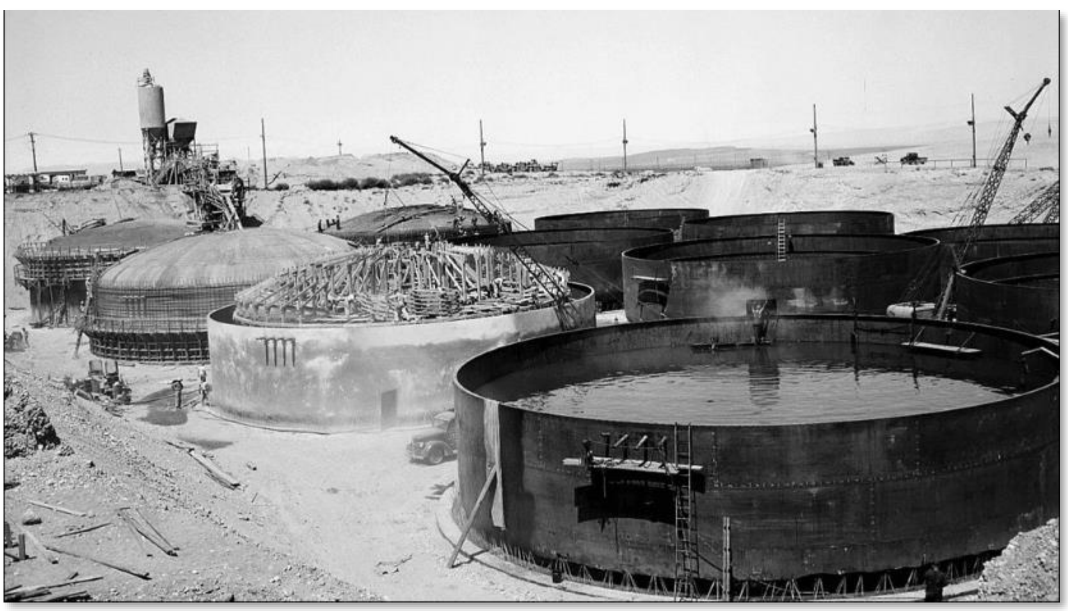


Figure 4-14: Tanks in Various Stages of Construction Showing Hydrostatic Testing of Liner (RPP-PLAN-61510)

Figure 4-15: View of Liner Coating and Wood Forms for Dome Concrete (RPP-PLAN-61510)

Figure 4-16: View of Wood Forms and Wall Reinforcing Steel (RPP-PLAN-61510)

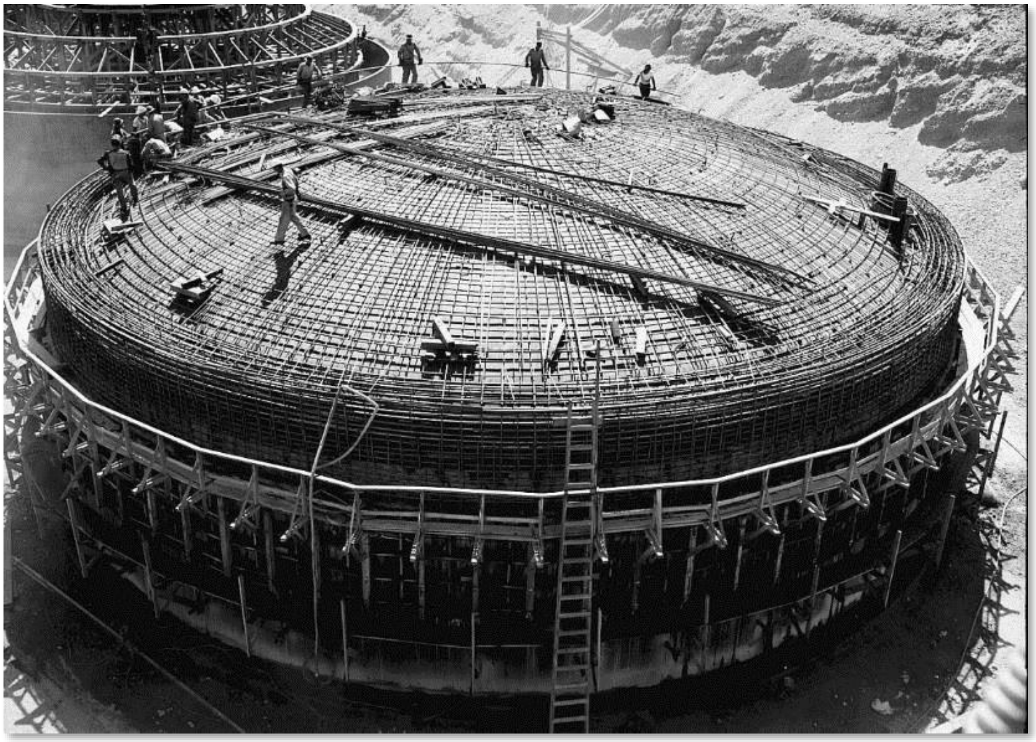


Figure 4-17: Placement of Dome Reinforcing Steel after Wall Concrete has been Poured (RPP-PLAN-61510)

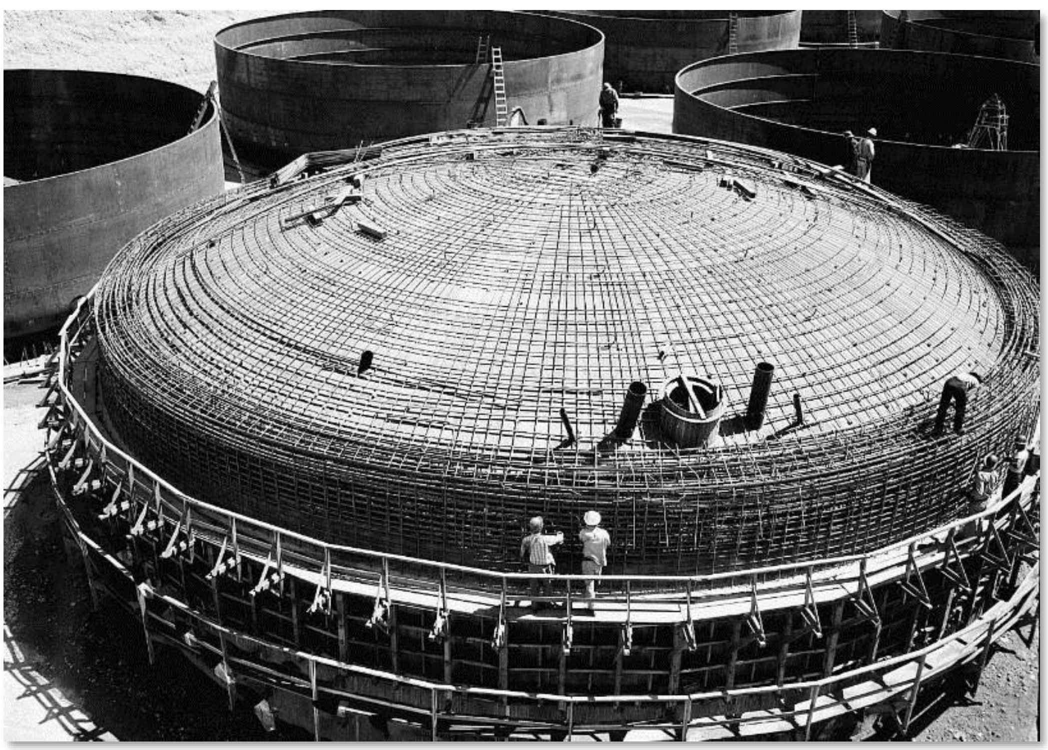


Figure 4-18: Placement of Dome Reinforcing Steel (RPP-PLAN-61510)

Figure 4-19: View of Dome Reinforcing Steel Showing Square and Deformed Round Bars (RPP-PLAN-61510)

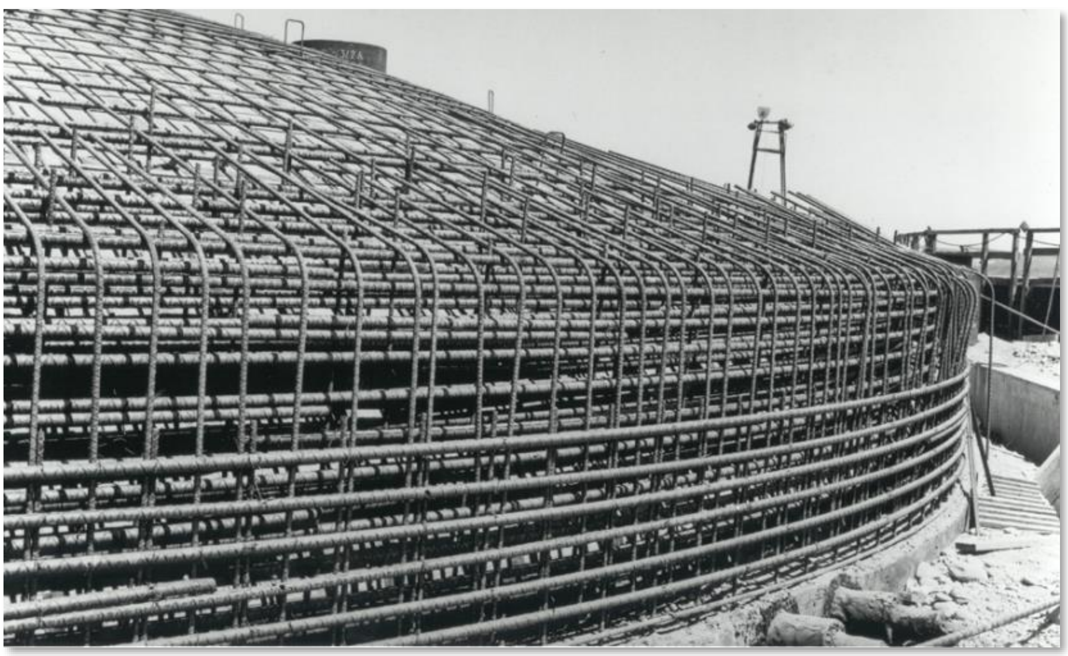


Figure 4-20: View of Reinforcement Steel in the Haunch Region (RPP-PLAN-61510)

Figure 4-21: Pouring of Dome Concrete (RPP-PLAN-61510)

Figure 4-22: Dome Concrete Being Vibrated BX Tank Farm (Photos 1326-Neg [1947] BX Tank Farm Progress)

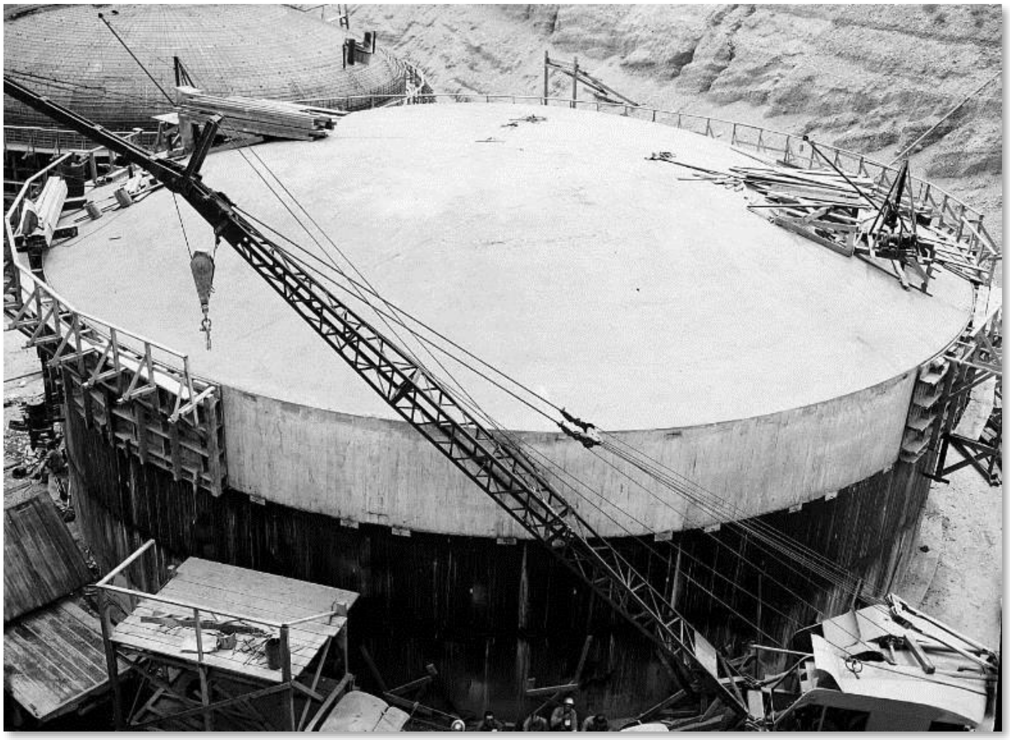


Figure 4-23: Removal of Exterior Forms from Dome Concrete (RPP-PLAN-61510)

Figure 4-24: Voids in Concrete Created During Construction (RPP-PLAN-61510)

Figure 4-25: Voids in Concrete Created During Construction Showing Reinforcing Steel (RPP-PLAN-61510)

Figure 4-26: Interior of Tank Dome Showing Construction Flaws and Visible Form Lines (RPP-PLAN-61510)

Figure 4-27: Interior of Tank Dome Showing Repair of Construction Flaws (RPP-PLAN-61510)

Figure 4-28: Interior of Tank Dome Showing Dome Penetrations and Repair of Construction Flaws (RPP-PLAN-61510)

4.3 POTENTIAL TANK CONSTRUCTION DEFICIENCIES

The design concrete clearances to the reinforcing ranged from 1-5/8 in. in the Type II tank domes to 4 1/8-in. for the bottom of the footings in Type III tanks (Table 4-8 through Table 4-13). During construction, in some areas of the tank dome the design clearance was not maintained during the concrete pour. This could have been caused by the construction crew walking on the top of the reinforcing during the pour.

Rock pockets are another source of voids in the concrete tank. The current standard practice is that the aggregate not exceed three quarters of the clear distance. The specification lists the maximum aggregate size as 1-1/2 in. For 1-1/2 in. aggregate size, this would be a minimum of 2 in. clear. Inadequate vibration of the concrete as it was poured can leave air voids in the concrete.

The concrete flaws observed during construction as shown in Figure 4-24 through Figure 4-28 were repaired. Figure 4-27 and Figure 4-28 show workers repairing the areas where the concrete did not adequately surround the bars. When this type of repair is done, some of the concrete is chipped out around the reinforcing and a cementous product is then sprayed on the surface or a grout is poured in the void to ensure a good bond between the reinforcing and the concrete. Alternatively, current ACI 318, *Building Code Requirements for Structural Concrete (ACI-318-14) and Commentary (ACI-318 R-14),* allows the surface to be roughened to ¼ in. prior to pouring new concrete adjacent to existing. Since all of the tanks were accepted, it is assumed that all visible reinforcing at the time of construction was repaired.

However, the inside face of the wall was not observable. Therefore, it is likely that some hidden voids may be located in the interior face of the concrete wall between the grout and the interior reinforcing. Any voids in the exterior face of the concrete walls were observable and repaired when the forms were removed. Based on the number of observed deficiencies, it is likely that the deficiencies located on the interior face of the concrete walls do not reduce the structural integrity of the tanks.

All repairs were accepted prior to putting the tanks into service.

Based on some of the visual inspections, most of the concrete patches are in place and are in good condition. There is photographic evidence inside some of the concrete domes that the reinforcing is exposed. In these locations, it is likely that the concrete patch did not adhere adequately to the concrete dome, or there was not adequate concrete cover on the bars and the concrete in these small areas fell off early in the life of the tank. There was no evidence observed that this exposed reinforcing is corroding in the general dome areas.

4.4 TANK STRUCTURAL LOADING CONDITIONS

Table 4-14 shows the original loading criteria for the SSTs. Table 4-15 through Table 4-20 show the current loading criteria and the historic maximum loads for the SSTs.

RHO-CD-1485, *Description of Potential Failure Modes for the Single-Shell Waste Tanks*, was published in 1981: "Loading conditions described include dead/live loads, seismic loads, hydrostatic loads, thermal loads, explosions, missiles, and pressure loads. Material conditions that contribute to the probability of failure are corrosion of the steel liner or reinforcing steel, degradation of the concrete, bond failure between concrete and reinforcing steel, changes in properties of the material with temperature, and creep of concrete. Conditions related to construction of reinforced concrete include tolerances, cold joints, strength testing, mixing of concrete, welding, and construction joints" (pg 2).

Table 4-14: Original Loading Criteria for Single-Shell Tanks

Tank Farm	Tank Type	Specific Gravity	pH [1]	Backfill Density (lbf/ft^3)	Soil Bearing Under Footing (lbf/ft^2) [2]	Equipment Load [2]	Internal Pressure (psi) [2]	Max Design Temperature (°F) [2]	Soil Coverage (inch)
B	Type I	1.25 [1,2]	10.0	100 [2]	8000	N/A	Atmospheric	220	132 [2]
C									
T									
U									
B	Type II	1.25 [1,2]	10.0	100 [2]	8000	34,000 lb concentrated load	Atmospheric	220	108 [2]
C									
T									
C									
BX									96 [2]
BY	Type III	1.5 [2]	8 to 10	110 [2] 115 [1]	6000	2x35,000 lb tractors +187 psf slab	Atmospheric	220	96 [2] 84 [1]
S									~74.6 [2] 84 [1]
TX									96 [2] 84 [1]
TY									~74.6 [2] 84 [1]
A	Type IV	2.0 [2]	8 to 10	110 [2]	6000	2x35,000 lb +187 psf slab tractors or 28 tons	-1.0 to 3.0	250	84 [2]
AX		2.0 [2]				40 psi plus 50 ton concentrated dome load	(-0.55) to 2.2	300	(101/103) ~78 [2] (102/104) ~90 [2]
SX		1.5 [2]				2x35,000 lb tractors +187 psf slab	Atmospheric	250	72 [2]

References:
[1] RPP-10435
[2] RPP-46644

Table 4-15: Current Loading Criteria and the Historic Maximum Loads Type 1 for Tank Farms B, C, T, and U

Tank Farm	Tank Type	Tank	Storage Volume [1] (gal)	Estimated Soil Cover (ft)	Historic Peak Temperature [1] (°F) (year)	Current Waste Volume [2] (kgal)	Date of Videos
B	Type I	201	55,000	11.45 [6]	112 (1989)	29.3	2016 [5]
		202			74 (1975)	29	2014 [4]
		203			110 (1989)	50	2013 [3]
		204			220 (1989)	50	2013 [3]
C	Type I	201		10.7 [6]	81 (1978)	0.14	
		202			80 (1978)	0.15	
		203			83 (1978)	0.14	
		204			-	0.14	
T	Type I	201		10 [6]	81 (1976)	31	2014 [4]
		202			73 (1994)	19	
		203			79 (1988)	36	2013 [3]
		204			77 (1976)	36	2013 [3]
U	Type I	201		9.5 [6]	78 (1977)	5	
		202			67 (1995)	5	
		203			82 (1977)	3	
		204			77 (1977)	3	

References:

[1] RPP-10435
[2] HNF-EP-0182
[3] RPP-RPT-55951
[4] RPP-RPT-58239
[5] RPP-RPT-59272
[6] RPP-11802

Table 4-16: Current Loading Criteria and the Historic Maximum Loads Type II for Tank Farms B, C, and BX

Tank Farm	Tank Type	Tank	Storage Volume [1] (gal)	Estimated Soil Cover (ft)	Historic Peak Temperature [1] (°F) (year)	Current Waste Volume [2] (kgal)	Date of Videos
B	Type II	101	530,000	6.30 [11]	137 (1977)	104	2016 [8]
		102		5.80 [11]	108 (1989)	31	2010 [3]
		103		6.10 [11]	83 (1976)	52	
		104		7.10 [11]	122 (1989)	369	2018 [10]
		105		6.30 [11]	107 (1989)	289	2018 [10]
		106		6.30 [11]	86 (1982)	117	2011 [4]
		107		6.30 [11]	124 (1989)	156	
		108		6.30 [11]	105 (1989)	85	
		109		7.30 [11]	105 (1989)	123	2014 [6]
		110		6.60 [11]	121 (1989)	244	
		111		6.80 [11]	98 (1979)	220	
		112		6.80 [11]	101 (1989)	33	
C	Type II	101	530,000	6.00 [11]	112 (1980)	5.5	2011 [4]
		102		6.00 [11]	106 (1978)	15.5	
		103		5.27 [11]	168 (1977)	2.5	
		104		5.87 [11]	195 (1982)	1.9	
		105		6.00 [11]	156 (1976)	1.5	
		106		5.77 [11]	216 (1994)	2.8	
		107		6.00 [11]	168 (1988)	10.0	
		108		5.47 [11]	99 (1980)	3.4	
		109		5.67 [11]	160 (1963	2.0	
		110		5.37 [11]	118 (1985)	2.1	2010 [3]
		111		6.00 [11]	190 (1964)	4.9	
		112		5.57 [11]	160 (1961)	10	2011 [4]
BX	Type II	101	530,000	8.30 [11]	240 (1951)	52	2013 [5]
		102		8.50 [11]	83 (1977)	74	2017 [9]
		103		8.65 [11]	99 (1979)	73	2013 [5]
		104		8.30 [11]	240 (1951)	97	
		105		8.30 [11]	126 (1977)	70	
		106		8.50 [11]	115 (1974)	38	2015 [7]
		107		8.30 [11]	88 (1977)	344	2017 [9]
		108		8.30 [11]	90 (1980)	30	
		109		8.30 [11]	77 (1993)	189	
		110		8.20 [11]	104 (1974)	212	2013 [5]
		111		9.20 [11]	111 (1977)	124	2014 [6]
		112		8.50 [11]	90 (1980)	158	

References:

[1] RPP-10435
[2] HNF-EP-0182
[3] RPP-RPT-48194
[4] RPP-RPT-51404
[5] RPP-RPT-55951
[6] RPP-RPT-58239
[7] RPP-RPT-58849
[8] RPP-RPT-59272
[9] RPP-RPT-60093
[10] RPP-RPT-60565
[11] RPP-11802

Table 4-17: Current Loading Criteria and the Historic Maximum Loads Type II for Tank Farms T and U

Tank Farm	Tank Type	Tank	Storage Volume [1] (gal)	Estimated Soil Cover (ft)	Historic Peak Temperature [1] (°F) (year)	Current Waste Volume [2] (kgal)	Date of Videos
T	Type II	101	530,000	6.55 [11]	103 (1988)	94	2014 [6]
		102		5.85 [11]	94 (1976)	30	2011[4], 2014[6]
		103		6.25 [11]	96 (1976)	26	
		104		6.75 [11]	90 (1978)	310	2017 [9]
		105		6.78 [11]	93 (1985)	92	2017 [9]
		106		7.78 [11]	93 (1979)	21	2017 [9]
		107		6.75 [11]	114 (1981)	166	2016 [8]
		108		7.63 [11]	90 (1978)	15	
		109		8.63 [11]	91 (1978)	98	2017 [9]
		110		6.55 [11]	91 (1976)	370	2016 [8]
		111		6.15 [11]	98 (1981)	424	2013 [5], 2014 [6], 2015 [7], 2016 [8], 2017 [9]
		112		6.15 [11]	87 (1978)	62	2011 [4], 2016 [8]
U	Type II	101	530,000	6.35 [11]	92 (1977)	23	
		102		6.25 [11]	134 (1978)	353	2016 [8]
		103		6.15 [11]	132 (1977)	418	2018 [10]
		104		6.45 [11]	240 (1955)	84	2010 [3]
		105		6.15 [11]	146 (1977)	350	2016 [8]
		106		5.75 [11]	122 (1976)	165	2011 [4]
		107		6.95 [11]	122 (1976)	277	2017 [9]
		108		6.05 [11]	130 (1980)	428	
		109		5.65 [11]	120 (1977)	401	
		110		7.15 [11]	260-300 (1954)	183	
		111		6.15 [11]	130 (1956)	219	2013 [5], 2014 [6]
		112		6.05 [11]	160 (1956)	43	

References:

[1] RPP-10435
[2] HNF-EP-0182
[3] RPP-RPT-48194
[4] RPP-RPT-51404
[5] RPP-RPT-55951
[6] RPP-RPT-58239
[7] RPP-RPT-58849
[8] RPP-RPT-59272
[9] RPP-RPT-60093
[10] RPP-RPT-60565
[11] RPP-11802

Table 4-18: Current Loading Criteria and the Historic Maximum Loads Type III for Tank Farms BY and S

Tank Farm	Tank Type	Tank	Storage Volume [1] (gal)	Estimated Soil Cover (ft)	Historic Peak Temperature [1] (°F) (year)	Current Waste Volume [2] (kgal)	Date of Videos
BY	Type III	101	758,000	9.50 [10]	322 (1965)	365	2013 [4]
		102		9.65 [10]	322 (1965)	316	2013 [4]
		103		9.59 [10]	240 (1970)	412	2014 [5]
		104		9.50 [10]	240 (1970)	401	
		105		9.45 [10]	240 (1970)	477	2016 [7]
		106		9.40 [10]	240 (1970)	429	2014 [5]
		107		8.75 [10]	240 (1970)	274	
		108		8.99 [10]	240 (1970)	221	
		109		8.77 [10]	240 (1970)	296	2017 [8]
		110		9.04 [10]	240 (1970)	348	2010 [3] 2015 [6]
		111		9.39 [10]	240 (1970)	399	2013 [4]
		112		8.50 [10]	322 (1967)	287	
S	Type III	101	758,000	6.31 [10]	300 (1953)	350	2010 [3]
		102		7.31 [10]	140 (1979)	93	
		103		7.31 [10]	130 (1979)	230	2010 [3]
		104		6.85 [10]	300 (1953)	283	2010 [3], 2017 [8]
		105		6.33 [10]	125 (1980)	508	2016 [7]
		106		6.56 [10]	144 (1976)	451	2014 [5]
		107		6.67 [10]	240 (1952)	358	2018 [9]
		108		6.36 [10]	195 (1982)	541	2010 [3], 2015 [6]
		109		6.56 [10]	150 (1974)	533	2013 [4]
		110		7.54 [10]	240 (1952)	387	
		111		7.50 [10]	169 (1976)	401	2013 [4]
		112		7.24 [10]	141 (1978)	2.7	

References:

[1] RPP-10435
[2] HNF-EP-0182
[3] RPP-RPT-48194
[4] RPP-RPT-55951
[5] RPP-RPT-58239
[6] RPP-RPT-58849
[7] RPP-RPT-59272
[8] RPP-RPT-60093
[9] RPP-RPT-60565
[10] RPP-11802

Table 4-19: Current Loading Criteria and the Historic Maximum Loads Type III for Tank Farms TX and TY

Tank Farm	Tank Type	Tank	Storage Volume [1] (gal)	Estimated Soil Cover (ft)	Historic Peak Temperature [1] (°F) (year)	Current Waste Volume [2] (kgal)	Date of Videos
TX	Type III	101	758,000	10.11 [3]	240 (1951)	87	2011 [4]
		102		10.22 [3]	240 (1970)	213	
		103		10.15 [3]	240 (1970)	144	2016 [8]
		104		9.82 [3]	128 (1977)	67	2011 [4]
		105		10.27 [3]	240 (1951)	600	2018 [9]
		106		10.19 [3]	240 (1970)	391	2018 [9]
		107		10.09 [3]	110 (1976)	27	
		108		10.38 [3]	116 (1977)	118	2015 [7]
		109		9.24 [3]	240 (1970)	359	2018 [9]
		110		9.73 [3]	240 (1970)	462	
		111		9.44 [3]	240 (1970)	359	2016 [8]
		112		9.88 [3]	240 (1970)	627	2013 [5]
		113		8.59 [3]	240 (1970)	634	2016 [8]
		114		9.07 [3]	240 (1970)	522	2015 [7]
		115		8.92 [3]	240 (1970)	544	2015 [7]
		116		8.45 [3]	240 (1970)	565	2016 [8]
		117		9.58 [3]	240 (1970)	626	2015 [7]
		118		9.07 [3]	240 (1970)	248	2018 [9]
TY	Type III	101	758,000	7.08 [3]	83 (1976)	105	
		102		6.90 [3]	82 (1977)	70	2014 [6]
		103		6.88 [3]	86 (1977)	152	2015 [7]
		104		7.05 [3]	114 (1976)	42	
		105		7.02 [3]	112 (1976)	231	2013 [5]
		106		7.39 [3]	106 (1976)	13	

References:
[1] RPP-10435
[2] HNF-EP-0182
[3] RPP-11802
[4] RPP-RPT-51404
[5] RPP-RPT-55951
[6] RPP-RPT-58239
[7] RPP-RPT-58849
[8] RPP-RPT-59272
[9] RPP-RPT-60565

Table 4-20: Current Loading Criteria and the Historic Maximum Loads Type IV-A for Tank Farm SX, Type IV-B for Tank Farm A, Type IV-C for Tank Farm AX

Tank Farm	Tank Type	Tank	Storage Volume [1] (gal)	Estimated Soil Cover (ft)	Historic Peak Temperature [1] (°F) (year)	Current Waste Volume [2] (kgal)	Date of Videos
SX	Type IV-A	101	1 million	6.32 [10]	320 (1957)	416	2010 [3], 2018 [9]
		102		6.62 [10]	212 (1985)	342	2014 [6]
		103		6.72 [10]	225 (1985)	599	2018 [9]
		104		6.22 [10]	300 (1956)	433	2015 [7]
		105		6.52 [10]	330 (1975)	376	2018 [9]
		106		6.82 [10]	195 (1963)	399	2013 [5]
		107		6.32 [10]	390 (1958)	96	2011 [4]
		108		6.52 [10]	320 (1958)	79	
		109		6.52 [10]	295 (1962)	241	
		110		6.22 [10]	310 (1966)	58	2017 [8]
		111		6.52 [10]	320 (1965)	117	
		112		6.62 [10]	315 (1962)	77	
		113		6.22 [10]	268 (1958)	22	2018 [9]
		114		6.52 [10]	335 (1958)	158	
		115		6.62 [10]	260 (1960)	4	
A	Type IV-B	101	1 million	7.00 [10]	441 (1961)	331	2015 [7]
		102		7.00 [10]	420 (1961)	40	2014 [6]
		103		7.00 [10]	594 (1961)	388	2013 [5], 2014 [6]
		104		7.51 [10]	578 (1963)	25	2017 [8]
		105		7.51 [10]	325 (1963)	37	2010 [3], 2017 [8]
		106		7.00 [10]	594 (1963)	79	2010 [3]
AX	Type IV-C	101	1 million	7.23 [10]	455 (1968)	320	2011 [4]
		102		7.47 [10]	250 (1970)	31	2010 [3]
		103		7.47 [10]	540 (1966)	104	2011 [4]
		104		7.47 [10]	460 (1970)	5	2011 [4]

References:

[1] RPP-10435
[2] HNF-EP-0182
[3] RPP-RPT-48194
[4] RPP-RPT-51404
[5] RPP-RPT-55951
[6] RPP-RPT-58239
[7] RPP-RPT-58849
[8] RPP-RPT-59272
[9] RPP-RPT-60565
[10] RPP-11802

4.5 ANALYSIS OF RECORD

The Analysis of Record (AOR) were performed for the four tank types due to Expert Panel Recommendation SI-1. Recommendation SI-6, Develop Engineering Mechanics Document, was also incorporated in the AORs and is included as part of the report conclusions (RPP-PLAN-45082).

For each of the four types of SSTs, a computer model was created for evaluating the SSTs ability to withstand gravity, hydrostatic, thermal, operating, and live loads. This model was a thin slice of the whole tank, which has the benefit of cutting down on computational time while taking advantage of the axisymmetric nature of the cylindrical tanks. A separate model was created for each of the tanks to evaluate the seismic demands on the tanks. Because seismic demands have a loading that acts horizontally a thin slice was not able to be used and so the tanks were 180° models. Separating the two models allowed for a more time-efficient computation. After determining the results of the separate models, the results were combined to determine the overall effects of the various loading conditions which were in accordance with the current building codes (at the time of analysis).

For the Type I, II, and III AORs, the analysis parameters were selected in order to capture the most demanding conditions between all of the tanks within the type (e.g., the maximum soil height at the dome may occur at tank C-101 and the maximum temperature may occur in tank C-105 but for the purposes of the analysis both were imposed on the same tank model). The Type IV tanks were comprised of three different designs: A, AX, and S Tank Farm tanks. The difference between the tanks included wall thickness, the dome slope, strength of the concrete, the reinforcing details, the slab details, thermal histories, and design point loads. Through a combination of bounding conditions and sensitivity studies, analysis parameters were selected. The analysis parameters selected are in Table 4-21.

Table 4-21: Analysis Parameters

Parameter	Type I	Type II	Type III	Type IV
Concrete Strength, f'_c	3 ksi	3 ksi	3 ksi	3 ksi
Rebar Yield Strength, F_y	40 ksi	40 ksi	40 ksi	40 ksi
Height at Center of Dome	26 ft	31 ft	37 ft	44 ft
Inner Diameter	20 ft	75 ft	75 ft	75 ft
Volume	55,000 gal	530,000 gal	758,000 gal	1,000,000 gal
Point Load[1]	142 kip	200 kip	200 kip	270 kip
Uniform Load	40 psf	40 psf	40 psf	40 psf
Soil Height at Center of Dome	11.45 ft	10 ft	11 ft	7.51 ft
Max Temperature	250 °F	310 °F	300 °F	594 °F
Specific Gravity of Waste	1.7	1.7	1.7	1.7

Reference: RPP-RPT-49989, RPP-RPT-49990, RPP-RPT-49992, RPP-RPT-49993
Note:
[1] Includes weight of the appurtenances on the tank.

The AORs also took into account variable conditions such as the quality/condition of the concrete, whether or not long term creep had relieved internal stresses, and various soil properties. In addition, the AORs took into account tank-to-tank interaction (TTI) to determine the impact of closely spaced tanks, a review of tank appurtenances to reflect conditions over the tanks, and a limit load analysis to determine the collapse loads.

Based on the design parameters and the induced loads, each of the tanks showed that the capacity to withstand loads exceeded the demand for the dome, haunch, and sidewalls (see Table 4-22). The allowed capacity was based on ACI 349-06, *Code Requirements for Nuclear Safety-Related Concrete Structures*. It was shown for each tank that the thermal demands on the slab exceeded the capacity. In each of these instances, the AOR concluded that the failure of the slab did not negatively impact the tanks stability, nor did the failure of the slab cause tank collapse or failure. Each of the AORs was reviewed to ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications,* standards and independently reviewed by Robert P. Kennedy, PhD of RPK Structural Mechanics and Anestis S. Veletsos, PhD, Professor Emeritus of Rice University. For a more in-depth overview of the AORs. See Appendix E.

Table 4-22: Demand/Capacity Ratios for Tanks

Tank	Direction	Dome	Haunch	Wall	Slab
Type I[4]	Meridional[A]	0.40	0.40	0.35	0.25
	Hoop[A]	0.25	0.25	0.25	0.25
	Shear out-of-plane[A,B]	0.30	0.20	1.00	0.30
	Shear in-plane[A,B]	0.40	0.40	0.20	0.20
Type II[1]	Meridional	0.27	0.81	0.46	2.16
	Hoop	0.80	0.56	0.71	0.47
	Shear	0.18	0.32	0.87	1.17
Type III[2]	Meridional	0.24	0.30	0.29	1.85
	Hoop	0.66	0.85	0.51	1.80
	Shear	0.32	0.22	0.46	0.42
Type IV[3]	Meridional	0.30	0.44	0.34	1.13
	Hoop	0.59	0.56	0.36	0.93
	Shear	0.07	0.54	0.50	0.65

Notes:
[A] Type I results in same format. These results were estimated from surface plots.
[B] For the Type I tanks was reported for both

Reference:
[1] RPP-RPT-49989
[2] RPP-RPT-49990
[3] RPT-RPP-49992
[4] RPP-RPT-49993

4.6 DOME DEFLECTION SURVEY PROGRAM AND DOME LOAD CONTROL PROGRAM

The Dome Deflection Survey Program and Dome Load Control Program are on-going processes where the additional loads are calculated prior to allowing equipment on top of the domes and verifying the dome elevations every two to three years. Expert Panel Recommendation SI-2 is to enhance this survey program by the addition of new survey points so the relative deflection between the center of the dome and the sidewall may be determined.

The 149 SSTs "were constructed between 1943 and 1964. During this time, horizontal and vertical survey control monuments were installed to control and record the location and elevations of the tanks and components" (RPP-26516, *SST Dome Survey Program*, pg 1). In the late 1970s and early 1980s, dome surveys began to be conducted and "were originally performed to monitor possible excessive dome deflection due to Salt Well pumping. The concern was that the waste accumulation on the in-tank equipment could result in additional concentrated dome loading" (TFC-PLN-142, *Dome Loading Management Plan*, pg 3). Since then, "Observations Concerning Current Conditions of Concrete Domes Surveys have been conducted on all of the SSTs approximately every two (2) years" (RPP-RPT-43116, pg 6). The protocol for the SST Dome Survey Program was established in RPP-26516 for the 133 100-series tanks. No surveys have been conducted on the 16 Type I 200-series tanks located in the B, C, T, and U Tank Farms.

The benchmarks and monuments were not all properly maintained prior to 2004. Some had obviously been knocked out of place and were replaced. In 2004, the current Dome Loading Program criteria were established. Since that time, the program has followed this basic criteria (RPP-RPT-55202, *Dome Survey Report for Hanford Single-Shell Tanks*). For this reason, only the survey data from 2004 onward is fully considered when examining the dome deflection data. Data prior to 2004 is still useful, as it also shows a historical trend of no excessive settlement or deflection.

The tank domes are "buried to a depth of 5- to 10-ft as measured from the tank dome apex" (RPP-26516, pg 7). Several steel risers are attached to the domes and extend to the surface. The locations for each tank surveyed are shown on the Historic Dome Load Record Data reports for each tank farm. Benchmarks were attached to these risers, which are then used in measuring deflections. Figure 4-29 shows a typical layout of survey controls at a tank. Section 3.4 of RPP-26516 lists general benchmark and monument locations at each tank farm:

- A minimum of two control monuments in the area of each tank farm
- A benchmark located on perimeter risers on each of the tanks to monitor tank settlement
- A benchmark located over the tank dome to monitor dome deflection.

The Tank Dome Survey shall be performed every two years ± four months for active tank farms and three years ± four months for all other tank farms (RPP-26516). This is required by TPA Milestone M-045-91E.

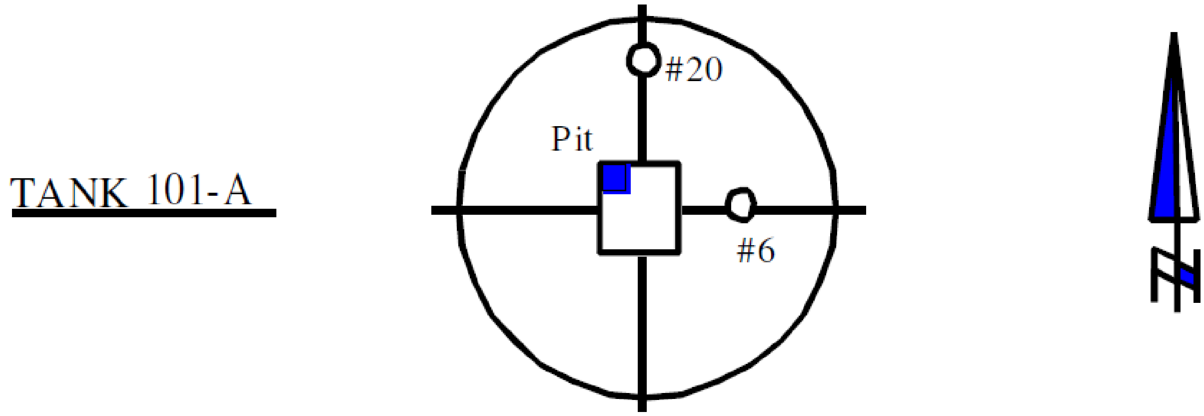


Figure 4-29: Tank 101-A Riser Locations (RPP-RPT-55202)

In 1975, ARH-CD-427, *Criteria-Waste Tank Dome Evaluation Surveys,* stated that benchmarks located outside of the tank farms shall be accurate to ±0.005 ft. "In the event that there are in-service tanks without bench marks attached to the dome, bench marks shall be installed…The bench marks attached to the tank domes shall be surveyed on an annual basis. If dome elevation changes of 0.01 foot are found between surveys, the frequency of surveys shall be increased to a monthly basis. Dome elevation changes of 0.02 foot between surveys, rates of dome elevation change greater than 0.01 foot per month and/or accumulated changes 0.05 foot shall be considered non-routine. Investigative action will be undertaken by Tank Farm Process Engineering Subsection to determine whether abnormal events have occurred. If the results of the investigation indicate no unusual activities, corrective action, e.g. scraping the earth cover off the dome, shall be taken." (ARH-CD-427, pg 4 of 5). This indicates that a change of more than 0.6 in. over time warrants further investigation, such as excavating to the top of the dome.

In 1983, SD-RE-TI-012, *Single-Shell Waste Tank Load Sensitivity Study*, performed analysis to determine the effect of additional vertical load on the concrete stress and deflections of the SSTs. The results of this report were that the change in deflection between the initial deflection and the deflection with the tank covered by 30 ft of soil was about 1.2 in. when no waste was in the tank. When waste was resisting the inward soil pressure this difference was about ¾ in. Therefore, the tank dome deflections are very small. As a result of this study, the language in the dome deflection survey procedures were modified to the current requirements.

RPP-46305, *Single-Shell Tank Inspection Report,* further addresses this deflection requirement. The dome on tank C-106 had an initial deflection under gravity loads of approximately ½ in. The addition of ¼ in. provides ¾ in. of deflection. The load associated with this additional deflection is "39% of the predicted collapse load. At a total dome deflection of 1.0 in. (0.5 in. above the baseline), the dome load is approximately…50% of the predicted collapse load" (RPP-46305).

The SST Dome Survey Program currently states " If a dome deflection has decreased by more than 0.02 feet and rechecking of the survey and survey data has been performed, then immediately notify the Civil/Structural Discipline Lead Engineer and Base Operations Engineering so the condition can be documented in the Problem Evaluation and Reporting (PER) system" (RPP-26516). "Deflection of the tank dome of up to approximately ½ inch is within dome load limits… ." Significant load is required to achieve this degree of deflection. All survey data should be reviewed by the responsible tank farm engineer and evaluated for tank settlement and for dome deflection. Measurable deflection of approximately ¼ inch could be expected but deflection in excess of ¼ inch should be reviewed by the Civil/Structural Discipline Lead Engineer"(RPP-26516).

According to RPP-RPT-43116, Section 3.1.1: "A maximum allowable decrease in the dome elevation of 0.24 inches, relative to the baseline measurement, has been specified as the acceptable limit for SSTs. Analytical studies … indicate a safety factor of approximately 3.0 or larger against dome collapse for the in-situ soil overburden load. An evaluation of the safety factor as a function of the increase in dome deflection over initial baseline measurements was conducted on Tank 241-C-106. This evaluation indicated a safety factor of approximately 2.5 for an additional downward deflection of 0.24 inch, and approximately 2.0 for an additional deflection of 0.48 inch. Thus, adequate safety margin exists if dome deflections do not increase more than 0.48 inch."

The latest survey report, RPP-RPT-55202, was reviewed. The Dome Survey and Loading Control Programs are adequate and are being followed. The majority of survey results that show deflections over 0.24 in. were due to disruptions to the benchmarks not actual tank displacement. These survey points have been repaired (PER-2004-4048). Additional reference points have been added to allow for comparison of the dome deflections between the center of the dome and above the sidewall in accordance with Expert Panel Recommendation SI-2. With the exception of the tanks shown in Table 4-23, the data does not show any excessive deflections or settlements that would indicate potential structural issues.

The Dome Deflection Survey Program has been the tool used to help determinate the tanks' structural integrity. Expert Panel Recommendation SI-2 also reinforced the program's importance to determining the tank's overall structural integrity: "The dome surveys are important as any future potential for dome collapse would be preceded by excessive downward dome deflection. The haunch data is important to determine whether dome deflections are due to downward displacement of the dome or of the footing under the sidewall" (RPP-RPT-55202). Table 4-23 indicates the two tanks that have exceed 0.24 in. between benchmarks on the tank dome. Figure 4-30 and Figure 4-31 are plots of the differences between the dome benchmarks over time.

Since excessive deflection could be an early harbinger of dome failure, the IQRPE recommends that when the deflection exceeds 0.30 in., a plan be created to determine what is causing the displacement and how to stabilize the tank, if possible. This plan should be implemented prior to the differential displacement of 0.36 in. The plan should consider the direction that the benchmarks are moving and may include but should not be limited to: removing soil from the top of the tank, excavating near the haunch of the tank to check for structural cracking on the exterior face, evaluation of the benchmark to see if it was physically displaced from the surface, visual inspection of interior of the tank, excavation of the benchmarks to determine if they are adhered to the top of the tank, etc.

Table 4-23: Tanks Where the Dome Elevations Between Points Exceed 0.24 in. (RPP-RPT-55202)

Tank	Concern	Resolution Possibilities
Tank AX-102, pg 46-48	Differential between pit and riser 009F located near the wall exceeds the 0.24" deflection tolerance. This deflection differential has been increasing since 2010. See Figure 4-30.	Conclusions of RPP-RPT-55202 Rev 02 state "Discrepancies between the true deflection and the calculated deflection can exist when the initial survey data is inaccurate. It is believed that the negative deflections measured in tanks AX-102 and B-111 were due to an early event that dirupted the benchmark elevation." pg 19 Recommend setting 1985 as the baseline to give a better understanding of the changes in deflection.
Tank TX-103, pg 347-349	The differential between Riser 13A and Riser 8 exceeds 0.24 in. These two risers are very close together and the pattern created by these differiential deflections was not explained in the report. See Figure 4-31.	The deflections of riser 13A have been rising gradually over time signifying that this riser has moved up. It does not make sense that this would be moving up while the adjacent riser is moving down if both are fixed to the top of the dome. Recommend verifying that riser 13A and riser 8 are both affixed to the top of the dome. If these points are floating in the top of the dome, new benchmark locations that are not floating should be established. It appears that riser 8 and riser 9A are moving roughly together, therefore consider the possibility that riser 13A is not an accurate benchmark point.

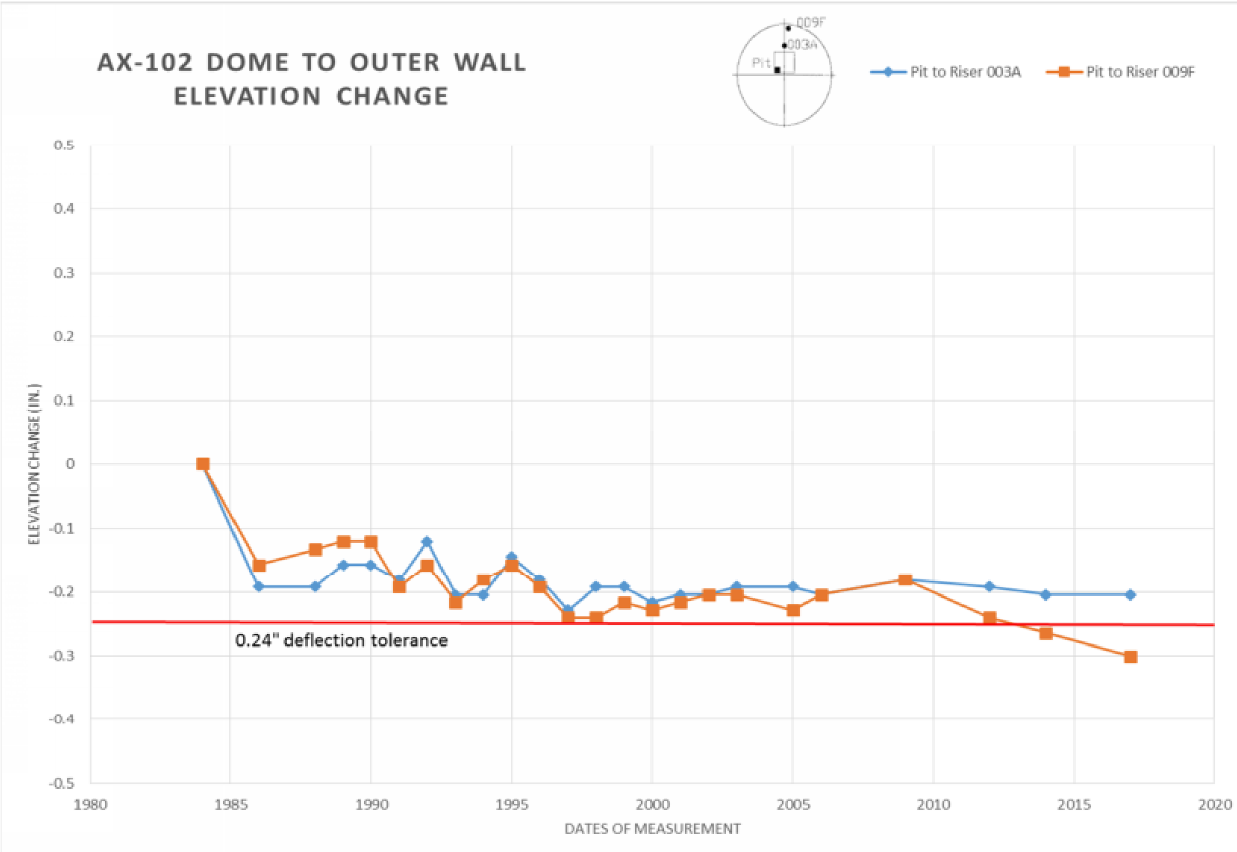


Figure 4-30: Tank AX-102 Differential Displacement (RPP-RPT-55202)

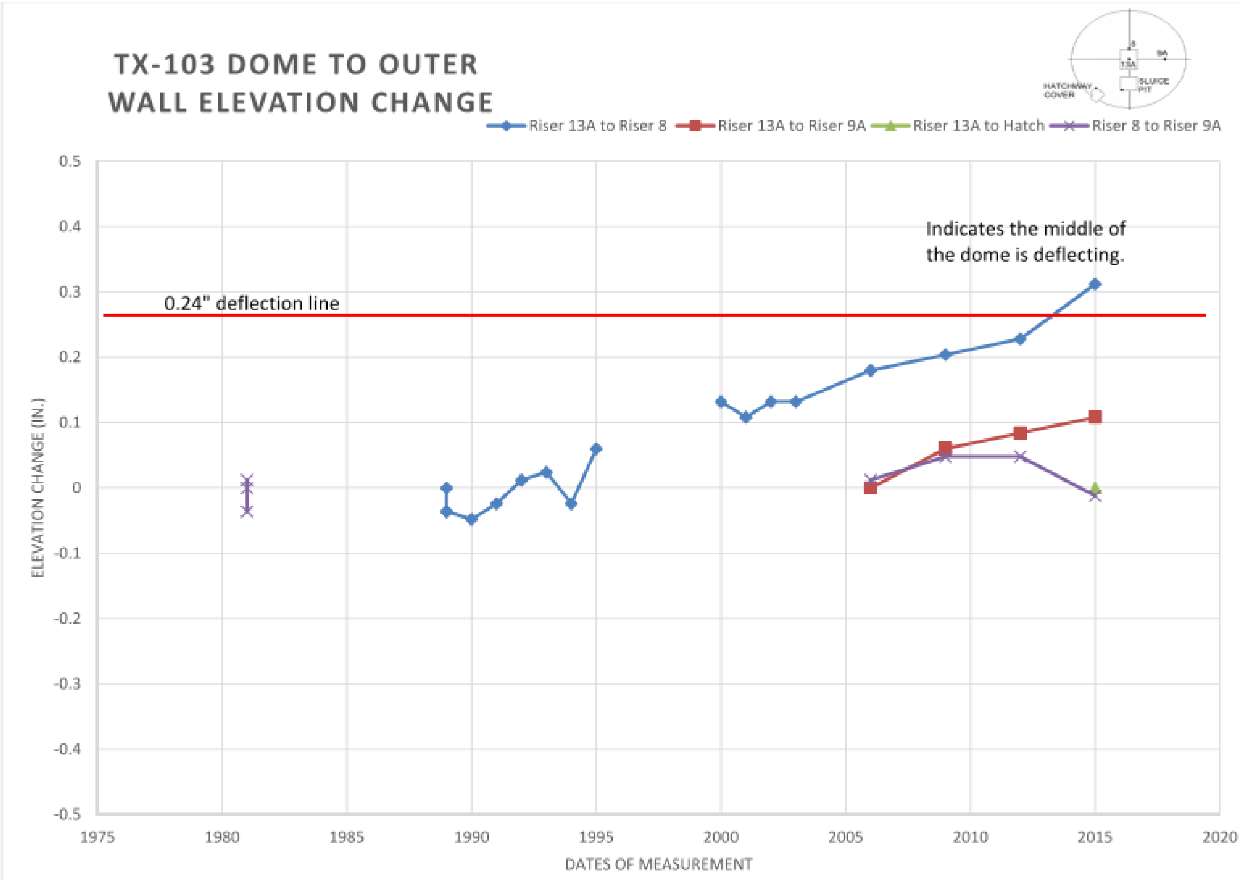


Figure 4-31: Tank TX-103 Differential Displacement (RPP-RPT-55202)

The Dome Control Program is maintained as part of the operating specifications for SSTs (OSD-T-151-00013, *Operating Specifications for Single-Shell Waste Storage Tanks*). Whenever a change to the dome loading occurs, whether it is adding a permanent load such as an impervious barrier or a temporary load such as a piece of equipment operating on or near the tank domes, the load is evaluated. An AOR is created that tracks the load additions and ensures that the total load does not exceed the documented tank load limits. These AOR documents are developed and maintained in accordance with control of dome loading, TFC-ENG-FACSUP-C-10, *Control of Dome Loading and SSC Load Control,* for each of the tanks. All these calculations are approved prior to the new or different loads being allowed on the domes. Several modifications to these records have occurred since the previous IAR. Some of those reviewed included new holes in the domes and new equipment to remove the salt cake, supernate, and sludge from the tanks, and the placement of infiltration barriers over the tank farms. The calculations were spot checked as part of this IAR to determine that the Dome Load Control Program requirements were met for the new loads added.

4.7 CONCRETE EXPOSURE TO HIGH TEMPERATURES

In 1977, non-load-bearing tank dome concrete core samples from A, T, and U Tank Farm tanks were submitted to CTL Group (formerly Construction Technology Laboratories, Inc., a division of the Portland Cement Association) to determine the strength and elastic properties of concretes from Hanford tank farms structures and to evaluate the effects of the service temperature history on these properties. Tests were conducted on concretes from the tank farms to determine strength and elastic properties at ambient and elevated temperatures (RHO-C-22, *Strength and Elastic Properties of Concretes from Waste Tank Farms*). Simultaneously, a 5-year research project was being conducted at CTL using 3,000 psi Hanford design mix concrete and 4,500 psi Hanford design mix concrete to determine the effect of exposing concrete to varying temperatures for long periods of time. Prior to these tests being conducted, most of the existing concrete tests on concrete with heat exposure were based on fire where the temperature increases rapidly then decreases rapidly when the fire is put out (RHO-C-54, *Effects of Long-Term Exposure to Elevated Temperature on the Mechanical Properties of Hanford Concrete*, pg 1-6).

Cores from the domes of the tank farms were tested at 70 °F and 250 °F. Elastic modulus, Poisson's ratio, and compressive and splitting tensile strengths were determined at ambient temperature and for specimens maintained at 250 °F for varying lengths of time. Variables examined in the test program were the effect of temperature, length of exposure to elevated temperature, and geometry of test specimens (RHO-C-22).

Compressive strength of the tank dome cores generally decreased after specimens were exposed to heat. Maximum losses were 20 to 33% of room temperature strength. Initially, stronger concretes lost a proportionately larger percentage of their strength after exposure than the weaker concrete. In some series, concrete appeared to gain strength after thermal exposure. In other series, concrete initially lost strength, then recovered strength after prolonged heating (RHO-C-22).

Splitting tensile strength of the heated specimens followed trends similar to those obtained for compressive strength. Highest strength losses were about 40%. However, in most cases, considerably less strength deterioration resulted from exposure to heat (RHO-C-22).

Modulus of elasticity and Poisson's ratio also decreased after exposure to heat. Greatest losses were about 40% of room temperature values, but amounts differed widely among test series. Testing, results, and statistical comparisons are discussed in RHO-C-22.

A 5-year research study was performed on Hanford concrete mix designs (3,000 psi and 4,500 psi) to determine the effects of heat on the concrete over time (RHO-C-22; RHO-C-28, *Elastic and Strength Properties of Hanford Concrete Mixes at Room and Elevated Temperatures*; RHO-C-40, *Strength and Elastic Properties of 1580-Day Old Hanford Concrete Cylinders at Room Temperature and 350F*; RHO-C-54). Figure 4-32 shows 3,000 psi concrete tested at 72, 250, 350, and 450 °F over time. There is significant scatter in the laboratory-cured cylinders. Normally concrete would continue to get stronger throughout its life when exposed to 70 °F temperature. The curve shown appears to reach a peak at 1,000 days, then starts decreasing in strength. Looking at the curves regardless of the data scatter, there is definitely a reduction of concrete strength as it is exposed to high temperature. Looking at the curves at 1, 200 days, the strength of the sample that maintained 250 °F was approximately 75% of the strength of the 70 °F specimens; the 350 °F samples were approximately 70% of the strength of the 70 °F specimens; and the 450 °F samples were approximately 60% of the strength of the 70 °F specimens.

Transient thermal loading in the dome is associated with tensile fractures in the outer surface. Concrete dome cores removed from tanks A-101 and SX-107 revealed tensile fractures extending from approximately mid-thickness to the outer surface. Cores taken at radii of 12, 22, and 25 ft all revealed similar cracking patterns, with cracks approximately perpendicular to the two principal stress directions. An examination of the thermal history for tank A-101 revealed an unusually rapid heat-up period in 1957. A heat transfer analysis modeling the heat-up demonstrated tensile yielding of the steel at various locations. Due to the change in stiffness of the section as tensile fractures appeared, there was a reduction of the actual forces developed by the section in resisting thermal deformations (ARH-R-45, *Interim Summary Report Stress and Strength Analysis for Waste Tank Structures at Hanford, Washington*).

RPP-10435 concluded that rigorous structural evaluations considering the effects of high temperature exposure of tank C-106 have indicated that high temperature exposure has not jeopardized the stability of the SST domes and supporting structure. Currently, the temperature of the waste in all tanks is below 200 °F, with most below 100 °F, and there has been a lack of any structural distress observed in the review of the visual examinations and dome elevation survey data for the tanks that contained high-temperature waste.

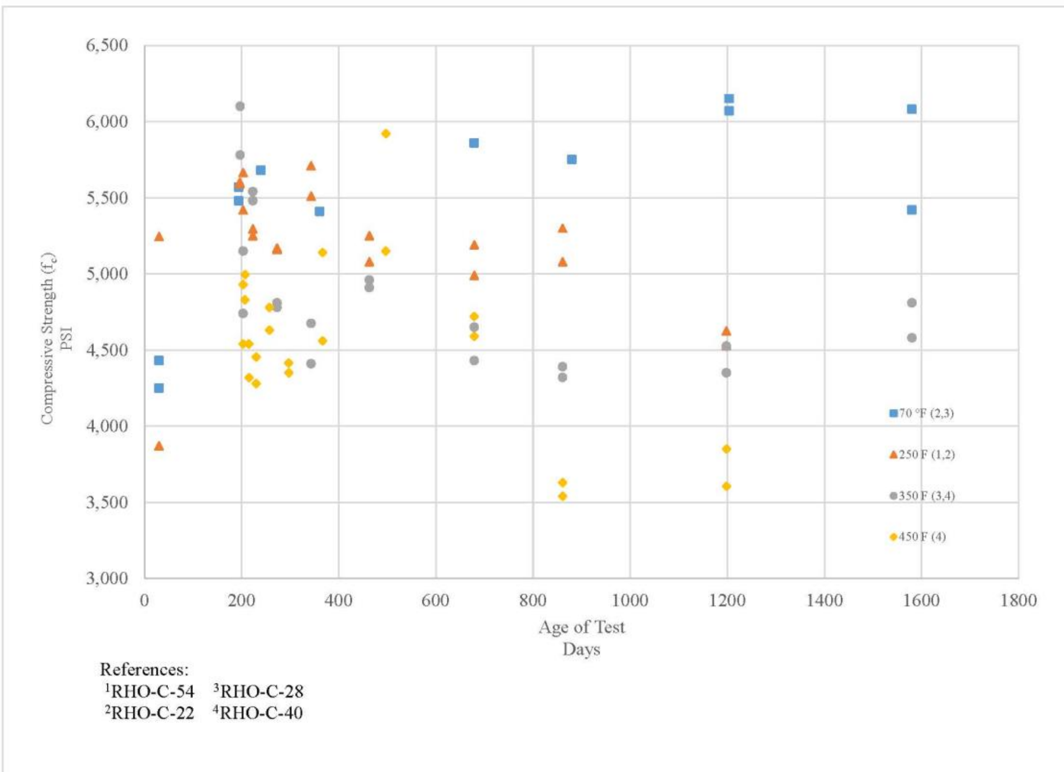


Figure 4-32: Concrete Compressive Strength at Elevated Temperature Over Time for 3,000 psi Hanford Mix Design Concrete Cured and Tested in Laboratory

4.8 SINGLE-SHELL TANK SIDEWALL CORE

Expert Panel Recommendation SI-3 was to obtain and test two sidewall cores. The purpose for these sidewall cores was to determine if adequate strength remains in the concrete sidewall to maintain structural stability of the tanks. This concern was raised because the original design maximum temperature for the SSTs was 200 °F, the actual temperatures in some of the tanks was much higher. Per RHO-CD-1485 (pg 22-23): "Concrete properties vary with time and temperature. Subjecting concrete to temperatures above 200 °F reduces the strength and modulus of elasticity of the concrete, with significant rapid decreases occurring above 800 °F. A reduction in concrete strength can cause structural failure of the waste tank. Reduction of the modulus of elasticity could lead to increased deflections of the structure, resulting in the tank becoming geometrically unstable."

In 1981, a concrete core sample was obtained from tank SX-115, which was a leaker that saw relatively high heat during its operation. The concrete in this tank was approximately 28 years old at the time of testing. Evidence was found that the cores taken from tank SX-115 were damaged due to the method of coring and retrieval causing some of the concrete to crumble. The samples that were obtained were tested and the results are shown in Table 4-24.

As a result of Expert Panel Recommendation SI-3, tank A-106 was selected for sidewall coring to obtain and test concrete that had been exposed to high temperatures for extended periods of time. Tank A-106 had sustained the highest heat load at 594 °F, recorded in 1963 when the tank was nearly full. The tank had also withstood temperatures over 200 °F (the point at which concrete begins to degrade) for over 80 months. The concrete from tank A-106 was approximately 59 years old at time of testing in 2013. See Appendix G for additional information.

About 38 ft of concrete core were successfully removed, to a depth approximately halfway through the tank footing. Figure 4-33 shows the core hole location in a top view of tank wall. Figure 4-34 shows the core hole configuration with guide tube. Nondestructive and destructive physical testing of the concrete core specimens was successfully performed by CTL Group. The testing included visual examination and determination of transverse and longitudinal resonant frequency and dynamic modulus of elasticity, pulse velocity, static modulus of elasticity, Poisson's ratio, and compressive strength. The testing indicated favorable results with values generally greater, and in many cases, significantly greater than expected in comparison with the values originally specified and those used in structural modeling of Type IV-B SSTs in the A Tank Farm.

The data obtained from the tank A-106 core was compared to the data from the vertical core data obtained from tank SX-115 in 1981. Results of the concrete wall tests are shown in Table 4-24. There is a large scatter in the data. None of the compression results were less than the design concrete compressive 28-day strength of 3,000 psi. The average compressive strength for the tank SX-115 wall core was 5,551 psi. The average for tank A-106 wall core was 10,132 psi. The average concrete strength for the tank A-106 sidewall core was over three times the original design concrete strength. In the 1981 tank SX-115 testing, the sample size for three of the four height segments was only two samples, which is not statistically significant. For the tank A-106 sidewall cores, the second to lowest section had an average compressive strength greater than the overall average of the compression strength in the sidewall core. Based on this data alone, it does not appear that the heat inside the tank affected the compression strength within the SSTs. The variability of concrete strengths within the mix design has a much larger effect on the performance than the hot temperatures in the tanks that have now cooled. This scatter in the data appears to be consistent with the scatter noted in the tests of concrete exposed to high temperature in Section 4.7. It is possible that the concrete in the sidewall of this tank might have been 40% higher if it was not exposed to the high temperatures.

Petrographic analysis determined that the concrete from tank A-106 within the examined core segments was in overall good condition, with a minor amount of microcracking and minor evidence of deleterious mechanisms that did not appear to have significantly affected the overall quality and integrity of the concrete. Overall, the results of the testing did not reveal any deficiencies with the structural integrity of the tank.

Table 4-24: Concrete Wall Test Results

	Core Run #	Start Depth to End Depth (ft)	# of Specimens For Compression of Tensile Tests	Compressive (psi)	Tensile (psi)	E (psi)	Poisson's Ratio
1981 Testing SX-115 [2]	#1	0 to 8'-0"	2	5,655	778	4,907,500	0.20
	#2	8'-0" to 16'-4"	3	6,527	771	5,263,333	0.18
	#3	16'-4" to 22'	2	5,235	814	5,025,000	0.22
	#4	22' to 32'-4"	2	4,298	694	4,590,000	0.2
	Average		9	5,551	765	4,978,333	0.20
A-106 [1]	#2	0.50 - 1.52	1	8,918		5,400,000	0.24
	#3	1.52 - 2.57	1	8,918		5,400,000	0.25
	#4	2.57 - 3.60	1	8,918		5,400,000	0.27
	#5	3.60 - 4.63	1	8,918		5,400,000	0.25
	#6	4.63 - 7.57	3	11,467		6,050,000	0.24
	#7	7.57 - 12.34	5	11,178		5,830,000	0.22
	#8	12.34 - 16.89	4	11,160		6,812,500	0.27
	#9	16.89 - 21.9	5	7,456		5,800,000	0.22
	#10	21.9 - 26.36	4	9,788		6,137,500	0.24
	#11	26.79 - 31.78	5	10,424		7,290,000	0.32
	#12	31.82 - 36.47	4	11,088		6,787,500	0.26
	#13	36.47 - 38.3	2	6,294		N/A	N/A
	Average		36	10,132		6,274,000	0.25

References:
[1] RPP-RPT-58254
[2] RHO-RE-CR-2

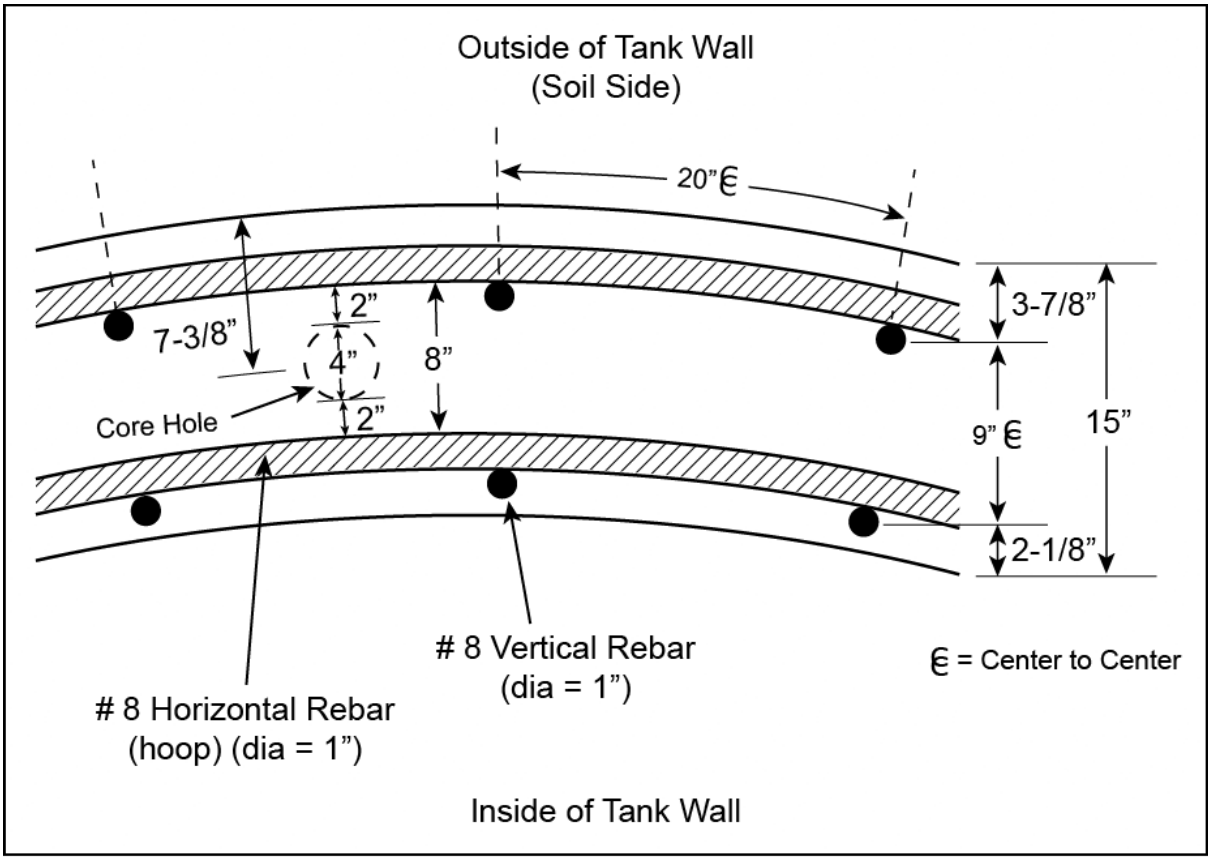


Figure 4-33: Core Hole Location in Top View of Tank Wall (RPP-49300)

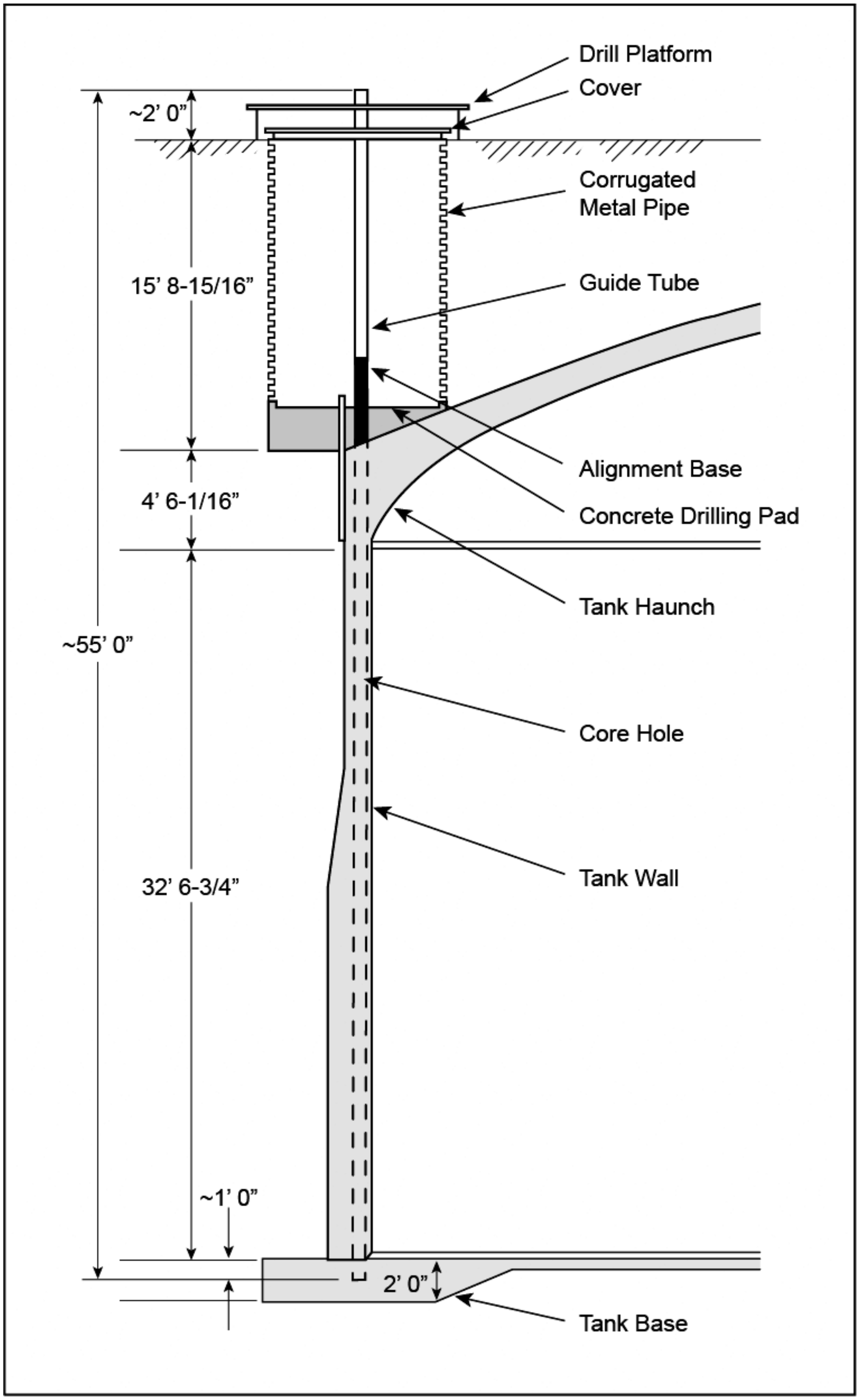


Figure 4-34: Core Hole Configuration with Guide Tube (RPP-49300)

Voids in the concrete wall were noted in both the tank SX-115 and tank A-106 cores. It is likely that these voids were air pockets during the construction of the walls. Workers were shown in Figure 4-22 vibrating the dome concrete. It is reasonable to assume that the wall concrete was also vibrated during construction. Some voids were repaired on the exposed surfaces of the concrete after the concrete had cured; therefore, it is reasonable to expect some voids to occur in the vertical walls in areas that were not exposed. It does not appear that these voids affect the structural stability of the SSTs. If visual inspections indicate a bowing of the tank walls, further investigation of the tank sidewalls is warranted.

An additional sidewall core, with the core segments tested, was recommended by the Expert Panel. In the follow up meeting after the results of the tank A-106 sidewall core were reviewed, the panel issued the following statement (RPP-ASMT-59981, pg 4): "The Panel acknowledges the difficulty and cost of obtaining these cores. The Panel considers obtaining an additional sidewall core sample a higher priority than the additional concrete degradation analysis discussed in SI-1."

From the very small sample, it appears that the sidewalls have a minimum of 3,000 psi concrete strength at this time. Due to these findings, it would be advantageous to determine the concrete strength of the tanks by the most economical means possible to increase the data pool for the current concrete strengths. Utilizing the concrete from holes cut in the domes for installation of equipment is an excellent source of information. On an opportunistic basis, it is recommended that as many cylinder compression tests as practical be made from every concrete plug removed from the SSTs. A minimum of three, but preferably a minimum of six cores, be tested for all of the concrete plugs removed from the domes for installation of equipment.

4.9 DOME CONCRETE TESTS

Recommendation SI-5, Test Dome Concrete and Rebar 'Plugs', identified that the waste retrieval process will require holes to be cut in the domes of the SSTs. Since current concrete strength data is limited, testing concrete removed from the domes will increase the knowledge base at relatively low cost. "The Panel recommends the following tests on concrete and rebar 'plugs' removed from domes during cutting: (1) concrete compression and bend tests, and (2) rebar diameter measurement and tensile tests. These tests will provide an opportunity to obtain data on the condition of the dome concrete and rebar." This data, combined with the sidewall core date, will give a better understanding of the SST structural integrity.

A 55-in. diameter hole was cut in the peak of the dome around an existing riser in tank C-107 during December 2010 to allow the deployment of the mobile arm retrieval system (MARS). This plug was removed from the tank and protected until testing was complete. A visual inspection of the concrete plug after removal found that the concrete cover for the top bars is 2-1/2 in. to 3-5/8 in. Figure 4-35 shows a typical view of the concrete plug reinforcing. The original design documents specified 3 in. (RPP-RPT-50934, *Inspection and Test Report for the Removed 241-C-107 Dome Concrete*, pg 13). The bottom concrete cover is estimated to be between 2-1/2 in. and 3 in. (RPP-RPT-50934, pg 14). Therefore, the rebar location is within the tolerances of the original design for the SSTs.

Fourteen nominal 4 in. by 8 in. concrete cores were removed from the plug on April 4 and 5, 2011. Selection of the sites for the cores was based on the need to avoid reinforcement bar and to collect as many cores as possible. The concrete plug with the cores removed is shown in Figure 4-36. The cores were inspected visually and microscopically at the CTL Group Material Services

Laboratory in Skokie, Illinois. The findings from the inspection and petrographic examination indicated that the concrete removed from the plug was in good condition, not in distress, and did not exhibit any deleterious mechanisms that would cause distress.

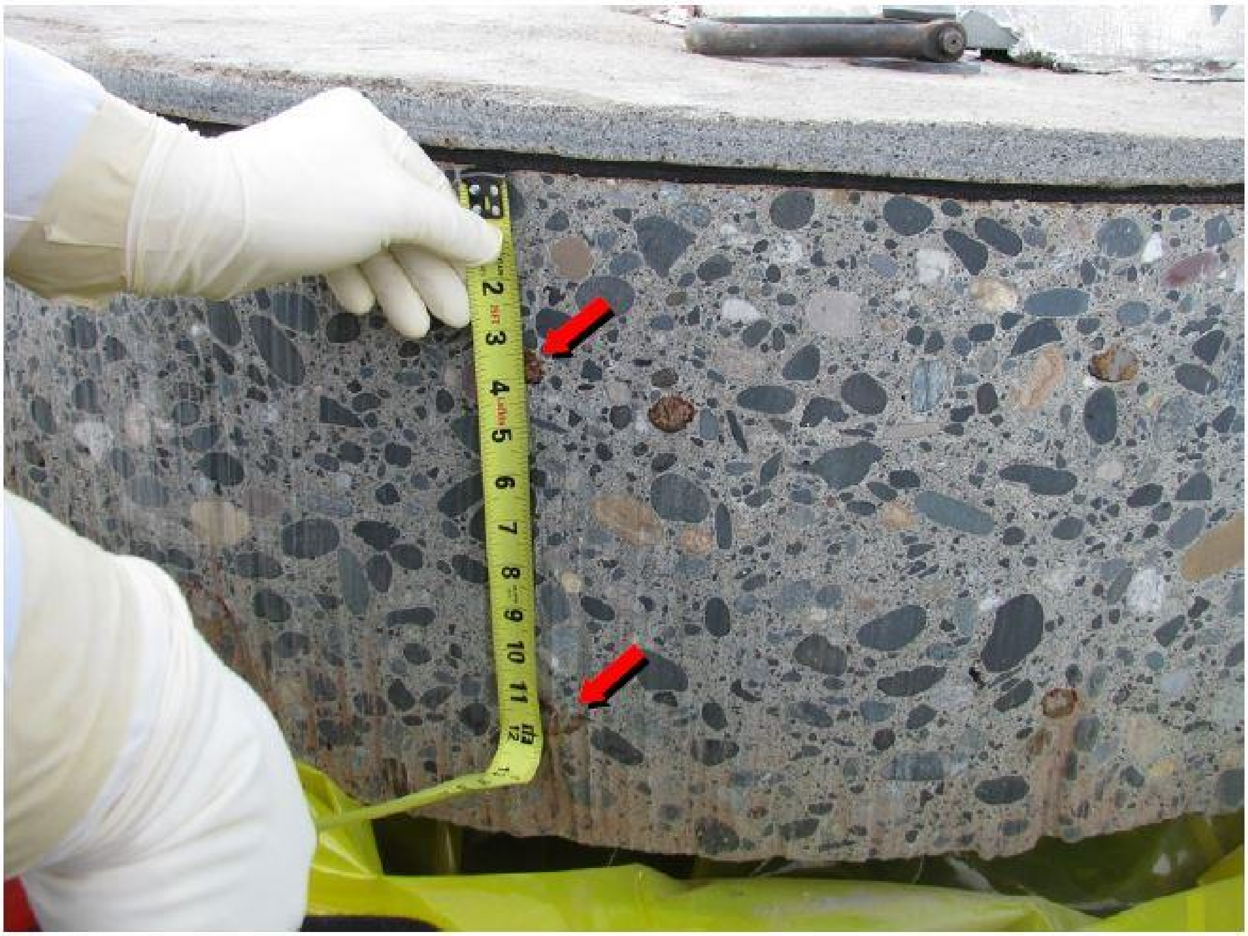


Figure 4-35: Typical View of the Concrete Reinforcing (RPP-RPT-50934)

Figure 4-36: Concrete Plug with the Cores Removed (RPP-RPT-50934)

The cores were then subjected to nondestructive and destructive physical testing. At the time of testing, the concrete for the tank C-107 cores was approximately 66 years old. The results of the concrete tests are shown in Table 4-25 and compared to dome concrete cores from A Tank Farm tanks that were approximately 21 years old. In the CLT laboratory, the 5-year test program tested concrete lab samples that were constructed using the 3,000 psi and 4,500 psi Hanford mix designs. Testing was completed between 1975 and 1979 and results are shown in in Table 4-26. The dome concrete cores for tank C-107 had a higher compressive strength than the 6,100 psi compressive strength estimated utilizing the equation for lab cured concrete for 66 years. The average concrete compressive strength of the cores was more than 2.5 times the original 28-day design strength specified at the time of construction. In no case was the current concrete strength less than the original design strength of 3,000 psi. The average concrete compressive strength of the concrete lab cores with age of concrete varying from 30 days to 1,580 days (4-1/2 years) was 5,580 psi. The tank C-107 dome concrete cores are 145% of the average of the lab cores.

Table 4-25: Concrete Dome Test Results

	Cylinder Number	Compressive (psi)	E (psi)	Poisson's Ratio
1977 Test Data A-Farm [2]	241A2-9	7,700	4,830,000	0.22
	241A1-11	8,240	5,320,000	0.19
	Average	7,970	5,075,000	0.21
Tank C-107 (2011) [1]	#1	9,890	5,900,000	0.20
	#2	9,670	6,500,000	0.23
	#3	9,290	6,000,000	0.24
	#5	8,530	5,950,000	0.24
	#6	9,030	6,000,000	0.23
	#11	6,810	5,850,000	0.23
	#12	5,890	5,800,000	0.21
	#13	6,800	5,750,000	0.23
	#15	7,530	5,900,000	0.23
	#17	7,800	6,100,000	0.19
	#19	6,840	5,500,000	0.20
	#20	8,850	5,950,000	0.20
	Average	8,078	5,933,333	0.22

NS - no significant difference from unheated specimens

Reference:

[1] RPP-RPT-50934

[2] RHO-C-22

Table 4-26: 3,000 psi Hanford Mix Concrete Data for 70 °F Laboratory Samples vs. Time

Specimen Number	Date of Test	Age at Test Days	Compressive (psi)	E (psi)	Poisson's Ratio
3K4-28	6/21/1975	30	4,430	4,480,000	0.15
3K4-30	6/21/1975	30	4,250	4,050,000	0.15
3K9-1	12/2/1975	194	5,570	4,650,000	0.16
3K9-3	12/2/1975	194	5,480	4,760,000	0.16
3K6-25	1/19/1976	240	5,680	4,870,000	0.17
3K6-28	5/17/1976	361	5,410	4,380,000	0.17
3K5-28	3/31/1977	679	5,860	5,060,000	0.15
3K8-28	3/31/1977	679		4,920,000	0.16
3K4-9	11/18/1977	880	5,750	4,610,000	0.15
3K4-15	11/18/1977	880		4,830,000	0.17
3K8-15	9/6/1978	1,204	6,070	4,980,000	0.16
3K8-18	9/6/1978	1,204		5,210,000	0.18
3K8-29	9/6/1978	1,204	6,150	5,060,000	0.16
3K7-12	9/13/1979	1,580	5,420	4,840,000	0.16
3K7-29	9/13/1979	1,580	6,080	5,060,000	0.16
Average			5513	4,784,000	0.16

Reference:
[1] RHO-C-54

The removal of rebar from the plug required demolition of the plug. Nine bundles of rebar were shipped to the CTL Group Material Services Laboratory. Prior to mechanics testing, the rebar pieces were checked and reported to be in good condition, with no observable cracking or defects. Following inspection, sub-lots were created, based on length, and subjected to tension and hardness testing. Of the 48 pieces tension tested as standard-size metallic specimens, 5 pieces were subjected to full section rebar testing, 14 pieces were subjected to hardness testing, and 2 pieces were subjected to impact testing.

The inspections and testing demonstrated that, even though tank C-107 was 67 years old at the time and among the oldest underground radioactive waste storage tanks, the plug concrete and rebar were still in satisfactory condition. It is our opinion that the existing test data for the reinforcing shows that there has been no change in the reinforcing strength. Therefore, it is our opinion that no additional rebar tests are required.

4.10 VISUAL INSPECTION

Expert Panel Recommendation SI-4 was to perform non-destructive evaluation of concrete. The Panel recommended "visual inspection of domes to identify cracks in excess of 1/16-in. wide, rust stains on the concrete, or spalling of the concrete" (RPP-RPT-43116, pg v). This recommendation is for the visual inspection program of the interior of the domes. The visual inspection program began in 2010. To date, no items have been seen that adversely affect the structural integrity of the tanks. To date, the reports on the visual inspections from 2010 to 2017 and the draft report for 2018 have been reviewed. These reports cover 63% of the tanks. The videos from approximately 10% of the reviewed tanks were also reviewed as part of this IQRPE assessment. No items were noted in the review of the videos that had not previously been noted in the reports of the visual inspections.

The cracks that one would expect to see in the tanks prior to failure would be similar to those recorded during the 1/10 scale model testing. Figure 4-37 shows the observed cracks inside the dome from the scale model.

It is important to continue to provide visual inspections of the tanks. Only 63% of the tanks have had visual inspections prior to July 2018. Nothing relevant to structural integrity has been observed in these inspections. Since defects that affect structural integrity may possibly be present in one of the tanks that have not yet been inspected, prioritizing a baseline for visual inspections needs to be completed for all the tanks. Once this first baseline video has been established, the future videos can be compared to determine if any structurally significant changes are happening.

It has been postulated that a potential failure mode is corrosion of the reinforcing steel. Once corrosion of the reinforcing steel has been observed, additional AORs may be required as recommended by Expert Panel Recommendation SI-9 to determine the amount of corrosion that is acceptable and still maintain the structural integrity of the SSTs. Videos to date do not show evidence of rebar corrosion. Figure 4-38 shows an anomaly in the dome of tank where a small section of reinforcing is exposed. Some localized spalling may be present at this exposed bar but it does not appear to be significant at this time. It appears likely that this rebar was actually very close to the concrete surface at this location when the concrete tank was constructed. It is recommended that this area be reinvestigated the next time the tank is video inspected so changes to this area can be noted. There is no need to increase inspection frequency of this tank based on the small area of exposed reinforcing.

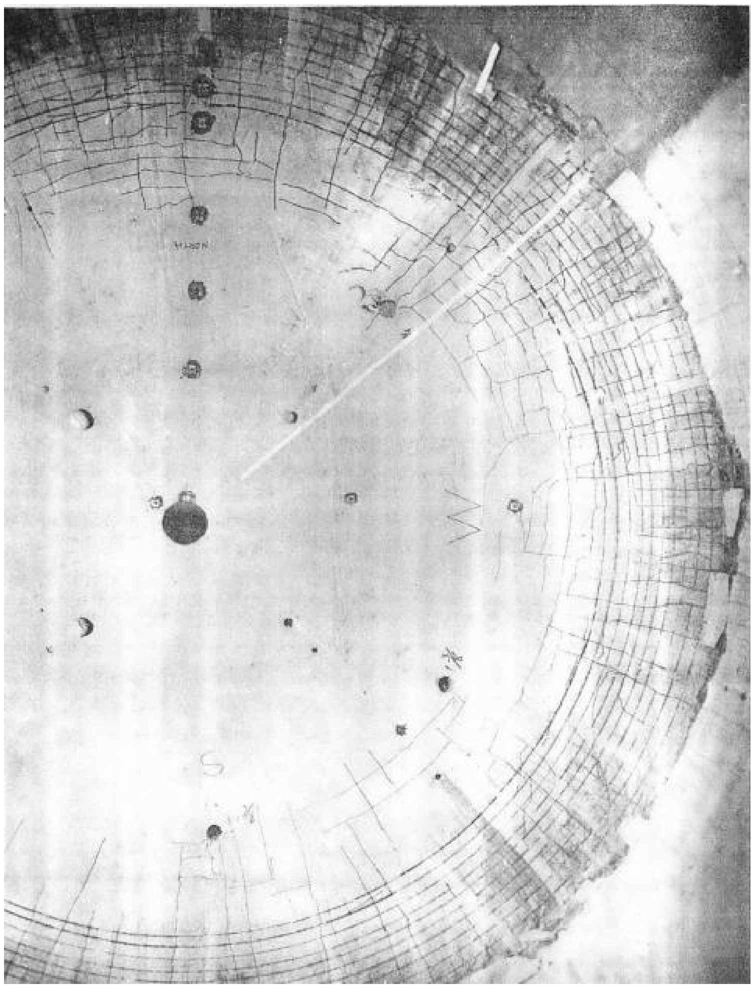


Figure 4-37: Undersurface of 1/10 Scale Model Dome After Failure (ARH-R-47)

Figure 4-38: Exposed Rebar in Tank S-109 (RPP-RPT-55951)

The Expert Panel recommended that any cracks or flaws larger than 1/16 in. be identified and a baseline and means of comparison be developed for calibrating the photos from the videos (RPP-ASMT-55981, pg 2). The current technology does not appear to be adequate to identify or calibrate a 1/16-in. flaw. Lighting, camera resolution, and riser access all contribute to the limitation for locating tank cracks and other flaws. It is important to document the exact location on the tank where a flaw is identified to enable future videos to examine the same location for modifications to the flaw. This IQRPE agrees that it is unrealistic to identify 1/16-in. wide flaws using video inspection. Figure 4-39 and Figure 4-40 are examples of cracks that have been observed during video inspection. These cracks do not appear to be located in the areas shown in Figure 4-37 after the failure of the 1/10 scale model. Due to the location and appearance, the crack in Figure 4-40 may be a construction joint during the dome concrete pour.

Figure 4-39: Possible Cracks in Tank TY-105 (RPP-RPT-55951)

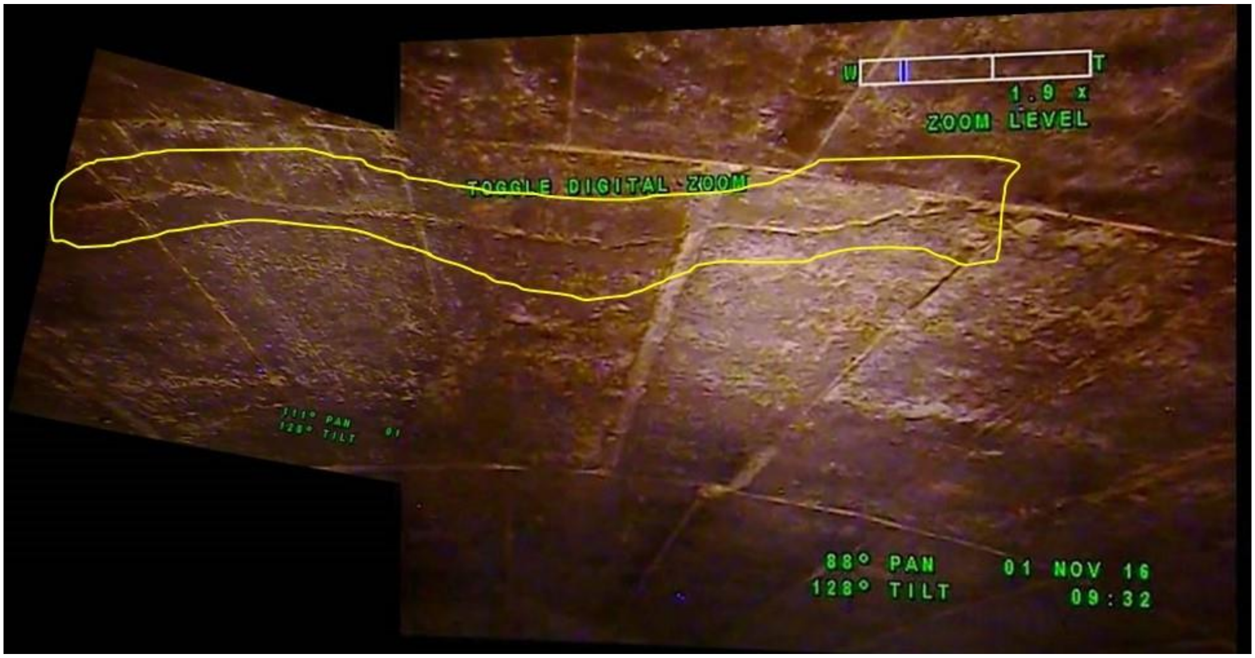


Figure 4-40: Possible Crack in Tank U-102 (RPP-RPT-59272)

The original form lines are visible in almost all the tank domes. Some of these lines have metal strips just below the surface as shown in Figure 4-41.

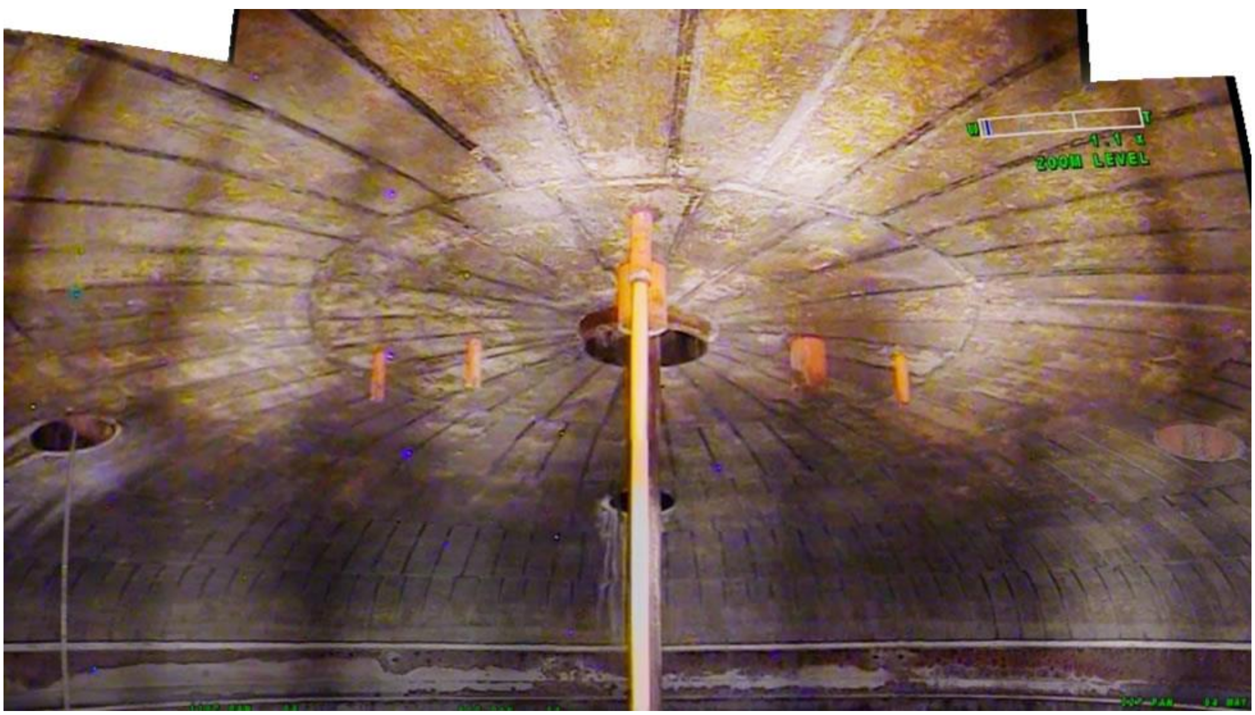


Figure 4-41: Composite of Tank BY-109 Concrete Dome (RPP-RPT-60093)

As indicated in the discussion of tank construction, some of the tanks had repairs made prior to being put into service. Figure 4-42 is an example of a previous repair.

Figure 4-42: Previous Concrete Repair on Tank BX-107 (RPP-RPT-60093)

It is the recommendation of this IQRPE to prioritize the tank videotaping of the tank interiors to provide an initial baseline video for each tank as soon as possible. There is no evidence seen in the reports and videos reviewed that indicate the need to re-videotape the interior of any of the tanks prior to obtaining the remaining baseline videos. This IQRPE recommends that each of the tanks have a visual inspection performed every 10 years once the baseline videos have been completed.

Continued visual inspections after the initial assessment will give warning if some outside source is causing the concrete to degrade or the reinforcing to corrode. Comparing the videos and photographs between multiple visual inspections will enable the operator to determine if any changes to the inside of the tanks are occurring. Therefore, when a flaw or potential corrosion is observed in a tank, the frequency of visual inspections in that tank should be increased. This IQRPE also agrees with the current WRPS policy to videotape the interior of the tank whenever the tank is accessed for any reason. Although this may modify the schedule for videotaping slightly, it is much more cost effective to videotape when the tank is already going to be open. This does not reduce the need for all tanks to be videotaped on a regular schedule not to exceed 10 years.

4.11 ADDITIONAL TANK ANALYSIS AND TESTING

4.11.1 Tank SX-108 Sidewall and Footing

Tank SX-108 was built in 1953–1954 and first placed into service in November 1955. The tank received reduction-oxidation (REDOX) salt waste, started self-boiling in June 1956, and was filled to capacity in January 1959. After the waste ceased boiling, the tank supernatant liquid was pumped out in early 1962.

The first significant leak was detected under tank SX-108 between August and December 1965. After testing the tank for ongoing leaks, the leak was determined to have self-sealed and the tank was returned to service. In March 1967, there was renewed evidence of a leak while the tank was in self-boiling operation, so the tank was removed from service.

The Tank Operations Contractor at that time contracted the Illinois Institute of Technology to conduct field soil tests and develop thermo-mechanical models of the SSTs. These models were to be used to analyze the state of stress in all the SSTs, accounting for active and reactive soil loads, liquid hydrostatic load, vapor pressures, and thermal loadings due to the self-boiling operations. Results of interim stress and strength analysis report ARH-R-45 concluded that the combined loads from self-boiling operation with sludge at a temperature of 300 °F on the tank bottom would result in cracking of the reinforced concrete tank in the circumferential (hoop) direction. For the SX Tank Farm tanks, this cracking was predicted to extend full depth through the footing from the outer edge, to back under the sidewall a foot or two into the floor of the tank, and a few feet up the sidewall of the tank.

Based on the concrete tensile strength, the cracks were predicted to occur at horizontal intervals of about 2 ft around the perimeter of the footing and lower sidewall. The cracking was caused by the thermal expansion of the bottom of the tanks, which is restrained by the cooler outside toe of the footing and the cooler sidewall concrete. The reinforced concrete tank floor goes into compression as it tries to expand in a radial direction, and the outer part of the floor, footing, and lower sidewall go into hoop tension trying to restrain the thermal expansion.

Analysis results further concluded that the concrete at the junction of the footing and sidewall cracked in tension when the sludge temperature reached 250 °F, which then transferred the load to the circumferential reinforcing steel. As the floor temperature increased to 300 °F, the cracks were calculated to have opened to apertures of 0.005 to 0.010 in. at temperature. The reinforcing steel remained in the elastic range, so the cracks would close on cooling. Given the results of a preliminary analysis for the SX Tank Farm tanks completed in 1967, a decision was made in late 1968 to sink an 8- to 10-ft diameter caisson down the side of tank SX-108 near the area of the leak, as reported in Hatch and Oberg (1968), *Comments on the Proposed Inspection of the Concrete Portion of Underground Storage Tanks*. The goal was to examine the condition of the concrete that had been contacted by tank waste and verify the concrete tensile cracking predicted by the analyses.

Cracking predicted by the Illinois Institute of Technology analyses was encountered extending downward through the footing and some distance up the tank sidewall. Some of the cracks in the footing toe initiated at the top of the footing, but did not extend full depth.

Two concrete core samples were taken of the tank SX-108 footing. Test results for these cores were between 5,000 and 6,000 ksi compressive strength (ARH-R-43, *Management of Radioactive Wastes Stored in Underground Tanks at Hanford*).

4.11.2 Analysis for 55-inch Dome Cores

Since 1998 the SSTs are slowly being emptied. In order to remove the sludge and saltcake from the inside of the tanks, larger dome openings were required than were provided in the initial design.

Analyses were performed on the tanks to receive the new penetrations that included the new penetration and the distributed loads that would be added to the domes during the removal process.

The first large dome opening was constructed in tank C-107. For tank C-107, a new 55-in. penetration was needed in the dome in order to allow for the installation of a new riser. The model that was used was a finite element analysis model from the DST AORs that was modified to represent the SSTs. This analysis checked the tank for both static and seismic loads and determined that the tank would not be negatively impacted by the new penetration. It should be noted that this analysis occurred prior to the larger effort in analyzing the SSTs and, as such, does not include many of the types of analyses that were used in subsequent AORs.

For tank C-105, a new 55-in. penetration was needed in the dome in order to allow for the installation of a new riser. The model that was used was for the analysis was taken from RPP-RPT-49989, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type II single-Shell Tank Thermal and Operating Loads and Seismic Analysis* (see Appendix E for further description) and three separate analyses were performed to check the adequacy. The first analysis was similar in nature to RPP-RPT-49989 and checked: gravity, thermal, and operating load analysis (TOLA) loading; seismic loading; combined TOLA and seismic loading; limit load; and dome buckling. The second analysis determined the maximum concentrated load (separate from the limit load analysis); the third analysis was to determine how the soil excavation and offset crane load impact the tank during the installation of the riser. Based on the analyses performed, the 55-in. dome penetration was deemed to not negatively impact the structural integrity of the tank.

4.12 DISCUSSION OF REVIEW

4.12.1 Discussion of Findings

- No findings were noted.

4.12.2 Discussion of Observations

- Original design standards for the tanks were appropriate.
- Concrete voids were observed during construction as shown in Figure 4-24 through Figure 4-28. Although those in the pictures were repaired, based on the number of observed void and the construction methodology, it is likely that some voids were located on the interior face of the concrete walls where they could not be observed or repaired. These voids would be insignificant and not reduce the structural integrity of the tanks.
- All 149 SSTs have sufficient structural integrity to not fail, collapse, or rupture under anticipated operational and seismic loading and the tanks meet the requirements of code ACI 349-06. The maximum demand/capacity ratios for the baseline models were below 0.90 for the walls, haunch, and dome portions of the tanks.
- The AORs show that the SST slabs are likely cracked and structurally separated from the foundation as a result of the thermal expansion and contraction. However, the AORs further show that the tanks remained stable and did not exceed their capacities when the slabs were removed from the analysis models.

- In addition to the baseline models, the AORs took into account tank-to-tank interaction (TTI) to determine the impact of closely spaced tanks, reviewed tank appurtenances to reflect conditions over the tanks, and performed a limit load analysis to determine the collapse loads.
- The load limit failure analysis showed that the factor of safety against collapse from static concentric surface loading is above 3.0 for Type II, III, and IV tanks. In addition, these failures presented with gross dome deflection (1.5 in. +) which will provide ample opportunity to predict failure prior to collapse with the current Dome Deflection Survey Program. See Appendix E.
- The 149 SSTs have been interim stabilized and the pumpable liquids have been removed.
- The wastes in the SSTs in C Tank Farm and tank S-112 have been retrieved. Therefore, 10% of the SSTs are essentially empty. Although these tanks are retrieved, they still must meet the WAC 173-303-640.
- The existing Dome Loading Monitoring Program prevents overloading the tank domes.
- The Dome Deflection Survey Program is to verify the dome deflections every two years or three years depending on the tank status.
- No excessive deflections or settlements that would indicate potential structural issues have been observed.
- The Dome Deflection Survey Program is adequate and is being followed.
- All of the concrete core samples that have been tested have exceeded the originally specified 28-day concrete design strength. In addition, the reinforcing that was tested meets the original yield strength requirements.
- SST visual inspections are scheduled to videotape all the tanks every tank every 10 years. Additional videos for tanks that have some abnormality observed are made.
- Additional analyses as required are performed for tanks that need to have new penetrations cut for retrieval of waste.
- Additional analyses are performed on for tanks for larger or usual dome loading conditions that are not covered by RPP-20473, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks* (e.g., postulated equipment drop, large eccentric load, internal pressure pulse, impervious surface barriers), on case-by-case basis.
- The procedures for structural assessments after a seismic event are outlined in TF-ERP-008, *Emergency Response Procedure 008 Seismic Event Response*, and TFC-ENG-DESIGN-C-30, *Post-Natural Phenomenon Hazard Assessment*.

4.12.3 Discussion of Recommendations

- The Dome Deflection Survey Program is to verify the dome deflections every two years or three years depending on the tank status should be continued. Based on the AORs, since any dome deflection is potentially significant, tanks with deflections above 0.24 in. should be subject to annual surveys and a visual inspection. (Summarized in Recommendation 2018-01 in Section 8.1.3.)

- Since excessive deflection could be an early harbinger of dome failure, when the dome survey deflection exceeds 0.30 in., a plan should be created to determine what is causing the displacement and how to stabilize the tank, if possible. This plan should be implemented prior to the displacement reaching 0.36 in. The plan should consider the direction that the benchmarks are moving and may include, but should not be limited to: removing soil from the top of the tank, removing tank waste, excavating near the haunch of the tank to check for structural cracking on the exterior face, evaluation of the benchmark to see if it was physically displaced from the surface, visual inspection of interior of the tank, excavation of the benchmarks to determine if they are adhered to the top of the tank, etc. (Summarized in Recommendation 2018-02 in Section 8.1.3.)
- On an opportunistic basis, when other activities require the removal or cutting of concrete from a tank, a minimum of three but preferably at least six, concrete cores samples should be taken and tested for compressive strength. In order to do this efficiently, the Owner/Operator should maintain a programmatic and technical capability needed to acquire, package, ship, and test these cores. (Summarized in Recommendation 2018-03 in Section 8.1.3.)
- Recommend prioritizing the initial internal visual surveys of all the tanks to establish a baseline for each of the tanks as soon as possible but no less than 10% of tanks per year. If possible, the initial visual surveys of all the tanks should be complete ahead of the current schedule. Since the wastes in C Tank Farm and tank S-112 have been retrieved, recommend that C Tank Farm and tank S-112 be last. It is further recommended that repeat video inspection of tanks with water intrusions be secondary to completing the initial visual survey of all the tanks. Visual surveys need to be of high quality with adequate lighting, although it is not expected that cracks of 1/16-in. size be discernable. (Summarized in Recommendation 2018-04 in Section 8.1.3.)
- Recommend that all of the tanks be visually inspected every 10 years until the tanks are closed. Continue repeating video inspections of tank locations where the concrete cracking, buckling of sidewalls, or spalling near corroded reinforcing appear severe in the previous videos. (Summarized in Recommendation 2018-05 in Section 8.1.3.)
- The existing Dome Loading Monitoring Program prevents overloading the tank domes and should continue to be rigorously enforced. (Summarized in Recommendation 2018-06 in Section 8.1.3.)
- Due to the cost and difficulty, additional full-depth sidewall cores are not recommended except as a potential part of Recommendation 2018-02. Instead, do opportunistic cores. (Summarized in Recommendation 2018-07 in Section 8.1.3.)
- Perform additional AORs as indicated in Expert Panel Recommendation SI-9 when evidence is found that significant concrete or reinforcing degradation is present. The most likely evidence of significant concrete or reinforcing degradation is the dome deflection survey or visual inspections. These AORs should consider large areas of degraded concrete and reinforcing steel to establish at what point the degradation renders the tank no longer structurally sound. (Summarized in Recommendation 2018-08 in Section 8.1.3.)
- When additional AORs are performed, model and report deflections at several locations on the foundation, haunch and the dome to determine if an actual deflection at these locations

may be indicators to predict degradation of the wall or footing of the tank prior to collapse. If this analysis determines addition locations of significant deflection that could be used to predict structural concerns, this data should be used to update the Dome Deflection Survey Program including the possible addition of new survey control points. (Summarized in Recommendation 2018-09 in Section 8.1.3.)

- When additional AORs are performed consider modifying the modeling techniques to address the following issues:
    - Use up-to-date evaluation procedures to consider the relative stiffness and yielding characteristics of the reinforcing steel, the concrete, and the surrounding soil.
    - Consider evaluating the seismic load combinations with the other loads in the same finite element model.
    - Consider separating the tank from the slab when evaluating the seismic forces on the tank. (Summarized in Recommendation 2018-10 in Section 8.1.3.)

4.12.4 Discussion of Conclusions

- For this structural evaluation, the SSTs have structural integrity, as listed in Appendix C.

5.0 WASTE COMPATIBILITY ASSESSMENT

5.1 WASTE CHARACTERIZATION – CURRENT CONDITIONS

The remaining volume of waste in the SSTs is 28,498,000 gallons consisting of 116,000 gallons of supernatant liquid; 8,344,000 gallons of sludge; and 20,039,000 gallons of saltcake. About 2,713,000 gallons of drainable interstitial liquid is trapped in the sludge and saltcake (HNF-EP-0182). Appendix F shows waste volumes by tank.

Existing waste characteristics were compiled and reviewed to ensure that the current waste parameters are within the defined design envelopes and operational safety limits for the tanks. Table 5-1.

Table 5-1: Tank Waste Characteristics by Tank Farm

Tank Farm	Number of Tanks	Total Waste (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)
A	6	900	12	117	771
AX	4	460	1	21	438
B	16	1,981	19	1,269	693
BX	12	1,476	30	1,155	291
BY	12	4,225	0	296	3,929
C	16	62.67	0.3	62.37	0
S	12	4,137.70	3.1	911.5	3223
SX	15	3,417	0	1,026	2,391
T	16	1,798	31	1,638	129
TX	18	6,544	1	764	5,779
TY	6	613	10	445	158
241-U	16	2,960	13	496	2,451

5.1.1 Hydrogen Generation and Mitigation

Waste generates hydrogen through the radiolysis of water and organic compounds, radiothermolytic decomposition of organic compounds, and corrosion of the tanks' carbon steel walls. Hydrogen is the flammable gas of most concern, with a lower flammability limit (LFL) of 4%. For salt slurries, gas is generated mostly through thermolysis of organics (complexants and degradation products). For sludges, gas is generated mostly through radiolysis. Nonflammable gases (e.g., nitrous oxide and nitrogen) are also produced. Additional flammable gases (e.g., methane, LFL = 5%; ammonia, LFL = 15%) are generated by chemical reactions between various degradation products of organic chemicals present in the tanks.

Hazards associated with flammable gas accumulation and ignition are described in RPP-13033, *Tank Farms Documented Safety Analysis (DSA),* Section 3.3.2.4.1, "Flammable Gas Accidents." A number of flammable gas accident scenarios are described and the resulting consequences are estimated.

The control strategy for these accidents is largely focused on preventing flammable gas accidents by establishing ventilation, process, flammable gas monitoring, and ignition controls.

The steady-state flammable gas hazard control strategy relies on flammable gas monitoring to confirm that sufficient ventilation is available to maintain the flammable gas concentration below the LFL in the SST headspace. Flammable gas sampling or monitoring is required in the tank headspace or in a location where the flammable gas sampling or monitoring method ensures a representative measurement of the tank headspace flammable gas concentration.

A limiting condition for operation is the tank headspace flammable gas concentration shall be ≤25% of the LFL. Flammable gas monitoring is performed to verify the flammable gas concentration is ≤25% of the LFL and, therefore, that sufficient ventilation is available to prevent the accumulation of flammable gases in the tank headspace above this control point.

Extensive flammable gas monitoring data on SSTs demonstrate that passive ventilation (and/or diffusion) sufficient to prevent steady-state flammable gas hazards is inherent in the normal operation and configuration of the SSTs. RPP-5926, *Steady-State Flammable Gas Release Rate Calculation and Lower Flammability Level Evaluation for Hanford Tank Waste*, calculates the steady-state flammable gas concentration in SSTs and shows that small ventilation rates (i.e., <1 ft^3/min) are adequate to prevent the flammable gas concentration from reaching 25% of the LFL and that very small ventilation rates (i.e., <0.2 ft^3/min) are adequate to prevent the flammable gas concentration from reaching 100% of the LFL. Therefore, to prevent steady-state flammable gas hazards in SSTs, the selected control is flammable gas monitoring to directly verify that the flammable gas concentration in the tank headspace is ≤25% of the LFL, which confirms that sufficient ventilation is available to control the steady-state generation of flammable gas in the SST.

Failure to take the actions required within the required time limit following failure to meet the limiting condition for operation is a violation. Should that situation occur, the response is dictated by Administrative Control 5.4.3, Response to a Limiting Control Setting or Limiting Condition for Operation Violation.

5.2 WASTE CHARACTERIZATION – HISTORICAL CONDITIONS

The waste acceptance envelope for waste receipts into the SSTs and DSTs has been gradually tightened since the first production waste was received in 1944. The current waste acceptance envelope was adopted in 1984 and, with the exception of specific waste type dependencies, has remained stable.

During the early operating years, SST waste receipt composition limits were sometimes relaxed to strike a balance between the extent of neutralization necessary to minimize corrosion of the mild steel liners and the chronic shortage of waste storage space.

The last SST was deactivated on November 21, 1980. Deactivation removed the remaining supernatant liquid down to pump suction, leaving typically 12 in. to 18 in. of liquid, roughly 33,000 gallons to 49,500 gallons for a 75 ft diameter tank. At the end of November 1980, the SST waste inventory was 39 million gallons, and the SSTs could no longer accept new waste (RHO-CD-14, *Waste Status Summary*). Two phases of waste stabilization ensued. Between 1978 and 2005, 147 SSTs were stabilized, 67 by jet pumping and the remainder either administratively or by supernatant liquid removal (HNF-SD-RE-TI-178, *Single-Shell Tank Interim Stabilization Record*).

SST deactivation and SST interim stabilization removed an estimated 7.9 million gallons of supernatant and interstitial liquid. Waste retrieval of the solid wastes left in the SSTs began with modified sluicing in tank C-106 on November 18, 1998, followed by the other C Tank Farm tanks, beginning with vacuum retrieval of tank C-203 on June 30, 2004 (RPP-RPT-26475, *Retrieval Data Report for Single-Shell Tank 241-C-203*), and saltcake dissolution retrieval of waste in tanks S-102 and S-112 on December 6, 2004, and September 26, 2003 (RPP-RPT-27406, *Demonstration Retrieval Data Report for Single-Shell Tank 241-S-112*). About 3 million gallons of waste have been retrieved.

RPP-10435 provides an overview of the SST system operating history prior to deactivation. Table 4-1 though Table 4-6 provide the ages of the tanks.

5.3 WASTE EFFECTS ON CONCRETE AND STEEL COMPONENTS

RPP-10435 identified the following three primary potential degradation mechanisms for the SSTs:

- Corrosion of the reinforcing bars
- Degradation of the concrete mechanical properties due to past high temperature exposure
- Caustic waste chemical exposure damage of the concrete in leaking tanks.

5.3.1 Tank Liner Corrosion Chemistry

Leak integrity is outside of the scope of this integrity assessment; however, the condition of the steel liner is important in determining the extent of contact between the liquid waste and the concrete in the past.

Corrosion testing of SST liner steel has been performed numerous times over many decades. Most corrosion testing focused on corrosion rates at the higher temperatures and storage conditions that no longer exist in the SSTs (ARH-ST-111, *Compilation Of Hanford Corrosion Studies*).

More recent testing, based on recommendations from the SSTIP Expert Panel, studied the corrosion behavior of SST waste simulants at 25 °C that fail to meet current DST temperature, nitrite, nitrate, and hydroxide concentration corrosion control limits. The examinations provide information on the potential for pitting, cracking, and corrosion at the liquid-air waste interface or corrosion of the liner in the vapor space. A primary reason for screening the SSTs using the DST corrosion controls is that the DST control limits are based on testing, and the waste simulants used are representative of the stored waste in the SSTs. Thus, these same DST corrosion mechanisms are typically also present in the SSTs.

Waste layers were identified in the SSTs that were not compliant with the DST chemistry control limits listed in OSD-T-151-00007, *Operating Specifications for the Double-Shell Storage Tanks*. Applying the DST limits, adding a nitrite inhibition limit, and adjusting the population for some higher waste storage temperatures identified 39 layers in 26 tanks that required testing; two additional tanks required tests at 40 °C.

During fiscal year (FY) 2013 and FY 2014, stress corrosion cracking and localized corrosion tests were conducted on SST waste layer simulants that were considered representative of the various waste chemistries that were not compliant with the DST limits. Tanks tested for localized corrosion as well as stress corrosion cracking were B-101, B-107, B-203, BX-110, S-104, T-102, TX-116, TX-117, U-106, and U-203. Tank T-110 was tested only for localized corrosion.

No evidence of stress corrosion cracking was observed in any of the tests (RPP-RPT-56141, *FY2013 DNV DST and SST Corrosion and Stress Corrosion Cracking Testing Report*; RPP-RPT-58300, *Fiscal Year 2014 DST and SST Chemistry Testing Report*); however, evidence of localized corrosion in the form of pitting and crevice corrosion was observed in the seven tanks B-107, B-203, BX-110, S-104, T-110, TX-116, and TX-117 (RPP-RPT-57096, *Examination of Simulated Non-Compliant Waste from Hanford Single-Shell Tanks*).

5.3.2 Concrete Exposure to Waste

Sixty-one SSTs have been identified as "assumed leakers" in HNF-EP-0182. However, based on investigations completed between 2007 and 2015, the number is thought to be closer to 25 SSTs that have actually leaked from liner failure (RPP-RPT-54909, *Hanford Single-Shell Tanks Leak Location and Cause: Summary Report*). The remainder of the assumed leakers are believed to have been misclassified due to overfilling, accelerated evaporation, retained gas releases, or other non-leak phenomena that resulted in unexplained decreases in the waste level or increases in soil radiation readings external to the tank. Eleven leak assessment reports, listed in Table 5-2, covering all 12 tank farms, support the expectation that there have been fewer leaking SSTs than previously reported.

Table 5-2: Leak Assessment Reports

Tank Farm(s)	Report Number
C	RPP-ENV-33418
A and AX	RPP-ENV-37956
SX	RPP-ENV-39658
TY	RPP-RPT-42296
BY	RPP-RPT-43704
BX	RPP-RPT-47562
S	RPP-RPT-48589
B	RPP-RPT-49989
U	RPP-RPT-50097
TX	RPP-RPT-50870
T	RPP-RPT-55084

As the SSTs age, corrosion will eventually breach all of the steel tank liners, providing a pathway for interstitial and supernatant liquids remaining in the tanks to reach the soil. This inevitability of the liner breaches was recognized as early as the 2002 IAR, which certified the structural integrity of the SSTs but could not assure their leak integrity.

When the steel liner is breached due to corrosion by the waste material, the reinforced concrete is exposed to the waste solution attack. If the reinforcing steel corrodes, the corrosion products will fill a greater volume than that of the original metal. This will subject the concrete to additional stresses, which can eventually cause cracking of the concrete. This process can continue until the reinforcing steel is exposed directly to the corrosive environment, potentially leading to loss of structural strength and integrity.

As noted in Section 4.11, thermo-mechanical modeling of the self-boiling tanks predicted cracking of the reinforced concrete tanks. These predictions were confirmed by field observations in tank SX-108, where cracks were observed downward through the footing and some distance up the tank sidewall. If a liner breach were present at a location where the reinforced concrete has cracked, then a pathway exists for immediate waste attack on the rebar that avoids concrete diffusion.

Early concerns about the effects of waste on the performance of the SST structural concrete in leaking tanks led to numerous laboratory investigations. RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel*, prepared by the Portland Cement Association, presents the results of four years of concrete degradation studies that exposed concrete and reinforcing steel, under load and at 180 °F, to simulated double-shell slurry, simulated salt cake solution, and a control solution. Exposure length varied from 3 months to 36 months. In all cases, examination of the concrete and reinforcing steel at the end of the exposure indicated there was no attack (i.e., no evidence of rusting, cracking, disruption of mill scale, or loss of strength) (RHO-RE-CR-8 P; RHO-RE-CR-4, *Effects of Moisture Loss Due to Radiolysis on Concrete Strength*; WHC-SD-TWR-RPT-002, *Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste Tanks*).

RPP-10435 concluded that examination of the areas of tank liners available for visual inspections have consistently shown that the liners are intact, indicating that leaks in the liner are generally localized in nature. Results of borehole leak investigations have also indicated that leakage through the concrete tanks is local. Such findings, coupled with the porous nature of the surrounding soil, support the position that the SST leak paths are local, precluding widespread damage to the concrete tanks. Concrete damage confined to local areas adjacent to a leak are not expected to jeopardize the overall tank stability even if the concrete is cracked creating a direct pathway for immediate waste attack on the rebar.

Only 10% of the waste, by volume, is supernate or drainable interstitial liquid. The remainder is sludge and saltcake. Saltcake waste is not expected to attack the reinforced concrete tank upon direct exposure. Any liquid waste that comes into direct contact with the concrete tank is expected to find localized migration paths and is not a concern for the tank's structural integrity.

5.3.3 Concrete Exposure to Radiation

Neutrons usually cause aggregate growth, water decomposition, and heating of the concrete. Gamma radiation produces heating and water migration. The energy flux from the tank waste is many orders of magnitude too low to reach the threshold for radiation damage.

5.4 EFFECTS OF WATER INTRUSTION ON WASTE

Currently, there are 22 SSTs with small surface water intrusions that have been observed during in-tank video inspections, and seven tanks with evidence of past intrusions based on increases in surface pool size, dome interior surface streaking, and other evidence (HNF-EP-0182). The principal concern with water intrusion into the SSTs is re-liquification of the semi-moist waste in tanks that have leaked. Re-liquification of the waste will not create waste that is outside of the waste acceptance criteria, so there are no compatibility concerns with the tank liner. As noted earlier, even direct contact of the liquefied waste with the concrete tank is expected to find localized migration paths and is not a concern for the tank's structural integrity.

The existing agreement with Ecology is to try to stop the intrusion and then remediate it as part of eventual waste retrieval (RPP-9937, Section 4.1.1 A.3). As of the writing of this assessment, 107 visual inspections have been completed on 94 SSTs. The intention is to complete visual inspections of all 149 SSTs every 10 years. Table 4-15 through Table 4-20 show the inspection dates of each of the SSTs.

Of the 94 SSTs inspected to date, 22 tanks (about 23%) have confirmed intrusions. An additional seven (7%) of the 94 SSTs show evidence of past intrusion. Many of the 94 tanks were selected because leak detection and monitoring surveillance data suggested an intrusion had occurred. The intrusions are not likely to be occurring at the same frequency in the remaining 55 SSTs that have not been inspected as of the writing of this report.

The most recent soil pH sample data are from tank farm locations in 200 East and 200 West Areas where waste transfer lines were excavated for external corrosion direct assessments. It should be noted that all of the SSTs are located in massive excavations that were backfilled from the soil piles without regard to the original soil stratigraphy. The soil resistivity in the range of 46-61 k Ω-cm and the pH in the range of 5.9 – 7.0 should be treated as generally indicative of Hanford Site tank farm soil properties, keeping in mind the limited number of sample locations and the fact that none of the measurements were from an SST farm.

5.5 INTRUSION WATER EFFECTS ON CONCRETE AND REINFORCING STEEL

As noted in Sections 5.3.1 and 5.3.2, the steel liner shows signs only of localized corrosion. Concrete damage confined to local areas adjacent to a leak are not expected to jeopardize the overall tank stability even if the concrete is cracked, creating a direct pathway for immediate waste attack on the rebar.

5.6 DISCUSSION OF REVIEW

5.6.1 Discussion of Findings

- No findings were noted.

5.6.2 Discussion of Observations

The general observations from the assessment of waste chemistry are as follows:

- The knowledge of waste constituents is sufficient for waste compatibility purposes.

- Hydrogen mitigation and response program are adequate.
- Waste layers were identified in the SSTs that were not compliant with the DST chemistry control limits listed in OSD-T-151-00007.
- As the SSTs age, corrosion will eventually breach all of the steel tank liners. The steel liner are non-structural and for the purposes of this report are consider failed, at least locally, such that there is direct exposure of waste to the reinforced concrete tank structure.
- Saltcake waste is not expected to attack the reinforced concrete tank upon direct exposure.
- Laboratory testing of waste simulants in contact with concrete and rebar at elevated temperatures for periods of up to 36 months did not result in either rebar corrosion or concrete degradation.
- Any liquid waste that comes into direct contact with the concrete tank is expected to find localized migration paths and is not a concern for the tank's structural integrity. This includes any re-liquification of the waste due to intrusion water.
- Currently, there are 22 SSTs with small surface water intrusions that have been observed during in-tank video inspections, and seven tanks with evidence of past intrusions based on increases in surface pool size, dome interior surface streaking, and other evidence. Volume of intrusion water is insignificant compared to the volume of the tank.
- Re-liquification of the waste due to intrusion water will not create waste that is outside of the waste acceptance criteria, so there are no compatibility concerns with the tank liner.

5.6.3 Discussion of Recommendations

- Since volume of intrusion water is not significant and is expected to find localized migration paths such that it is not a concern for the tank's structural integrity, it is recommended that video inspection of tanks with water intrusions be secondary to completing the initial visual survey of all the tanks. (Summarized in Recommendation 2018-04 in Section 8.1.3.)

5.6.4 Discussion of Conclusions

- For this waste compatibility evaluation, the SSTs have structural integrity, as listed in Appendix C.

6.0 CORROSION ASSESSMENT

6.1 LINER AND REBAR CORROSION

This section discusses corrosion in the SSTs. Corrosion can occur due to waste contact with the steel liner or the reinforcing steel in the concrete dome, walls, footings, or slab. Since leaking is not part of this assessment, the liner is discussed only to show the potential of the waste to attack the structural reinforcing bars. Plus, the steel liner is visually observable whereas the reinforcing bars are typically concealed.

The steel liner is not structural and was intended only to contain the waste. This section does not attempt to predict liner corrosion. Its only purpose is to provide a brief historical review of past liner concerns and findings.

Initially the steel liners would have been considered important to prevent waste from leaking out and through concrete porosities. Knowing now that the liners can fail mechanically or by corrosion, the emphasis on liner condition is when the liners leak, how likely is the waste to exacerbate concrete porosity? This is discussed in Section 5.3.1.

As noted in ARH-ST-111, early corrosion work applicable to Hanford carbon steel waste tanks was reported, by early 1944, at the Clinton Laboratories at the Clinton Engineering Works near Clinton and Oak Ridge, Tennessee. Solutions at or above pH 10 were considered relatively non-corrosive but by maintaining a pH of 7 – 9, less waste would be produced and would be more cost effective in terms of chemicals needed and volumetric concerns.

Additionally, as ARH-ST-111 reported, uniform corrosion was determined over the years during testing to be relatively minor with the greatest concern being pitting and, in some solutions, stress-corrosion cracking. It was also noted that, based on laboratory studies, corrosion was worse in salt-cake systems and in the vapor phase than in liquid waste.

Examples of specific tests include laboratory work with pH 11, 200 °F, REDOX waste where corrosion rates varied between 0.02 and 6 mpy which were difficult to apply to in-tank situations (HW-26201, *Corrosion Tests – SAE 1010 Mild Steel in Synthetic Neutralized REDOX Waste Solution*). Other laboratory work with boiling neutralized plutonium-uranium extraction (PUREX) waste showed severe initial pitting that decreased with time but had uniform rates of about 1 mpy (HW-32734, *A Laboratory Study of the Extent of Pitting and General Corrosion of SAE-1010 Steel in Simulated Neutralized PUREX Process Waste Solution*). In this case, in-tank tests corroborated, the results showing corrosion rates of less than 0.2 mpy in both the liquid and vapor (HW-49574, *Examination of Corrosion Test Coupons in PUREX 101 Waste Storage Tanks – RM-147*).

In addition to the liner, SST design measures to prevent corrosion to the concrete tank include the internal corrosion protection on the dome, walls and base as listed in Table 4-7. Since the liner has failed in some tanks, it is likely the wall and base protective materials may have been damaged with liner failure and may be of limited effectiveness.

As discussed in Section 5.3 and Section 5.6.2, as the SSTs age, corrosion will eventually breach all of the steel tank liners. The steel liner is non-structural, and for the purposes of this report, are considered failed, at least locally, such that there is direct exposure of waste to the reinforced concrete tank structure. Saltcake waste is not expected to attack the reinforced concrete tank upon direct exposure. Finally, laboratory testing of waste simulants in contact with concrete and rebar at elevated temperatures for periods of up to 36 months did not result in either rebar corrosion or concrete degradation. Therefore, concrete and rebar are unaffected by long term elevated temperature contact with waste.

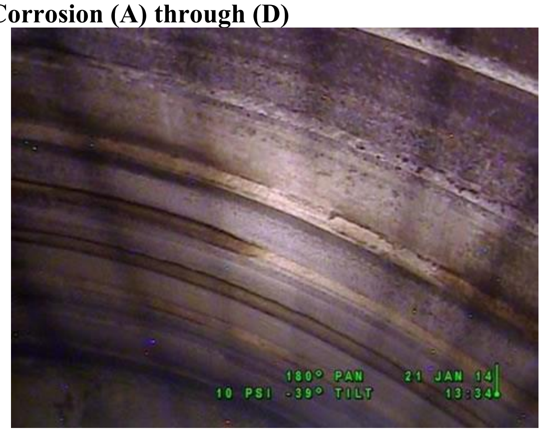
Visual inspections of selected SSTs using remotely operated video cameras were conducted in fiscal years 2010, 2011, 2013, 2014, 2015, 2016, 2017, and 2018; additional inspections are planned for the future. Not all tanks have been reviewed to date. The inspections included surveillance of domes/tops, liners, in-tank equipment, and risers, as well as waste surfaces.

While corrosion and any consequent failure of liners, in-tank equipment, or risers, are not a major structural concern, a brief historical review of the subject is of interest.

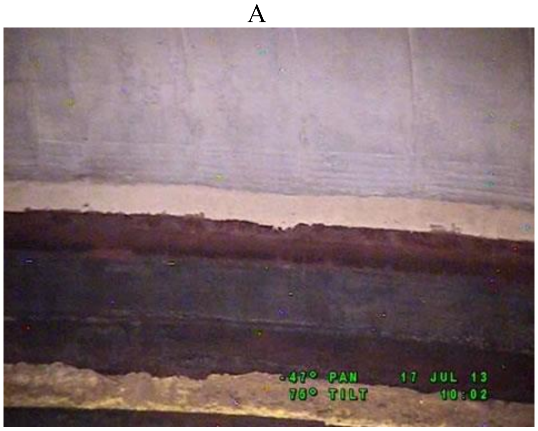
Based on data in RPP-RPT-55951, *Fiscal Year 2013 Visual Inspection Report for Single-Shell Tanks*, the definitions of the degrees of corrosion are shown in Figure 6-1, images A to Z.

Examples of Mild Liner Corrosion (A) through (D)

A



B

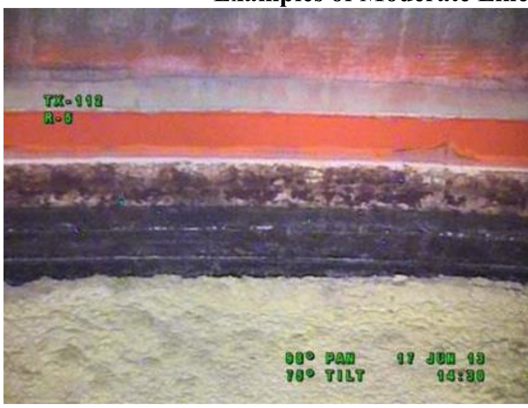


C

D

Figure 6-1: Pictorial Definitions of Degrees of Corrosion (RPP-RPT-55951) (6 sheets)

Examples of Moderate Liner Corrosion (E) through (H)



E

F

G

H

Figure 6-1: Pictorial Definitions of Degrees of Corrosion (RPP-RPT-55951) (6 sheets)

Examples of Severe Liner Corrosion (I) through (L)

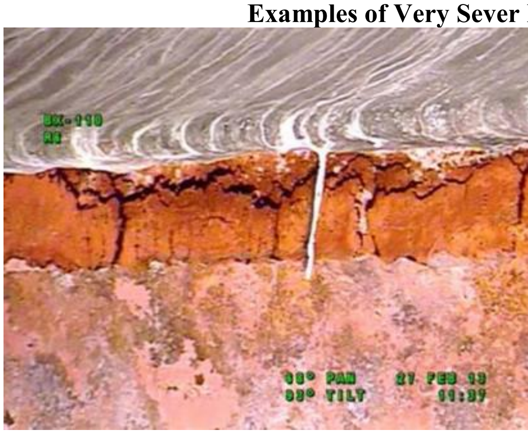
I (some growth material)

J

K (some growth material)

L

Examples of Very Sever Liner Corrosion (M and N)



M

N

Figure 6-1: Pictorial Definitions of Degrees of Corrosion (RPP-RPT-55951) (6 sheets)

Examples of Mild Equipment and Riser Corrosion (O) through (R)

O

P

Q

R

Figure 6-1: Pictorial Definitions of Degrees of Corrosion (RPP-RPT-55951) (6 sheets)

Examples of Moderate Equipment and Riser Corrosion (S) through (V

S

T

U

V

Figure 6-1: Pictorial Definitions of Degrees of Corrosion (RPP-RPT-55951) (6 sheets)

Examples of Severe Equipment and Riser Corrosion (W) through (Z)

W

X

Y

Z

Figure 6-1: Pictorial Definitions of Degrees of Corrosion (RPP-RPT-55951) (6 sheets)

These are the "definitions" on which the authors of the FY 2010–2018 visual inspection reports based their descriptions of the state of corrosion in the inspected tanks. The results of the above noted eight years of visual inspections are summarized in Appendix G. From Appendix G, it is clear that the extent of uniform/general corrosion is relatively light. Only a few locations have severe corrosion. Pitting also appears to mainly occur at the liquid-air interface. Appendix G further sorts the data by tank leak status and corrosion.

In TID-26431, *Report on the Investigation of the 106-T Tank Leak at The Hanford Reservation, Richland, Washington*, it was considered that the cause of the leak was corrosion. However, in RPP-RPT-54909, it was considered that waste chemistry (essentially corrosion) was a minor cause though no other definitive leak mechanism was stated. Table 6-1, from RPP-RPT-54909, summarizes the current view of tank failure mechanisms. The column labeled "design" is referring to design of the liner, not the tank structure.

Table 6-1: Causes of Leaks

Tank	Design	Tank Construction Conditions	Bulging Liner	Thermal Conditions	Waste Chemistry	Other	Other than a Liner Leak
A-104	⬤	•	·	⬤	●	–	–
A-105	⬤	•	⬤	●	•	⬤	–
B-107	–	–	–	·	●	–	–
BY-103	–	•	–	•	●	–	–
C-101	–	–	–	·	•	–	Spare inlet and/or cascade outlet line leak
C-105	–	–	–	•	•	–	Spare inlet, cascade inlet line, Line V103, and/or condenser leak
SX-107	⬤	•	•	⬤	⬤	–	–
SX-108	⬤	•	•	⬤	⬤	–	–
SX-109	⬤	•	•	⬤	●	–	–
SX-111	⬤	•	•	⬤	⬤	–	–
SX-112	⬤	•	•	⬤	●	–	–
SX-113	⬤	•	•	⬤	•/–	–	–
SX-114	⬤	•	•	⬤	⬤	–	–
SX-115	⬤	•	•	⬤	⬤	–	–
T-106	–	–	–	·	·	·	–
T-111	–	–	–	·	·	·	–
TX-107	–	–	–	•	•	–	–
TX-114	–	–	–	•	•	–	–
TY-103	–	·	–	•	●	–	–
TY-104	–	·	–	•	●	–	–
TY-105	–	·	–	•	●	–	–
TY-106	–	·	–	•	●	–	–
U-104	–	–	●	•	–	–	–
U-110	–	–	–	•	•	–	–
U-112	–	–	–	·	•	·	–

1. Probable cause(s) for liner leaks illustrated by relative size of circles.

Taken from Table 12-1 of RPP-RPT-54909, Rev. 00, *Hanford Single-Shell Tanks Leak Location and Cause: Summary Report*.

Where tank design is listed as the source of leaks, RPP-RPT-54909 indicates "tank construction design factor limiting thermal expansion of liners, and the weld design between the liner walls and the liner base plate.

6.2 DISCUSSION OF REVIEW

As noted, this review is for background and historical purposes only. The liners are assumed to be subject to failure, as some have, and so the only critical concern is whether current or future leaks can exacerbate concrete, and therefore, structural failure. Because of the current waste chemistry, corrosion of the rebar is expected to be minimal even if the concrete disintegrates.

Diffusion of the liquid waste components through intact concrete is expected to be minimal and to not affect significant rebar corrosion that would result in deterioration of the concrete.

6.2.1 Discussion of Findings

- No findings were noted.

6.2.2 Discussion of Observations

- Corrosion does not appear to have been a major contributor to leaking of SSTs. The degree of liner, in-tank equipment, and riser corrosion is less than anticipated.
- Although liner failure is not a direct structural effect, increased waste exposure to concrete and rebar could, in theory, impact the structure. Studies, noted earlier, have indicated concrete and rebar were unaffected by long-term elevated temperature contact with simulated waste, see Section 5.3.
- Although, for the historical record, it would be of interest to continue visual inspections of the tanks, there is no corrosion reason to do visual inspections. Further visual inspections are only useful for monitoring the concrete structure. Therefore, there are no recommendations for continuing visual inspections solely for liner corrosion.
- Of the failed tanks visually inspected, only two (tanks T-111 and TX-114) appear to have significant liner corrosion as noted in Appendix G. Indeed, the leak cause matrix (Table G-1) suggests the major failures were mostly due to poor liner design, bulging, thermal effects, or other causes with much less effect due to waste chemistry (corrosion). The failed tanks with "significant" waste chemistry effects had little observable corrosion.
- Generally corrosion appears to be localized – pitting or cracking. Large-scale liner failures appear to have been mechanically or thermally induced. The inference is that corrosion would not provide a pathway for sufficient fluid to significantly affect the reinforced concrete tank shell. A major mechanical failure due, say to a bulge, could expose a significant area of concrete to the waste – discounting the protective asphaltic layer.

6.2.3 Discussion of Recommendations

- No recommendations were noted.

6.2.4 Discussion of Conclusions

- For this corrosion evaluation, the SSTs have structural integrity, as listed in Appendix C.

7.0 GEOTECHNICAL AND HYDROGEOLOGICAL IMPACTS

7.1 BACKGROUND

The SSTs are underground reinforced concrete tanks. The tanks were grouped together into tank farms and are located in the 200 East and 200 West Areas. Figure 4-1 shows B Tank Farm under construction prior to backfill. Since these tanks are underground, these tanks must resist soil pressures and surcharge loads from equipment on the ground surface. The tanks also must resist other external earth loads such as seismic.

As described in Section 5.0, interim stabilized waste does not attack tank concrete or rebar. However, water intrusions can cause re-liquification of stabilized waste, which over the long term could be a structural concern. This section will discuss geological items including the following:

- Site geology
- Seismic design considerations
- Earth pressures and surcharges
- Water intrusion
- Soil corrosivity parameters.

7.2 SITE GEOLOGY

The tank farms general vicinity consists of the following anticipated geologic units, listed in order from the ground surface.

- **Fill** – An approximately 40- to 45-ft thick backfill between and around the underground tanks. The backfill materials are anticipated to consist of mixed native materials, including the Dune Sand and upper portions of the Hanford Formation (see below).
- **Dune Sand** – An approximately 2- to 17-ft thick surficial layer of loose to medium dense wind-blown silt and sand.
- **Hanford formation** – Medium dense to very dense sand and gravel that extends to a depth of about 270 to 320 ft below the ground surface (bgs). This formation also includes cobbles and boulders.
- **Ringold Formation** – Fluvial gravel and sand with interbedded zone(s) of lacustrine clay, silt, and sand that extends to a depth of about 375 to 420 ft bgs.
- **Basalt Bedrock** – The Elephant Mountain Member of the Columbia River Basalt Group underlies the Ringold Formation.

The SST foundations are likely founded within the sand of the Hanford formation at greater than 40 ft bgs.

Local groundwater is estimated to be greater than approximately 300 ft bgs based on previous site experience.

7.3 SEISMIC DESIGN CONSIDERATIONS

The latest seismic evaluation (AORs) of the SSTs was based on seismic design ground motions developed in accordance with the 2009 IBC criteria (RPP-RPT-49994, *Summary Report for the*

Hanford Single-Shell Tank Structural Analyses of Record-Single-Shell Tank Integrity Project Analysis of Record). Design earthquake ground motions are specified in the 2009 IBC as two-thirds of a maximum considered earthquake (MCE) ground motion; the MCE is defined as ground motions with a 2% probability of exceedance in 50 years (approximately 2,500-year return period) with a deterministic maximum cap in some regions.

The 2009 International Building Code (IBC) provides national maps and Site Class coefficients to determine the MCE ground motions at a given site. These ground motion maps were developed by the U.S. Geologic Survey (USGS) National Seismic Hazard Mapping Project (NSHMP) in 2002 (Frankel et al. 2002, *Documentation for the 2002 Update of the United States National Seismic Hazard Maps*). Alternatively, the 2009 IBC allows for a site-specific determination of the MCE ground motions in lieu of USGS NSHMP maps and/or Site Class coefficients. Site-specific probabilistic seismic hazard analyses (PSHA) have been performed for Hanford that are applicable to the SST sites that meet the 2009 IBC criteria for developing site-specific design ground motions. For the latest seismic evaluation (RPP-RPT-49994), the results of Hanford site-specific analyses by Rohay and Reidel were used. In RPP-RPT-49994, the Rohay and Reidel ground motions are compared to the USGS NSHMP updated 2008 ground motions. The Rohay and Reidel ground motions are shown to be conservative (i.e., larger) relative to ground motions based on the updated 2008 USGS NSHMP map values with the 2009 IBC Site Class coefficients (code-based motions) for periods of approximately two seconds and less. For periods greater than two seconds, the Rohay and Reidel results are less than the 2009 IBC code-based motions. However, per IBC requirements, the design ground motions for periods greater than two seconds are greater than or equal to 80% of the code-based motion, and thus are acceptable.

The USGS NSHMP has continued to update their national seismic ground motion hazard estimates and maps. The 2014 USGS NSHMP maps provide code-based motions within approximately 10% of the 2008 USGS NSHMP maps and results in the same conclusions that Rohay and Reidel ground motions are conservative relative to the code-based motions for periods less than about two seconds.

Pacific Northwest National Laboratory (PNNL) completed a sitewide PSHA (PNNL-23361, *Hanford Sitewide Probabilistic Seismic Hazard Analysis).* The PSHA provides both estimates of rock motion and a methodology to develop site-specific ground motions. It is anticipated that any future seismic evaluation of the SSTs will be based on the latest site-specific ground response methodology to provide design ground motions that meet the latest version of the IBC adopted for use at the site at that time. Calculations are currently underway to determine the site specific ground motions at the SST locations. Once these new response spectra are available they should be compared to the previous spectra and evaluated to determine if there are significant differences. Since the AORs showed the SSTs to be adequate with additional capacity and estimated that seismic was 10% to 30% conservative (see Appendix E), it is not anticipated that the new PSHA would justify any new AORs.

7.4 EARTH PRESSURES AND SURCHARGES

The lateral pressures against a buried wall are dependent on many factors, including method of backfill placement and degree of compaction, backfill slope, surcharges, the type of backfill and native soil, drainage, and whether or not the wall can yield or deflect laterally or rotate at the top after or during placement of backfill. If the wall is free to yield at the top an amount equal to approximately 0.001 times the wall height, the soil pressures will be less (active case) than if this movement is not allowed because of stiffness or wall resistance (at-rest condition). Table 4-14 shows the original design criteria. The soil loading used in the AORs was a soil density of 125 pcf and an at-rest coefficient of 0.5. Both of these values are appropriate. However, the AORs did not consider the sequence of construction. On some tanks, soil was backfilled almost to the top of the wall prior to dome installation. This creates a preloading of the walls that the AOR analysis did not consider. This refinement should be considered if future AORs are completed.

7.5 WATER INTRUSION

Intrusion of water into the SSTs has been known to occur in recent years. Twenty-two tanks show evidence of recent intrusion. Seven additional tanks show evidence of past intrusions that were not active at the time of the visual inspection (HNF-EP-0182). Of these, tanks B-201, BX-101, BX-110, BY-103, T-101, T-107, and T-111 are assumed leakers. The remaining 15 are non-leaking tanks.

There are effectively three potential means of entry for intrusion water:

- **Water or waste from other site components** – All water sources have been isolated from the tank farms; there are no active transfers except for SSTs in retrieval. These transfers use above ground encased transfer lines where a waste leak would be immediately detected. Therefore, the waste from other site components is considered to be a negligible source of intrusion water. So, ultimately, the source of intrusion water is precipitation (rain or snow).
- **Entry of ground water, rainwater, or snow melt into tanks** – There are engineered penetrations such as concrete pipe encasements between tanks and joints in cover blocks on tank pump pits that are suspected of accumulating rain water and snow melt, and channeling it into the tanks via pit drains or unsealed interface between tank risers and the surrounding concrete. These seem to be the most likely entry route.
- **Precipitation that migrates through the soil and penetrates the tank dome or walls** – Most precipitation in this area evaporates. Generally, it is not anticipated that the suspected water intrusion is due to precipitation infiltrating through the subsurface soils due to the relatively low precipitation common to the Columbia Basin region and relatively low moisture contents in the native soils. The portion of the water that falls above or near the tank dome that does not evaporate could percolate to the top of the dome and then flow down the sides of the tank. Some channelization of these flows could occur. The asphaltic coatings on the domes of the tanks should prevent intrusion water. An undamaged asphaltic coating in good initial condition has nearly an unlimited life and would minimize penetration. In any case the in leakage would have to be localized and is believed to be minimal. Because the measured pH in the shallower Dune Sand ranges from approximately 6.6 to 8.4, and approximately 7.6 to 8.2 in the Upper and Lower Sand units of the Hanford formation and because corrosivity test results indicate the sulfate content of the Dune Sand and Hanford formation soils are less than 0.04%, any water that does penetrate the coatings and the concrete will have little effect on rebar.

Intrusion water into the SSTs was studied with the results shown in RPP-RPT-50799, *Suspect Water Intrusion in Hanford Single-Shell Tanks.* Some tanks have been identified as having water intrusion. Currently, all video inspections include documentation of surface water in the tanks. Dripping during the video inspections is also recorded. In addition, ENRAF inspections are made to monitor water infiltration. Annual evaporation rates have been determined to aid in determining the actual intrusion into the tanks.

Impervious barriers have been installed in the T, and TY Tank Farms. The design and construction of an impervious barrier at the SX Tank Farm is in process. The purpose of these barriers is "to reduce the driving force for containment migration" (RPP-33431, *Design Analysis for T-Farm Interim Surface Barrier (TISB),* from containment plumes resulting from tank leaks. Likewise, the impervious barriers were not installed to reduce intrusion water.

The impervious barriers that have been installed do not appear to significantly change the intrusion water into the tanks and were not designed to protect the tanks. Therefore, impervious barriers are not suggested as a means to reduce intrusion water.

The original design criteria required asphaltic coatings on portions of the exterior of the most of the tanks as shown in Table 4-7. An undamaged asphaltic coating in good initial condition has nearly an unlimited life, which should prevent intrusion water. So, any modifications to tanks need to require repair of this coating.

Although intrusion water could corrode reinforcing, the chemistry of intrusion water is such that corrosion is will be limited. At least a good portion of intrusion water is observed leaking in locally at pipe penetrations, and not penetrating through the concrete dome or sidewall. The amount of intrusion water noted in RPP-RPT-50799 is not significant for structural integrity.

7.6 DISCUSSION OF REVIEW

7.6.1 Discussion of Findings

- No findings were noted.

7.6.2 Discussion of Observations

- The soil design parameters were reasonable in the advanced AORs.
- The seismic design criteria in the AORs was conservative.
- Intrusion of water into the SSTs has been known to occur in recent years.
- Impervious barriers have been installed in the T and TY Tank Farms for the purpose of reducing the driving force for waste plumes under and around the outside of the tanks. Likewise, the impervious barriers were not installed to reduce intrusion water.
- The asphaltic coatings, where present, of the tanks should limit accumulation of intrusion water through the top of the dome concrete. An undamaged asphaltic coating in good initial condition has nearly an unlimited life. Any modifications to tanks need to require repair of this coating.

7.6.3 Discussion of Recommendations

- When additional AORs are performed, analysis should consider the sequence of construction in regards to soil backfill and compaction. (Summarized in Recommendation 2018-11 in Section 8.1.3.)

- When additional AORs are performed, analysis should consider all current loading criteria (e.g., dead, live, seismic) at the time of analysis. (Summarized in Recommendation 2018-12 in Section 8.1.3.)
- Since volume of intrusion water is not significant and is not a concern for the tank reinforcing, it is recommended that video inspection of tanks with water intrusions be secondary to completing the initial visual survey of all the tanks. (Summarized in Recommendation 2018-04 in Section 8.1.3.)

7.6.4 Discussion of Conclusions

- For this geological evaluation, the SSTs have structural integrity, as listed in Appendix C.

8.0 INTEGRITY ASSESSMENT CONCLUSIONS

8.1 DISCUSSION OF REVIEW

The SST integrity assessment review process is outlined in Figure 8-1. For each tank, an assessment was made as to whether the feature is in scope; appropriately designed; structurally adequate; and compatible with the waste such that the feature will not collapse, rupture, or fail. Once those steps were completed, findings, observations, and recommendations were developed.

For this report, the following definitions apply:

- **Finding** – An individual item that does not meet requirements.
- **Observation** – A condition that helps perpetuate the SSTs as structurally sound such that the entire system is adequately designed, and is structurally adequate and compatible with the waste to ensure that the system will not collapse, rupture, or fail and have structural integrity. Observations were made for enhancements of the SST operation.
- **Recommendation** – An activity considered by the IQRPE that, if implemented, will rectify conditions or processes identified by findings, address issues raised by observations, or implement activities identified by conclusions.

8.1.1 Discussion of Findings

- After careful consideration, there are no findings (i.e., no conditions that failed to meet requirements were found).

8.1.2 Discussion of Observations

Observations were made for enhancements of the SSTs and their operation. The observations are listed in Sections 3 through 7 and compiled in Appendix D and, as such, are not repeated in this section. Any recommendation that was generated from an observation is listed in Section 8.1.3.

The 2002 IAR identified some significant structural uncertainties. Each of these will be explored in detail.

2002 IAR stated:

> "Due to the limited amount of inspection data, the caustic chemical damage to the tank basemat and footing concrete, in leaking tanks, cannot be defined with high confidence. The conclusion that the concrete damage is local in nature cannot be proven, but is inferred from dome surveillance data and leak investigations."

Since the 2002 report, the AORs have been done which show that the tanks meet the requirements of ACI 349. The AORs determined the basemat slab is likely cracked and structurally separated from the foundation but the tanks remained stable and did not exceed their capacities when the slabs were removed from the analysis models.

Visual inspections for 63% of the SSTs have been completed which show no signs of any significant structural concern. Based on the testing done on simulated waste, the waste does not degrade the concrete or rebars. The Dome Deflection Program continues. Thus, with 16 years of additional information, it is clear that any concrete damage is local in nature and that this 2002 uncertainty can be considered closed.

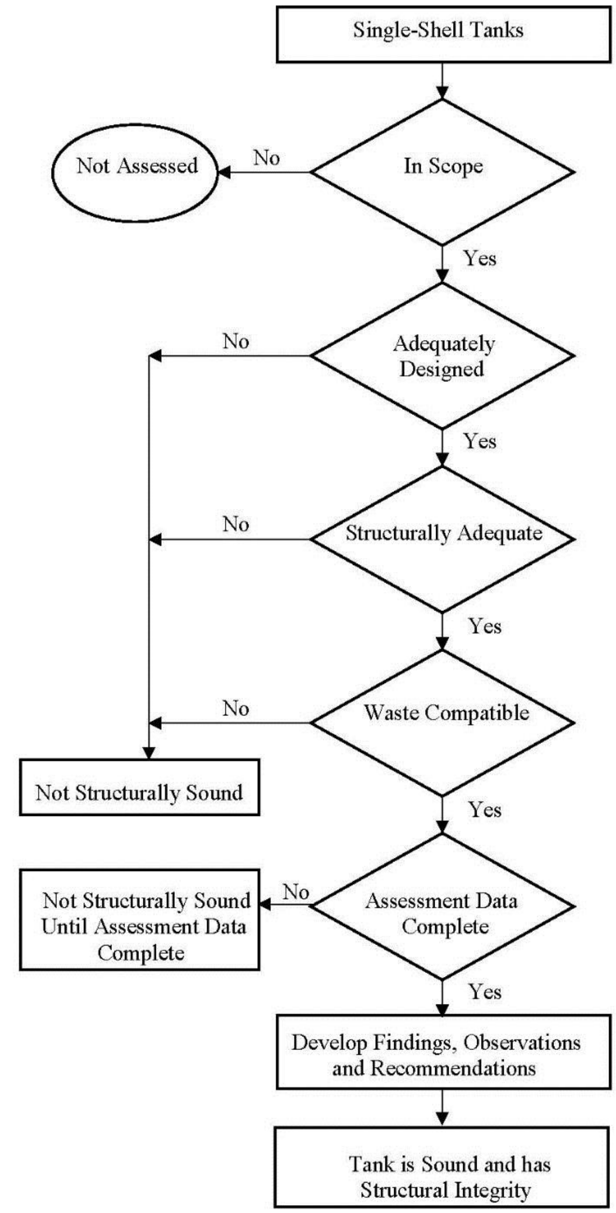


Figure 8-1: Single-Shell Tank Assessment Review Process

The next 2002 IAR uncertainty is:

> "The long-term SST structural integrity predictions are based largely upon the relatively benign future operating conditions, when compared to the more aggressive operating conditions of the past. Because operating conditions during future retrieval and closure operations are not fully defined, some uncertainty remains in future tank environments through closure. This statement is especially true for "closure" since SST closure has yet to be defined. As the load conditions associated with future operations become more clearly defined, confirmation will be needed that the loads fall within the existing analysis envelope or additional analyses will be necessary."

In concurrence with the 2002, the last 16 years have shown that the current operating conditions are relatively benign compared to the conditions of the past. Temperatures continue to drop, the interim stabilized waste does not degrade the concrete or rebars. Intrusion water is insignificant. The Dome Load program is enforced such that any new openings or equipment or loading are analyzed. Therefore, since current operating conditions are relatively benign and new analyzes are performed as needed, this 2002 uncertainty can also be considered closed.

8.1.3 Discussion of Recommendations

The following recommendations are those considered by the IQRPE to (1) rectify conditions or processes identified by findings, (2) address issues raised by observations, and (3) implement activities identified by conclusions. The recommendations are prioritized from most important to least important. The priorities are based on those most impactful to preserving structural integrity of the SSTs.

These recommendations also address the SOW requirement for consideration of the conclusions and uncertainties identified in Chapter 4 of RPP-10435 with respect to the intervening time period between assessments and the expectations for continued waste storage.

2018-01: The Dome Deflection Survey Program is to verify the dome deflections every two years or three years depending on the tank status and should be continued. Based on the Analyses of Record (AORs), since any dome deflection is potentially significant, tanks with deflections above 0.24 in. should be subject to annual surveys and a visual inspection. (For additional information, see Section 4.0.)

2018-02: Since excessive deflection could be an early harbinger of dome failure, when the dome survey deflection exceeds 0.30 in., a plan should be created to determine what is causing the displacement and how to stabilize the tank, if possible. This plan should be implemented prior to the displacement reaching 0.36 in. The plan should consider the direction that the benchmarks are moving and may include, but should not be limited to: removing soil from the top of the tank, removing tank waste, excavating near the haunch of the tank to check for structural cracking on the exterior face, evaluation of the benchmark to see if it was physically displaced from the surface, visual inspection of interior of the tank, excavation of the benchmarks to determine if they are adhered to the top of the tank, etc. (For additional information, see Section 4.0.)

2018-03: On an opportunistic basis, when other activities require the removal or cutting of concrete from a tank , a minimum of three but preferably at least six, concrete cores samples should be taken and tested for compressive strength. In order to do this efficiently, the Owner/Operator should maintain a programmatic and technical capability needed to acquire, package, ship, and test these cores. (For additional information, see Section 4.0.)

2018-04: Recommend prioritizing the initial internal visual surveys of all the tanks to establish a baseline for each of the tanks as soon as possible but no less than 10% of tanks per year. If possible, the initial visual surveys of all the tanks should be completed ahead of the current schedule. Since the wastes in C Tank Farm and tank S-112 have been retrieved, recommend that C Tank Farm and tank S-112 be last. It is further recommended that repeat video inspection of tanks with water intrusions be secondary to completing the initial visual survey of all the tanks. Visual surveys need to be of high quality with adequate lighting, although it is not expected that cracks of 1/16-in. size be discernable. (For additional information, see Sections 4, 5, and 7.)

2018-05: Recommend that all of the tanks be visually inspected every 10 years until the tanks are closed. Continue repeating video inspections of tank locations where the concrete cracking, buckling of sidewalls, or spalling near corroded reinforcing appear severe in the previous videos. (For additional information, see Section 4.0.)

2018-06: The existing Dome Loading Monitoring Program prevents overloading the tank domes and should continue to be rigorously enforced. (For additional information, see Section 4.0.)

2018-07: Due to the cost and difficulty, additional full-depth sidewall cores are not recommended except as a potential part of Recommendation 2018-02. Instead, do opportunistic cores as described in Recommendation 2018-03. (For additional information, see Section 4.0.)

2018-08: Perform additional AORs as indicated in Expert Panel Recommendation SI-9 when evidence is found that significant concrete or reinforcing degradation is present. The most likely evidence of significant concrete or reinforcing degradation is the dome deflection survey or visual inspections. These AORs should consider large areas of degraded concrete and reinforcing steel to establish at what point the degradation renders the tank no longer structurally sound. (For additional information, see Section 4.0.)

2018-09: When additional AORs are performed, model and report deflections at several locations on the foundation, haunch and the dome to determine if an actual deflection at these locations may be indicators to predict degradation of the wall or footing of the tank prior to collapse. If this analysis determines locations of significant deflection that could be used to predict structural concerns, this data should be used to update the Dome Survey Program including the possible addition of new survey control points. (For additional information, see Section 4.0.)

2018-10: When additional Analyses of Record (AORs) are performed consider modifying the modeling techniques to address the following issues:

- Use up-to-date evaluation procedures to consider the relative stiffness and yielding characteristics of the reinforcing steel, the concrete, and the surrounding soil.

  - Consider evaluating the seismic load combinations with the other loads in the same finite element model.
  - Consider separating the tank from the slab when evaluating the seismic forces on the tank. (For additional information, see Section 4.0.)

2018-11: When additional Analyses of Record (AORs) are performed, analysis should consider the sequence of construction in regards to soil backfill and compaction. (For additional information, see Section 7.0.)

2018-12: When additional Analyses of Record (AORs) are performed, analysis should consider all current loading criteria (e.g., dead, live, seismic) at the time of analysis. (For additional information, see Section 7.0.)

8.1.4 Work Plan for Future Integrity Assessments

TPA Interim Milestone M-045-91I established the requirement for this SST Structural IAR to include the following:

> *A work plan and schedule for additional integrity assessment activities will be submitted as a change package to cover any time period between the end date of the IQRPE certification and the end date of the mission.*

The work plan for the future activities up to the next IAR should include the following activities:

- The Dome Deflection Survey Program is to verify the dome deflections every two years or three years depending on the tank status and should be continued. Based on the AORs, since any dome deflection is potentially significant, tanks with deflections above 0.24 in. should be subject to annual surveys and a visual inspection. (IAR Recommendation 2018-01.)
- Since excessive deflection could be an early harbinger of dome failure, when the dome survey deflection exceeds 0.30 in., a plan should be created to determine what is causing the displacement and how to stabilize the tank, if possible. This plan should be implemented prior to the displacement reaching 0.36 in. The plan should consider the direction that the benchmarks are moving and may include, but should not be limited to: removing soil from the top of the tank, removing tank waste, excavating near the haunch of the tank to check for structural cracking on the exterior face, evaluation of the benchmark to see if it was physically displaced from the surface, visual inspection of interior of the tank, excavation of the benchmarks to determine if they are adhered to the top of the tank, etc. (IAR Recommendation 2018-02.)
- On an opportunistic basis, when other activities require the removal or cutting of concrete from a tank , a minimum of three, but preferably, at least six, concrete cores samples should be taken and tested for compressive strength. In order to do this efficiently, the Owner/Operator should maintain a programmatic and technical capability needed to acquire, package, ship, and test these cores. (IAR Recommendation 2018-03.)
- Recommend prioritizing the initial internal visual surveys of all the tanks to establish a baseline for each of the tanks as soon as possible but no less than 10% of tanks per year. If possible, the initial visual surveys of all the tanks should be completed ahead of the current schedule. Since the wastes in C Tank Farm and tank S-112 have been retrieved,

recommend that C Tank Farm and tank S-112 be last. It is further recommended that repeat video inspection of tanks with water intrusions be secondary to completing the initial visual survey of all the tanks. Visual surveys need to be of high quality with adequate lighting, although it is not expected that cracks of 1/16-in. size be discernable. (IAR Recommendation 2018-04.)

- Recommend that all of the tanks be visually inspected every 10 years until the tanks are closed. Continue repeating video inspections of tank locations where the concrete cracking, buckling of sidewalls, or spalling near corroded reinforcing appear severe in the previous videos. (IAR Recommendation 2018-05.)
- The existing Dome Loading Monitoring Program prevents overloading the tank domes and should continue to be rigorously enforced. (IAR Recommendation 2018-06.)

The schedule for a future IAR is addressed in Section 8.1.5.

8.1.5 Discussion of Next Integrity Assessment

This section discusses the recommended timing for future IQRPE assessments. Per WAC 173-303-640(2)(e), the schedule must be based on the results of the following:

- Past integrity assessments
- Age of the tank system
- Materials of construction
- Characteristics of the waste
- Any other relevant factors.

Section 3.8 of Ecology Publication 94-114, *Guidance for Assessing and Certifying Tank Systems,* says "WAC 173-303-640(2)(c) can be used as a minimum basis for these subsequent assessments." WAC 173-303-640(2)(c) references API 653, *Tank Inspection, Repair, Alteration, and Reconstruction*, which also provides guidance on the interval for future IARs.

8.1.5.1 Past Integrity Assessments

As to timing of future assessments, the 2002 IAR (RPP-10435) found the system had adequate collapse margin such that continued safe storage of waste was justified, but did not give a suggested timing for future IARs. As discussed in Section 3.3, it is likely the 2002 IAR was based on complete SST closure in 2024. Since integrity is only required when there is waste present, the 2002 IAR would have considered 2024 to be end of mission at that time. Based on that, it is implied that the 2002 IAR allowed at least a 22-year period to the next IAR.

8.1.5.2 Age of Tank System

The ages of the SSTs are listed in Section 4.0. Age is important to determine an ERUL. If one can establish a rate of degradation, then the remaining useful life of the structure can be extrapolated. For the concrete SSTs, API 653 is of limited applicability since it is based on steel tanks. On steel tanks, the thickness of the steel can be measured by ultrasonic testing and compared to design thickness.

Based on the structural analyses performed to date, the SSTs have a large collapse margin. API 653 does limit assessments to the lesser of remaining useful life divided by 4 or 15 years. Again, API is for steel tanks, so its applicability to concrete tanks is questionable. One might argue that the API limits are for both leaking and structural capability. However, the API methodology is really just based on the structural materials and their capacity.

Unfortunately, with the lack of structural data, ERUL is impossible to calculate at this time. There are no wall thicknesses or even visual observation of about 40% the tanks. Even then, the structural aspects of the visual inspections are only of the dome and part of the shell above the liner. Furthermore, dome and shell observations are sometimes difficult to observe the structure due to poor lighting and non-structural staining of the surfaces.

Another question is when is end of mission? TPA Milestone M-045-70 currently lists complete waste retrieval from remaining SSTs to be December 31, 2040. TPA Milestone M-045-00 currently lists complete closure of SST farms by January 31, 2043. RPP-RPT-60192, *System Plan, Revision 8, Lifecycle Cost Analysis*, lists dates as late as FY 2078 for closure. So, the end of mission (i.e., SST closure) appears to be between 2043 and 2078 based on various funding/planning scenarios.

API 653 would suggest a 15-year period to the next integrity assessment, but its applicability to concrete tanks is limited.

8.1.5.3 Materials of Construction/Characteristics of the Wastes

The materials of the SSTs are listed in several sections of this report. The characteristics of the wastes of the SSTs are also listed, primarily in Section 5.0. The conclusions of those sections is that the materials of the SSTs are compatible with the wastes.

This is especially true for interim stabilized waste, and the relatively benign future operating conditions, when compared to the more aggressive operating conditions of the past. Interim stabilized waste does not attack concrete or steel reinforcing. The vapor space is also in a less demanding condition and is being visually observed. The one concern is intrusion water that could cause re-liquification of stabilized waste. But even then, any attack on concrete would be localized and not cause damage to significant portions of the tank structure.

Structurally the AORs show tanks are compliant with code even considering conservative material properties and applied loads. The Dome Deflection Survey Program should identify if there are any structural concerns. The survey limits are reported to have a factor of safety of about 3 above collapse. The allowed loads on the tanks are controlled to conservative limits based on the analyses.

8.1.5.4 Other Relevant Factors

The SSTs are in a less demanding mode than earlier in their lives:

- 594 °F maximum temperature, currently most are less than 100 °F
- Pumpable liquids have been removed, so lower hydrostatic pressure
- Dome Deflection Survey Program should identify if there are any structural concerns
- Dome load limits being carefully controlled.

As a result, any degradation rates should be lower now than experienced in the early years.

8.1.5.5 Conclusion

This 2018 IAR recommends the following:

1. 22 years based on the previous interval between assessments.
2. 15 years based on API 653, but limited applicability to concrete tanks.

Unlike the 2002 IAR where complete closure was expected in 22 years, this IAR does not have such an expectation. Additionally, as tanks are closed, the amount of waste would be decreasing. Again, that was a consideration in 2002 but not for this report.

The API is not really applicable to concrete tanks. Based on these two periods, it was decided to weight the periods ¾ to API and ¼ to the previous assessment, rounded down to the nearest year, which is 16 years. Sixteen years is also consistent with the period between the 2002 assessment and this 2018 assessment. Therefore:

2018-13: Complete the next integrity assessment in 16 years (by September 31, 2034) for the SSTs.

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RPP-56892, 2014, *Independent Qualified Registered Professional Engineer Installation Integrity Assessment Report for C-107 MARS-S Slurry Pump Replacement – IQRPE Installation Integrity Assessment Report No. IA-259835-01*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

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RPP-RPT-49993, 2014, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type I Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

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RPP-RPT-55951, 2015, *Fiscal Year 2013 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-56141, 2014, *FY2013 DNV DST and SST Corrosion and Stress Corrosion Cracking Testing Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-56390, 2014, *IQRPE Integrity Assessment Report for C-105 Waste Retrieval Project Phase 2,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-57096, 2014, *Examination of Simulated Non-Compliant Waste from Hanford Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58239, 2015, *Fiscal Year 2014 Visual Inspection Report for Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58254, 2014, *Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58300, 2015, *Fiscal Year 2014 DST and SST Chemistry Testing Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58849, 2015, *Fiscal Year 2015 Visual Inspection Report for Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-59272, 2017, *Fiscal Year 2016 Visual Inspection Report for Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60093, 2018, *Fiscal Year 2017 Visual Inspection Report for Single-Shell Tanks,* DRAFT, Washington River Protection Solutions, LLC, Richland, Washington.

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RPP-RPT-60565, 2018, *Fiscal Year 2018 Visual Inspection Report for Single-Shell Tanks,* DRAFT, Washington River Protection Solutions, LLC, Richland, Washington.

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APPENDIX A

PERSONNEL QUALIFICATIONS

Paul Giever, PE, SE

Independent Qualified Registered Professional Engineer

Mr. Giever has over 30 years of civil/structural engineering related experience and currently serves as Structural Technical Manager. As a Lead Engineer, he is responsible for the structural design of steel, concrete, masonry, and wood structures. His extensive experience includes nuclear, industrial, medical facilities, laboratories and commercial facilities. He has done integrity assessments per WAC-173-303-640 for tank systems as the Independent Qualified Registered Professional Engineer. Other areas of expertise include the structural design of nuclear facilities, commercial tanks, pressure vessels, multi-level buildings, rehabilitation of trusses and foundation designs for pre-engineered metal buildings. He has also been involved in designing normal and seismic loads of nuclear, industrial, public commercial buildings, schools, and hospitals and plan checking of steel, concrete, masonry, timber and highway bridge structures.

Education

Master of Science, Civil Engineering, University of Idaho, 1988

Bachelor of Science, Civil Engineering, University of Idaho, 1986

Registrations/Licenses/Certifications

Professional Civil Engineer (PE): Washington (as well as 28 additional states)

Professional Structural Engineer (SE): Washington (as well as 19 additional states)

Project Experience

100-D Septic Tank, Hanford, WA

100-H Expansion, Hanford, WA

105 Construction Assistance, Hanford, WA

105-KE ISS SSE Design, Hanford, WA

109-N Demolition Support, Hanford, WA

116-C-3 Tank Remediation, Hanford, WA

200W Pump & Treat Injection Building 2, Hanford, WA

200W Lime Treatment Project, Hanford, WA

242-A Evaporator Integrity Assessment, Hanford, WA

291-S Control House, Hanford, WA

308-A Reactor, 309 Reactor & 340 Building, Hanford, WA

B-Reactor RAWP Support, Hanford, WA

B12 Structural Evaluation, Hanford, WA

B75 Analysis on Flex Building, Hanford, WA

Conditioned Storage Building, 200E Area, Hanford, WA

Diesel Generator Building, Hanford, WA

Double-Shell Tank System Integrity Assessment, Hanford, WA

Excavation Sluice Pit at Tank 241-C102, Hanford, WA

K-Basin Filter Mockup Skid, Hanford, WA

KW Annex Modification, Hanford, WA

L-691, 200W Sewer Lagoon Building, Hanford, WA

LAW Annex - Structural/Plumbing, Hanford, WA

Leak Check Tank Analysis, Richland, WA

N-Reactor Overbuild, Hanford, WA

Remedial Action for 100N Area Waste Sit, Hanford, WA

Vit Plant Duct Calculations - Analytical, Hanford, WA

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THIS CERTIFIES THAT THE PERSON OR BUSINESS NAMED BELOW IS AUTHORIZED AS A

ENGINEERING/LAND SURVEYING CORPORATION

PE: PAUL MICHAEL GIEVER

[redacted]

710	12/05/1986	10/31/2018
License Number	Issued Date	Expiration Date

Pat Kohler

Pat Kohler, Director

Jill Shuttleworth, PE, SE

Subject Matter Expert – Structural Engineer

Mrs. Shuttleworth has over 34 years of experience in structural engineering related experience. She is responsible for the design of steel, concrete, masonry and wood structure. Her extensive experience includes commercial, agricultural, religious, schools and residential structural design. She has been involved with the design of new structures and rehabilitation of existing structures.

Education

Master of Science, Civil Engineering, Washington State University, 1985

Bachelor of Science, Civil Engineering, Washington State University, 1984

Registrations/Licenses/Certifications

Professional Civil Engineer (PE): Washington (as well as Oregon and Idaho)

Professional Structural Engineer (SE): Washington (as well as Oregon and Idaho)

Professional Affiliations

National Council of Engineering Exam Services, Structural Exam Committee

National Council of Structural Engineering Associations

Structural Engineers Association of Washington, Past State President

Project Experience

242-A Evaporator Integrity Assessment, Hanford, WA

Ammonia Receiver Foundation, Burbank, WA

Areva NP Site Seismic Documentation Support, Richland, WA

AX Air and Water Service Building, Hanford, WA

B75 Analysis on Flex Building, Hanford Area, Richland, WA

DG HVAC Enclosure, Hanford, WA

Double-Shell Tank System Integrity Assessment, Hanford, WA

ELO Building - Raffinate Tanks Support Analysis, Hanford, WA

Energy Northwest DG HVAC Enclosure, Richland, WA

Energy Northwest Standby Service Water Connector, Richland, WA

Existing Gasoline Storage Tank Structural Analysis, Richland, WA

KW Basin Annex Modification, Richland, WA

Limerick Generating Station, Pottstown, PA

Single-Shell Tank Structural Integrity Assessment, Hanford, WA

Standby Service Water Connector, Hanford, WA

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PROFESSIONAL ENGINEER
CIVIL, STRUCTURAL

JILL T SHUTTLEWORTH
[redacted]

25811	01/27/1989	03/17/2020	Pat Kohler
License Number	Issued Date	Expiration Date	Pat Kohler, Director

Andrew Klein, PE

Senior Engineer/Chemical

EXPERIENCE

Consulting Engineer, May 2006 to Present

Self-Employed - Founded ***A S Klein Engineering, PLLC*** *in January 2013, Pasco, WA*

Prior to its founding, consulted for Marshall A. Klein & Associates, Inc., based in Eldersburg, MD

- Acted as the independent waste compatibility subject matter expert (SME) for Hanford Tank Farms to assess the likelihood and severity of consequences of both reactions within the waste and corrosion/degradation caused by waste properties on containment materials. Waste-contacting materials were thoroughly investigated including stainless steels, carbon steels, bronze, compressed asbestos, PTFE (Teflon), PVDF (Kynar) and PEEK. Polymer films in pump and valve pits including Amercoat, Amerlock 400FC epoxy and polyuria were confirmed to be compatible with tank wastes in the event of primary containment failure.
- Performed third-party reviews/inspections on the selection and installation of gaskets in bolted flange connections throughout an entire semiconductor fabrication campus. Selection of adequate gaskets, including gasket-specific certificates for tightness coefficients (gasket factors), was verified. Inspection was performed after installation to ensure compliance with ASME and EN standards including: verification of proper torqueing and re-torqueing, spring washer locations, washer/flange material combinations, gasket material compatibility with process fluids, etc.
- Assessed the overall Tank Farms Contractor corrosion mitigation program that specified maintaining tank waste properties within specifications, assessing the resultant waste combinations before transfer or mixing, waste sampling, confirmation of annulus tank ventilation and annulus video inspections.
- Reviewed the chemical compatibility of gases and chemicals upon mixing and with duct, pipe, flange and gasket materials for a semiconductor fabrication campus. Chemicals included acids, bases, solvents, and fabrication waste.

- Consulted on the proper storage of chemicals, separation based on incompatibilities, secondary containment measures, and fire protection and life safety adequacy for chemical storage warehouses to ensure compliance with the International Fire Code, OSHA regulations and governing standards.
- Performed design reviews and inspections on chemical storage systems, chemical processing systems, tools and machinery to confirm whether design theories would work as intended, that materials were compatible and that operations were code-compliant.
- Performed design review, inspections, and fire hazard analyses for high-hazard occupancies and special use buildings (e.g., semiconductor, gas/chemical storage, heavy mechanical, coating/dipping operations, refrigerated storage warehouses, Hanford infrastructure, specialty gas processes).
- Performed building and system plan review for compliance with the International Codes (e.g., IBC, IFC, IMC), legacy codes (Uniform, BOCA, and Standard), NFPA codes and standards, ASME standards, SEMI standards and a variety of other referenced standards.
- Technical code and standard committee representation for a variety of client interests.
- Investigated the compatibility of antifreeze solutions with piping and sealing components in residential sprinkler systems.
- Created spreadsheet programs for hydraulic calculations ranging from pressure losses in waste water treatment piping systems to sizing programs for automatic fire sprinkler systems. Transformed the Plumbing Engineering and Design Handbook of Tables into a standalone program for the American Society of Plumbing Engineers (ASPE).

Process Flowsheet Engineer, July 2007 to January 2013

URS Corporation, River Protection Project – Hanford Waste Treatment Plant (WTP): Richland, WA

- Process Engineer responsible for the validation of the design for a $12 billion nuclear waste treatment plant.
- Analyzed the predicted composition of waste, close to 200 compounds, within all systems throughout the WTP.
- Verified the material compatibility of ultrafilters with Hanford waste and that the erosion corrosion was below specified limits based on process demand and throughput requirements.
- Reviewed the effects of chemical and radiological degradation on ion exchange resins to determine the estimated number of regeneration cycles that can be realized before resin replacement. Determined the estimated total cesium loading for each cycle based on the resin degradation calculations.
- Analyzed exhaust compositions from the WTP for compliance with Washington State Department of Ecology and Environmental Protection Agency (EPA) standards.
- Performed design review of the following systems: exhaust and scrubbers, ion exchange, ultrafiltration, evaporators, melters, transfer and mixing pumps.

- Managed the calculation and implementation of RAMI data within an Operations Research model.
- Composed reports ranging from in-house technical documentation to U.S. Department of Energy (DOE) contract-deliverable assessments.

Evaporation and Distillation Products Specialist, October 2006 to June 2007

Buchi Corporation, New Castle, DE

- Provided onsite bench-scale evaporation and distillation technical support for the U.S. customer base.
- Advised customers on appropriate consumable material selections for their bench-scale products based on the proposed equipment and chemical use.
- Drafted technical documents and presentations to help the U.S. sales team and customers understand governing scientific principles of evaporation and vapor recovery.

PROFESSIONAL LICENSES

Licensed Professional Chemical Engineer (WA Lic. #47831)

Licensed Professional Fire Protection Engineer (WA Lic. #47831)

EDUCATION

Master of **Engineering & Technology Management**, 2010

Washington State University, Tri-Cities, WA

Graduate Certificates in Engineering Management & Project Management

Bachelor of Science in **Chemical Engineering**, 2006

University of Delaware, Newark, DE

Minors in Chemistry & Mathematics

PROFESSIONAL SOCIETY MEMBERSHIPS & COMMITTEE APPOINTMENTS

American Institute of Chemical Engineers (AIChE)
Member
2006 – Present

Association of Energy Engineers (AEE)
Member
2010 – Present

Benton-Franklin Council of Governments (BFCG)
Board Member
Benton-Franklin Economic Development Council
2014 – Present
Committee Member
Comprehensive Economic Development Strategies (CEDS) Strategy Committee
2014 – Present

International Association of Plumbing & Mechanical Officials (IAPMO)
Technical Committee Member
Uniform Solar Energy & Hydronics Code (USEHC)
2013 – Present

International Code Council (ICC)
Member
2012 – Present
Code Development Committee Member
International Energy Conservation Code (IECC) – Commercial Code
2015 – 2017 Code Development Cycle

National Fire Protection Association (NFPA)
Technical Committee Member
NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages
2012 – Present
NFPA 101/5000, Life Safety Code: Industrial, Storage & Misc. Occupancies
2012 – Present

Society of Fire Protection Engineers (SFPE)
Member
2014 – Present

STATE OF WASHINGTON

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THIS CERTIFIES THAT THE PERSON OR BUSINESS NAMED BELOW IS AUTHORIZED AS A

PROFESSIONAL ENGINEER
CHEMICAL, FIRE PROTECTION

ANDREW SCOTT KLEIN
[redacted]

47831	01/03/2011	01/12/2020	Pat Kohler
License Number	Issued Date	Expiration Date	Pat Kohler, Director

CHEMMET, LTD., PC

JAMES R. DIVINE
Chief Engineer

EXPERTISE

- Evaluation of the safe and proper use of engineering materials including the investigation of corrosion and degradation of metals and polymers in waste management, nuclear, construction, and industrial operations.
- Selection of materials of construction for waste processing systems including alkaline and acid (HNO_3 and HF) solutions.
- Independent oversight of hazardous waste system designs and construction.
- Chemical interactions of high level wastes.
- Mitigation of buried materials degradation including materials selection.
- Application of chemical and electrochemical engineering principles to industrial processes.
- Inter-disciplinary information exchange with emphasis on chemistry and engineering.

EDUCATION

UNIVERSITY

BS. (with honors)	Chemical Engineering University of California, Berkeley
PhD	Chemical Engineering (minors: Chemistry & Mathematics) Oregon State University, Corvallis

INDUSTRY (Selected Courses)
Arctic Engineering, Univ. of British Columbia
Principles of Safety Evaluation for Managers
Hazardous Waste Operator 24 hour Training for Supervisors with 8 hour Refreshers

PROFESSIONAL CERTIFICATIONS

Registered/licensed professional engineer in Washington (#12231), Alaska (#EC 5925), Idaho (#10292), Oregon (#17,054), and Maryland (#21365)

Corrosion Specialist (#867) certified by the NACE International

Registered with the **National Council of Examiners for Engineering and Surveying** (#13634)
Registered with the **USCIEP International Registry of Professional Engineers** (#137)

Authorized Chemical-terrorism Vulnerability Information (CVI) User, Dept. of Homeland Security: CVI-20100712-1055509

EXPERIENCE

— Current Responsibilities

In 1991, Dr. Divine was instrumental in organizing ChemMet, Ltd., PC, a licensed professional services engineering corporation for which he serves as Chief Engineer. He is in charge of the management of chemical and corrosion engineering tasks including environmental assessment efforts, evaluation of operational safety in industrial and nuclear facilities including the use of toxic and hazardous chemicals, and the development of programs that combine the principles of chemistry and materials.

Some of his recent projects involve:

- ◊ Selection of materials for a proposed nuclear-waste treatment plant;
- ◊ Member Corrosion Assessment Technical Advisory Group for the Washington (DC) Suburban Sanitary Commission Bi-County Water Tunnel;
- ◊ Evaluation of cracking of stainless steel and corrosion of carbon steel in high-temperature wood product process systems;
- ◊ Services as an independent qualified registered professional engineer (IQRPE) for several Hanford nuclear waste tank farm piping systems during design and construction;
- ◊ Metallurgical and corrosion evaluation of the failure of bolts on valves on potable water lines;
- ◊ Studies on and evaluation of aqueous corrosion and erosion in piping;
- ◊ Evaluation of pitting in acid drain systems;
- ◊ Corrosion and metallurgical evaluation of welded chlorination water treatment skids for West Valley Nuclear;
- ◊ Participation in a corrosion study of welds, conducted at the Columbia Basin College welding department;
- ◊ Participation in the oversight committee for the USDOE Rapid Commercialization Initiative;
- ◊ Participation in a technical review of international waste storage at Idaho Falls National Engineering Laboratory as one of three nationally selected NACE corrosion experts;
- ◊ Oversight of corrosion design evaluations for the US Army Corps of Engineers, Alaska;
- ◊ Corrosion monitoring and evaluation of the safety of Hanford nuclear waste storage tanks and underground waste sites;
- ◊ Corrosion evaluations, including integrity assessments, of waste and chemical processing operations;
- ◊ Failure analysis of agricultural systems;
- ◊ Mechanical and chemical evaluation of polymers for use at waste treatment and disposal sites;
- ◊ Evaluation of coated systems used at national waste treatment site;
- ◊ Evaluation of buried stainless steel pipe corrosion.

He has been an Adjunct Faculty Member of the Chemical Engineering Department at the Tri-Cities Campus of Washington State University. He has taught courses in fluid flow, heat transfer, thermodynamics, and corrosion as well as review courses in mathematics.

— Prior to 1991

Dr. Divine joined Battelle-Northwest in 1965 and was primarily concerned with studying corrosion mechanisms and kinetics in high-temperature water. He participated in programs aimed at establishing the effects of process parameters, including fluid hydraulics, heat flux, and radiation, on corrosion processes, corrosion product transport and deposition. Dr. Divine was also associated with studies on the dissolution of uranium and plutonium oxides, corrosion processes in nonaqueous solvent systems, and the electrodeposition of coatings on thin wires. During this period, he contributed to three invention reports and was a co-author of a US patent. He also developed, from a basic concept, a research program on corrosion of grinding steel in the mining industry that included international participants.

In 1974, he joined Westinghouse Hanford Company as a Senior Process Chemical Engineer for the development of the Acid Digestion Process for the reduction of combustible transuranic waste volumes.

During this period, he conceived of a novel method of processing acidic off-gasses to reduce their effective corrosiveness, which was prepared as an invention report, collaborated on the development of methods of waste volume reduction, and assisted in the preparation of Safety Analysis Reports.

He returned to Battelle-Northwest in 1978 as a Senior Research Engineer where he conducted studies on corrosion and the mass transport of corrosion products in aqueous systems as well as studies on chemical decontamination of nuclear reactor systems. He also consulted on refinery failures due to corrosion and metallurgy. As Technical Leader of the Electrochemical and Corrosion Processes Group, he had the added responsibility of monitoring the technical performance of a group of eight professionals while serving as project manager for his own programs. He participated in and guided activities to promote and market the capabilities of the group and section.

In 1983 - 1985, while serving as Technical Leader, he was promoted Staff Engineer. During this period, he oversaw several technical programs as well as simultaneously serving in an administrative position. Typical programs included:

- A corrosion and metallurgical evaluation program on storage tank construction materials in simulated Hanford caustic waste mixtures which included developing and evaluating methods for in-tank corrosion monitoring.
- Development of inert anodes and cathodes for aluminum production by chemical and metallurgical engineering methods and by electrode reaction mechanisms studies using ac/dc methods.
- Evaluation of atmospheric corrosion in Alaska to extend the database of the contiguous United States into the Cold Regions.

He served as Manager, Corrosion and Metallurgy Section, 1985-1989. During this period, he oversaw an average of 30 (maximum of 55) exempt and non-exempt staff, an average annual section funding of about $5,000,000, a capital equipment inventory with a value of over $6,000,000, and over 35,000 ft^2 of facility space.

He provided technical and safety oversight on programs in the areas of: Corrosion Testing; High-temperature and High-pressure pH and Conductivity Sensor Development; Chemical Cleaning (Nuclear and Chemical Systems); Geothermal System Materials Monitoring; Hazardous Waste Barrier Development; DOE/Industry Technology Transfer; Operation of a 100-Unit Autoclave Facility; Basic Electrochemical Processes of Stress Corrosion Cracking; and Natural Gas Pipeline Corrosion.

Administratively he promoted the expansion of program development into new technical areas with the participation of all professional members of the section staff. He worked towards the simplification of the preparation of proposals, and instigated centralized control of Section Quality Assurance records to provide expeditious management oversight, increase staff acceptance to new regulations, and hold down costs. He developed and implemented a safety plan and training records system for the section that was copied for use at higher administrative levels. He also had developed and implemented an equipment inspection procedure for high temperature/pressure test equipment.

While Section Manager, Dr. Divine maintained his own technical activities where he consulted with corporate, national, and local groups, primarily on corrosion and environmental effects on materials including the testing of improved clothing materials exposed to surety agents. He conducted studies as the principal investigator in these areas. A 15-20% level of effort was allocated to these technical efforts.

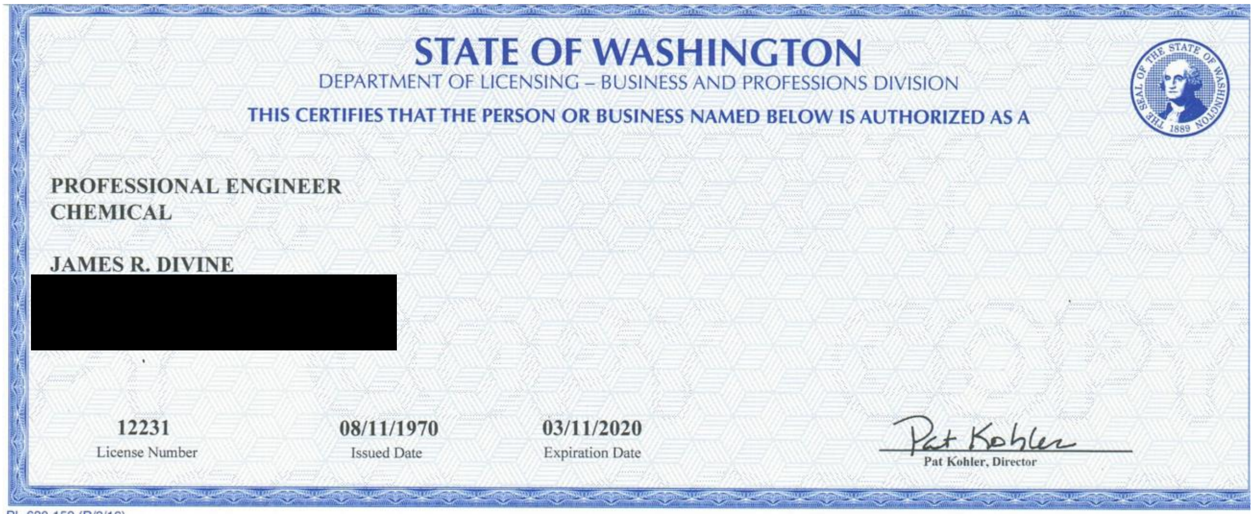
Following his tenure as Section Manager, he served as Principal Investigator and Project Manager for corrosion and materials test programs. Typical programs included studies on the corrosion of Hanford waste tanks and processing operations, the corrosion of steel in Hanford soil, and the testing and evaluation of polymeric liners for waste storage sites.

SELECTED COURSES TAUGHT

- Session on Fluid Mechanics for the ChemEng PE Refresher course in March, 1970, WSU-Tri-Cities
- Corrosion Short Course, with Dr. R. S. Johnson, at Idaho National Engineering Laboratory, July, 1994
- Sessions on Toxicology and Confined Space Entry for Hazardous Waste Operator Courses, 1996 through 2005
- Session on Stoichiometry for the ChemEng PE Refresher course in August, 1996, WSU-Tri-Cities
- Session on Materials for MechEng PE Refresher course in September, 2002, Bechtel National
- Session on BWR Corrosion, with a translator, to staff of the Bilibino Nuc. Pwr. Sta., Russia, in Anchorage, AK, October, 1997

PROFESSIONAL AFFILIATIONS

—	American Chemical Society	**Member - Emeritus**
—	American Institute of Chemical Engineers, AIChE	**Sr Member - Emeritus**
—	American Water Works Association, AWWA	**Member**
—	American Society for Testing & Materials, ASTM	**Member**
—	ASM International	**Member**
—	Association of Consulting Chemists & Chemical Engineers	**Member**
—	NACE International (The Corrosion Society)	**Fellow - Life Member**
—	National Society of Professional Engineers, NSPE	**Lic. Member - Life**
—	Society of Plastics Engineers, SPE	**Sr Member**



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PROFESSIONAL ENGINEER
CHEMICAL

JAMES R. DIVINE
[redacted]

12231	08/11/1970	03/11/2020	Pat Kohler
License Number	Issued Date	Expiration Date	Pat Kohler, Director

PL-630-159 (R/3/16)

NACE INTERNATIONAL INSTITUTE
CORROSION SPECIALIST

James Divine
Cert No. 867 Expires: May 31, 2019
The person to whom this has been issued has fulfilled the examination and experience requirements of the NACE Institute in order to attain the status of *Corrosion Specialist* certification.

Clinton A. Wilson, PE | Geotechnical Engineer

EDUCATION

BS, Forest Engineering, Oregon State University, 2001
Graduate Studies, Civil (Geotechnical) Engineering, Washington State University, 2001-2003

REGISTRATION

Professional Engineer-Civil, Oregon, 65542
Professional Engineer-Civil, Washington, 44864

EXPERIENCE OVERVIEW

Clint is a project manager with about 15 years of engineering experience. His geotechnical experience includes projects involving rock excavation, shallow and deep foundations, and construction on slopes. His areas of expertise include rock competency characterization, foundation design, global stability, pavement assessment, and roadway planning and design. Clint has performed geotechnical engineering for a variety of nuclear facilities, including for decommissioning and demolition activities and new facilities, highways and bridges, dams, levees, canals, tunneled and open-excavation pipelines, tanks, and commercial and residential development projects in Washington, Oregon, Idaho, Nevada, Utah, and California.

LOW-ACTIVITY WASTE PRETREATMENT SYSTEM (LAWPS) PROCESSING FACILITY, HANFORD RESERVATION, WA. Project Manager. The LAWPS is part of an overall system to vitrify nuclear material processing waste currently held in single- and double-shell tanks. Clint was responsible for the day-to-day management and coordination of Shannon & Wilson's geotechnical design services, including scope, fee, and contract negotiations; training coordination of our personnel and subcontractors; execution of field explorations and testing (test pits, CPTS, borings up to 375 feet deep, and downhole and surface geophysical testing); laboratory testing; subsurface characterization for both static and dynamic analyses, and geotechnical engineering analyses for design and construction of temporary and permanent shoring, spread footing and mat foundations.

C-105 HEEL PIT REMOVAL, HANFORD RESERVATION, WA. Project Manager/Engineer. Shannon & Wilson provided geotechnical services for the C-105 Heel Pit Removal project within the 241-C Tank Farm. The C-105 tank is scheduled for Mobile Arm Retrieval System (MARS) deployment. The MARS deployment requires removal of the C-105 Heel Pit, an approximately 65-kip concrete box located over the tank riser, so that a large hole may be cut through the C-105 tank top. The 241-C Tank Farm consists of an array of closely-spaced approximately 75-foot-diameter tanks interconnected by waste transfer lines. Significant construction site constraints consist of: 1) the outrigger pad proximity to the open excavation, 2) a concrete encasement extending below grade from the C-05C Sluice Pit to CR-153, and 3) hoses located in a 12-inch-deep ditch and covered with a 2-inch steel plate extending within close proximity to another outrigger. Washington River Protection Solutions (WRPS) plans to excavate around the pit to cut off all interconnecting pipes, then excavate as necessary to gain access below the heel pit for rigging placement. Our report presented a summary of our literature and data review, a description of the existing site geology, and the results of our engineering evaluations of the proposed crane setup. Evaluations included global stability analyses of the excavation with the proposed crane placement, including outrigger pad bearing resistance and stress distribution. We developed the excavation stability model for various outrigger pad sizes and locations relative to the proposed excavation top of cut.

300 AREA DECOMMISSIONING AND DEMOLITION, HANFORD RESERVATION, WA. Project Manager/Engineer. Shannon & Wilson has provided geotechnical services for multiple projects in the 300 Area involving deep excavations, heavy lifts, crane and other equipment placement on slopes for the removal of buildings, facilities, and contaminants. Three projects to date have included the following:

Building 309 Plutonium Recycle Test Reactor (PRTR) Removal. The 309 Building complex included a former reactor building and various support structures. Reactor removal required a gantry crane on dual rails straddling the deep reactor vessel. Our report provided earthwork, lateral earth pressure, and subgrade modulus recommendations, and seismic design criteria.

321 Building/Excavation. Shannon & Wilson provided a slope stability assessment to allow for steeper than 1½H:1V slopes along some excavation portions.

340 Vault Removal. Shannon & Wilson completed an initial assessment of the 340 Vault support options to allow for lift beam and jacking framework installation. We provided allowable bearing capacity for the chosen lateral pipe pile supports and the jacking pads located at the vault corners for the lift structure. Later, Shannon & Wilson completed plate load tests along the vault area access ramp to increase our knowledge of the exposed material properties, thereby providing justification for an increased bearing capacity for the lateral pipe pile supports with frequent deflection monitoring. We also provided a slope stability assessment for the support crane located near the crest of the excavation west slope.

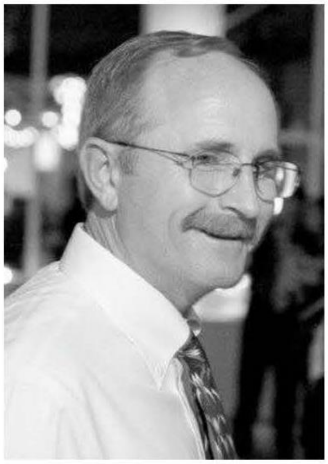
105-KE OVERBUILD, HANFORD RESERVATION, WA. Project Manager/Engineer. Shannon & Wilson provided geotechnical services for the 105-KE Reactor Overbuild project in the Hanford Site's 100 East Area. The 105-KE Reactor produced weapons-grade plutonium from about 1955 to 1971. Most of the facilities were deactivated when operations were halted. Subsequent environmental studies concluded that operations, disposal practices, spills, and unplanned releases resulted in contamination of facility structures and underlying soil and groundwater. Shannon & Wilson's services were provided to the design engineer preparing plans to construct an interim safe storage (ISS) facility over the remaining reactor building. The ISS facility will be constructed upon a minimum of 23 feet of import fill due to contaminated soil remediation. The underlying soils below the imported fill are contaminated, which restricts the construction means, methods, and efforts. Our report presented a subsurface conditions review summary and provided earthwork, foundation, lateral earth pressure, and subgrade modulus recommendations, and current seismic design criteria for the fill placement and structure foundations.

COLUMBIA RIVER HDD CROSSING, BENTON & FRANKLIN COUNTIES, WA. Project Manager/Engineer. The US Department of Energy (DOE), through their consultant Cascade Natural Gas Corporation (CNG), proposes to construct an approximately 30-mile-long natural gas transmission pipeline through Franklin and Benton Counties, which will require a Columbia River undercrossing. One potential undercrossing location stretches from the Esquatzel Wasteway, on the Franklin County side, to the south Hanford 300 Area. Shannon & Wilson has provided geotechnical services for the potential Esquatzel Route undercrossing, including a desktop geotechnical study, land-based explorations including sonic rotary borings on the Franklin County side of the river, laboratory testing, and preparation of a geotechnical report for preliminary design of the undercrossing. 2013

ISFSI EXPANSION, RICHLAND, WA. Project Manager/Engineer. Shannon & Wilson provided geotechnical services for a planned Independent Spent Fuel Storage Installation (ISFSI) expansion consisting of three new pads measuring approximately 260 feet long, 30 feet wide, and 2 feet thick. Field explorations and testing included ground penetrating radar (GPR), test pits, and plate load tests. Clint prepared a report that presented our site evaluation, including review of Shannon & Wilson's extensive geotechnical and geological studies for the CGS over many decades, and conclusions and recommendations in support of the proposed design and construction. 2014

BASE POINT, INC.

Scott W. Seiler
Regulatory Compliance Specialist



CAPABILITIES

Management Leadership: Thirty-five years of results oriented leadership, with a substantial record of successfully managing diverse activities in challenging environments. Experienced in regulatory compliance and government contracting.

Program and Project Management: Successful planning and execution of multiple complex projects involving systems engineering, risk analysis, and regulatory compliance for construction, operations, demolition, and remediation projects.

Regulatory Compliance: Trained and experienced in the compliance application of a full suite of local, state, and federal environmental, building, and land use codes and standards. Extensive experience applying these requirements on Federal sites.

EXPERIENCE

1999-current **Base Point, Inc. – President**
Small business providing program and project management, infrastructure assessments, environmental compliance, and land use planning.

Relevant Regulatory Compliance Projects:

IQRPE Regulatory Compliance, Meier A.E, 2006 - current: Providing CFR and WAC compliance assessments for IQRPE Hanford Tank Operations reviews. Requires in depth understanding of 40CFR 265, Subpart J & WAC 173-303-640.

IQRPE Program, Tank Operations Contractor, 2003 - 2006: Developed and implemented a compliant IQRPE program within TOC at Hanford. Required extensive understanding and communication of 40CFR 265, Subpart J & WAC 173-303-640 requirements. Program has been operating in compliance since then.

Tank Waste Vitrification Baseline, Tank Operations Contractor, 2000-2003: Management support developing the first inclusive Tank Waste Baseline. Supported subsequent DOE HQ reviews, and then environmental compliance and Tri-Party Agreement negotiations with the State of Washington. Required knowledge of a full suite of environmental requirements, including RCRA, CERCLA, TOSCA, Air, Water, Land Use, etc.

Long Term Stewardship, DOE-RL, 1999-2001: Developed Hanford Site Long Term Stewardship Plan and Hanford Site Institutional Controls Plan, which was signed by the Tri-Parties in 2002. Required in-depth knowledge of RCRA and CERCLA post closure liabilities and obligations.

BASE POINT, INC.

1996-1999 **ICF Kaiser International, Inc. – Program Manager, Consulting Group**
Provided environmental compliance services to federal and state clients across the U.S.

Relevant Regulatory Compliance Projects:

Transport & Disposal Options, Kaiser-Hill, Rocky Flats, 1999-2000: Lead options analysis for transportation and disposal of nuclear facilities debris. Results used in public and regulatory information and decision processes to determine best path for site clean-up. Required extensive knowledge and presentation of road and rail safety and compliance requirements, as well as disposal criteria and costs, including NHTSA, MUTCD, HAZMAT, and Intermodal Traffic Analyses.

American Medical - License Review, Nuclear Regulatory Comm., 1999: Feasibility review and witness support for the cleanup and closure of an abandoned radiological source manufacturing facility in Cleveland, Ohio. Assessed existing conditions and recommended compliance actions. Required in-depth understanding of Federal and State of Ohio environmental standards.

Closure Strategy, Kaiser-Hill, Rocky Flats, 1996-1999: Integration of infrastructure closure requirements with demolition, transportation, and disposal strategies. Resulted in Quadrant Closure Plan, which led to site closure. Required knowledge and application of demolition, transportation, and disposal standards – in conjunction with necessary infrastructure support requirements.

1989-1996 **ICF Kaiser Hanford – Manager, Site Planning Division**
Life cycle planning for general support facilities, infrastructure, and land use.

Relevant Regulatory Compliance Projects:

Comprehensive Land Use Plan, 1993-1996: Initiated and implemented Hanford Site Land Use Planning process, in order to support end-state clean-up decision making. Included establishing the Future Site Uses Working Group, which became the Hanford Advisory Board. Required in-depth knowledge of RCRA and CERCLA process standards, in conjunction with State and Local land use laws.

General Facilities Demolition Program, 1990-1993: Burned, imploded, and demolished 62 General Purpose Facilities across the Hanford Site. Included nuclear and hazardous materials removal and disposal, as well as incorporation of Clean Air and Clean Water Standards into work planning and regulatory approval processes.

1987-1989 **Boeing Advanced Systems Division – Administrator, Capital Assets Program**
Coordinated capital and strategic facility planning and implemented projects for this division of Boeing in Seattle.

Relevant Regulatory Compliance Projects:

Duwamish Riverfront Reclamation, 1988: Remediated contaminated soils and sedimentation, in order to allow reuse of the site for industrial purposes. Required in-depth knowledge and integration of EPA, USACE, State of Washington, and Port of Seattle environmental requirements.

BASE POINT, INC.

1985-1987 **City of Bellevue, Washington – Manager, Design and Development Dept.**
Responsible for permitting process for jurisdiction located directly east of Seattle.

Relevant Regulatory Compliance Projects:

Steep Slopes and Wetland Developments, 1985-1987: Extensive application and negotiation of sensitive area requirements for development of land. Required in-depth knowledge of Federal, State, and City environmental protection rules, City land use – zoning requirements, and Uniform Building Code.

1982-1985 **Rockwell Hanford Operations – Project Manager, Facilities Department**
Responsible for facility and infrastructure upgrade projects.

1980-1982 **Benton County Planning Department, Washington – Associate Planner**
Defined and implemented both short and long range land use plans, codes, and standards. Required extensive public and political contact, while ensuring compliance with state and local laws and requirements for development within the County.

1979-1980 **Washington State University, Facilities Department – Design / Draftsman**
Responsible for the design and implementation of grounds and facilities improvement projects. Included transportation upgrades, campus-wide signs program, land use assessment, and an athletic complex re-development project.

EDUCATION

BS, Land Architecture, Washington State University, 1980
Supplemental Tracks: Civil Engineering
Urban and Regional Planning

TRAINING

Real Property Management Practices
Uniform Building Code Plans Review
Activity Based Planning and Management
NEPA / CERCLA / RCRA Requirements and Processes
40 hr Hazardous Waste Training (expired)
Behavior Based Safety Training

AFFILIATIONS

International Facilities Management Association
International Conference of Systems Engineers
American Institute of Certified Planners
Tri-Cities Industrial Development Council
West Richland Planning Commission (past chair)

AWARDS

Washington State Planning Achievement Award, 1983
Westinghouse Quality Achievement Award, 1991
DOE Office of River Protection Recognition Award, 2001

CLEARANCES

Department of Energy 'Q' – Inactive
Department of Defense 'Secret' – Inactive

In addition to the Subject Matter Experts, Meier would like to thank the assistance of:

Ahrens, Rick, Meier, P.E., S.E.

Butterfield, Alex, Meier, P.E.

Cockbain, Anthony, Meier, P.E. and Project Manager

Mahoney, Leiloni, Lucas, Technical Editor

Matthews, Shari, Meier, Technical Editor

Shumway, Kristi, Meier, P.E.

APPENDIX B

COMPLIANCE MATRIX

LIST OF TABLES

COMPLIANCE MATRIX OVERVIEW

This compliance matrix is to be a summary cross reference from *Washington Administrative Code* (WAC) and *Hanford Federal Facility Agreement and Consent Order – Tri Party Agreement* (TPA) milestone requirements to the subject matter expert (SME) assessment activities, SME primary reference documents, and SME compliance conclusions. This matrix summarizes this 2018 Single- Shell Tank Structural Integrity Assessment Report (IAR) and serves as a guide to the report. The main text of this IAR provides a much more complete description of assessment activities, references and conclusions.

Table B-1 is a summary of all the compliance matrixes by the Independent Qualified Registered Professional Engineer (IQRPE). Compliance matrixes Tables B-3 to B-7 are broken down by each area of SME review and then summarized in Table B-1 by the IQRPE. For example, the corrosion SME Table B-5 does not cover age of tanks, that information is covered under the structural SME Table B-3 and then summarized in Table B-1. Table B-2 is to provide a crosswalk between the tables.

TPA Interim Milestone M-045-91I defines this 2018 IAR as:

> " ... an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonable certify. The analysis supporting the certification shall be performed in accordance with the requirements identified for analysis in WAC 173-303-640(2)... IQRPE certification of the SST leak integrity is not required. ..."

Thus, leak integrity is not part of this assessment. Additionally, TPA Interim Milestone M-045-91I limits the integrity assessment to the structural integrity of the 100-series and 200-series single-shell tanks. In summary, whenever the assessment report uses the terms "tank system" or "ancillary equipment" it means the 100-series and 200-series single-shell tanks. See Section 1.3 for definitions.

An "N/A" in the Compliance Matrix identifies a non-applicable requirement of WAC 173-303-640(2).

Table B-1: IQRPE Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
	(2) Assessment of existing tank system's integrity.			
SST IQRPE Assessment	(a) For each existing tank system[1], the owner or operator must determine that the tank system is not leaking[2] or is unfit for use[3]. Except as provided in (b) of this subsection[4], the owner or operator must obtain and keep on file at the facility a written assessment reviewed and certified by an independent, qualified registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that attests to the tank system's integrity by January 12, 1988, for underground tanks that do not meet the requirements of subsection (4) of this section and that cannot be entered for inspection[5], or by January 12, 1990, for all other tank systems[6].	1. Prepared this 2018 IAR.	1. Primary items assessed would include all the documents listed in this column in this Table B-1.	SSTs have structural integrity and the IQRPE has certified the report per WAC 173-303-810 (13)(a), see page ii of report.
SST IQRPE Assessment	(b) Tank systems that store or treat materials that become dangerous wastes subsequent to January 12, 1989, must conduct this assessment within twelve months after the date that the waste becomes a dangerous waste.[7]	N/A	N/A	N/A
SST IQRPE Assessment	(c) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following:	1. Reviewed AORs.	1. RPP-RPT-49989, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49990, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type III Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49991, *Single-Shell Tank Integrity Project Analysis of Record Tank to Tank Interaction Study of the Hanford Single-Shell Tanks.* RPP-RPT-49992, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type IV*	1. and 2. Structural strength: Based on the modern FEA AORs and the concrete and rebar tests, the structure has a large safety margin over collapse. Therefore, the SSTs have structural integrity.

[1] As stated in the Introduction to the Compliance Matrix, every reference to tank systems are just the SSTs themselves.
[2] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[3] SSTs have already been declared unfit for use per DOE Letter 02-OMD-036, so this IAR does not alter this status.
[4] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.
[5] SST tanks are underground tanks and do not meet the requirements of subsection 4 and cannot be entered.
[6] Since the SSTs are classified under previous footnote, the SSTs do not qualify as other tank systems in this subsection.
[7] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.

Table B-1: IQRPE Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
			Single-Shell Tank Thermal and Operating Loads and Seismic Analysis. RPP-RPT-49993, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type I Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49994, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record – Single-Shell Tank Integrity Project Analysis of Record.*	
		2. Reviewed results of concrete core drilling reports.	2. RPP-RPT-54564, *Inspection and Test Report for the Removed 241-C-107 Dome Rebar.* RPP-RPT-58254, *Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project.*	
		3. Reviewed whether waste causes degradation of concrete or corrosion of rebar.	3. RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel.* HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018,* Rev. 366.	3. to 6. Compatibility with the waste: Interim stabilized waste does not cause degradation of concrete. Intrusion water could cause waste to be re-liquified, but volumes are insignificant and even then the attack would be localized. Waste does not cause corrosion of rebar. Therefore, SSTs have structural integrity.
		4. Reviewed operating specifications.	4. OSD-T-151-00013, *Operating Specifications for Single-Shell Waste Storage Tanks.*	
		5. Reviewed intrusion water concerns.	5. See Sections 5 and 7.	
		6. Reviewed previous 2002 IAR.	6. RPP-10435, *Single-Shell Tank System Integrity Assessment Report*.	
		7. Reviewed Dome Load Program.	7. RPP-16660, *200 Series SST Dome Load Capacity (200 B, C, T, and U).*	7. Dome Load Program should be enforced to ensure SSTs are not overloaded.

Table B-1: IQRPE Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
			RPP-20473, *Design and Dome Load Criteria for Hanford Waste Storage Tanks.* RPP-16363, *Tank-Specific Allowable Dome Load for Hanford-Site 100-Series Single-Shell.* RPP-CALC-35333, *Impact of Increasing Tank Radius by One Foot on Dome Load Calculation in RPP-33431.* TFC-ENG-FACSUP-C-10, *Control of Dome Loading and SSC Load Control.* RPP-19747, *Engineering Management Assessment Dome Load Control Program.* RPP-21916, *Engineering Management Assessment of The Tank Farms Dome Load Controls Program.* RPP-ASMT-27757, *Engineering Management Assessment of the Dome Load Program.* TFC-PLN-142, *Dome Loading Management Plan.*	
SST IQRPE Assessment	(i) Design standard(s), if available, according to which the tank system was constructed;	1. Reviewed 2002 IAR	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	Design standards were appropriate for original structural design.
SST IQRPE Assessment	(ii) Dangerous characteristics of the waste(s) that have been and will be handled;	1. Reviewed previous 2002 IAR for waste compatibility conclusions. 2. Reviewed whether waste causes degradation of concrete or corrosion of rebar. 3. Reviewed operating specifications for waste criteria.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.* 2. RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel.* 3. OSD-T-151-00013, *Operating Specifications for Single-Shell Waste Storage Tanks.*	Interim stabilized waste does not cause degradation of concrete. Intrusion water could cause waste to be re-liquified, but volumes are insignificant and even then the attack would be localized. Waste does not cause corrosion of rebar. Therefore, SSTs have structural integrity.

Table B-1: IQRPE Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
		4. Reviewed waste inventory reports.	4. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018,* Rev. 366.	
SST IQRPE Assessment	(iii) Existing corrosion protection measures;	1. Reviewed if waste is corrosive.	1. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018,* Rev. 366. RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel*	Although liner failure is not a direct structural effect, increased waste exposure to concrete and rebar could, in theory impact the structure. Studies, noted earlier, have indicated concrete and rebar were unaffected by long term elevated temperature contact with simulated waste. Therefore, SSTs have structural integrity.
SST IQRPE Assessment	(iv) Documented age of the tank system, if available (otherwise, an estimate of the age);	1. Reviewed 2002 IAR	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	Ages of tanks are well established.
SST IQRPE Assessment	(v) Results of a leak test[8], internal inspection, or other tank system integrity examination such that:	1. Reviewed Dome Deflection Program and surveys.	1. RPP-26516, *SST Dome Survey Program.* RPP-RPT-55202, *Dome Survey Report for Hanford Single-Shell Tanks.*	Dome Deflection Surveys should be continued at current frequency. Based on the Analyses of Record (AORs), since any dome deflection is potentially significant, tanks with deflections above 0.24 inches should be subject to annual surveys and a visual inspection. Since excessive deflection could be an early harbinger of dome failure, when the dome survey deflection exceeds 0.30”, a plan should be created to determine what is causing the displacement and how to stabilize the tank, if possible. This plan should be implemented prior to the displacement reaching 0.36”.

[8] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I, so there are no leak tests.

Table B-1: IQRPE Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
		2. Reviewed tank A-106 sidewall core.	2. RPP-CALC-53887, *SST 241-A-106 Sidewall Coring Structural Analysis Dome Loading and 4-In. Plug Removal from Tank Sidewall.* RPP-PLAN-50182, *Sampling and Analysis Plan for the Single-Shell Tank Sidewall Coring Project.* RPP-PLAN-50376, *Single-Shell Tank Sidewall Coring Project Sampling and Analysis Work Plan.* RPP-RPT-54764, *Independent Qualified Registered Professional Engineer (IQRPE) Report for Single-Shell Tank 241-A-106 Sidewall Coring Project.* RPP-RPT-58116, *Sidewall Core Drilling Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project.* RPP-RPT-58254, *Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project.*	2. to 4. As the opportunity presents, perform concrete compression on any concrete from the SSTs. This requires maintaining a program to facilitate testing of these concrete cores.
		3. IQRPE evaluation and test results.	3. See Table 3-1.	
		4. Reviewed tank C-107 dome core.	4. RPP-PLAN-48753, *Analytical Test Plan for the Removed 241-C-107 Dome Concrete and Rebar.* RPP-RPT-54564, *Inspection and Test Report for the Removed 241-C-107 Dome Rebar.* RPP-RPT-50934, *Inspection and Test Report for the Removed 241-C-107 Dome Concentrate.*	
		5. Reviewed visual inspection reports.	5. RPP-RPT-48194, *Fiscal Year 2010 Visual Inspection Report for Single-Shell Tanks.* RPP-RPT-51404, *Fiscal Year 2011 Visual Inspection Report for Single-Shell Tanks.*	5. Visual inspections of tanks should be continued. All the tanks should be done every 10 years. It is recommended to finish all the tanks, prior to further investigations of intrusion water.

Table B-1: IQRPE Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
			RPP-RPT-55951, *Fiscal Year 2013 Visual Inspection Report for Single-Shell Tanks.* RPP-RPT-58239, *Fiscal Year 2014 Visual Inspection Report for Single-Shell Tanks.* RPP-RPT-58849, *Fiscal Year 2015 Visual Inspection Report for Single-Shell Tanks.* RPP-RPT-59272, *Fiscal Year 2016 Visual Inspection Report for Single-Shell Tanks.*	In summary, SSTs have structural integrity. Next IAR should be in 16 years.
	(A) For nonenterable underground tanks, the assessment must include a leak test that is capable of taking into account the effects of temperature variations, tank end deflection, vapor pockets, and high water table effects[9]; and	N/A	N/A	N/A
	(B) For other than nonenterable underground tanks and for ancillary equipment, this assessment must include either a leak test, as described above, or other integrity examination, that is certified by an independent, qualified, registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that addresses cracks, leaks, corrosion, and erosion[10].	N/A	N/A	N/A
SST IQRPE Assessment	(e) The owner or operator must develop a schedule for conducting integrity assessments over the life of the tank to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The schedule must be based on the results of past integrity assessments, age of the tank system, materials of construction, characteristics of the waste, and any other relevant factors.	1. Prepared this 2018 IAR	1. RPP-IQRPE-50028, *Single-Shell Tank Structural Integrity Assessment Report.*	SSTs have structural integrity. Next IAR should be in 16 years. See Section 8 for more information.
		2. Reviewed Ecology 94-114 and API 653	2. Publication No. 94-114, *Guidance for Assessing and Certifying Tank Systems,* Department of Ecology, State of Washington, Olympia, Washington. API 653, 2014, *Tank Inspection, Repair, Alteration, and Reconstruction*.	
		3. Reviewed TPA milestones for waste retrieval and complete closure of SSTs	3. TPA Interim Milestone M-045-91I. TPA Milestone M-045-70. TPA Milestone M-045-00.	

[9] Although the SSTs are non-enterable underground tanks, Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[10] This subsection is not applicable since the SSTs are non-enterable underground tanks and ancillary equipment are not fit for use and not included in this assessment.

Table B-1: IQRPE Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
			ORP-11242 RPP-RPT-60192	
	SOW Requirements in Addition to the WAC:			
SST IQRPE Assessment	The assessment shall meet the requirements of TPA Interim Milestone M-045-91I. *"DOE shall provide to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify. The analysis supporting the certification shall be performed in accordance with the requirements identified for analysis in WAC 173-303-640(2) and will include a due diligence review of RPP-10435. IQRPE certification of the SST leak integrity is not required. A work plan and schedule for additional integrity assessment activities will be submitted as a-change package to cover any time period between the end date of the IORPE certification and the end date of the mission."*	1. Reviewed 2002 IAR	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	Certification is on page ii of the report. Section 8 has a discussion of when the next assessment should be completed and end of mission. SSTs have structural integrity. Next IAR should be in 16 years. See Section 8 for more information. This due diligence review of RPP-10435 is in Section 3.3. Overall, RPP-10435 was a very thorough report and did a commendable review of the available information.

Table B-2: Compliance Matrix Crosswalk

WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	IQRPE Table B-1	Structural Table B-3	Waste Compatibility Table B-4	Corrosion Table B-5	Geo-Technical Table B-6
(2) Assessment of existing tank system's integrity.					
(a) For each existing tank system[11], the owner or operator must determine that the tank system is not leaking[12] or is unfit for use[13]. Except as provided in (b) of this subsection[14], the owner or operator must obtain and keep on file at the facility a written assessment reviewed and certified by an independent, qualified registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that attests to the tank system's integrity by January 12, 1988, for underground tanks that do not meet the requirements of subsection (4) of this section and that cannot be entered for inspection[15], or by January 12, 1990, for all other tank systems[16].	X				
(b) Tank systems that store or treat materials that become dangerous wastes subsequent to January 12, 1989, must conduct this assessment within twelve months after the date that the waste becomes a dangerous waste.[17]	N/A	N/A	N/A	N/A	N/A
(c) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following:	X	X	X	X	X
(i) Design standard(s), if available, according to which the tank system was constructed;	X	X	X	X	X
(ii) Dangerous characteristics of the waste(s) that have been and will be handled;	X		X		
(iii) Existing corrosion protection measures;	X			X	
(iv) Documented age of the tank system, if available (otherwise, an estimate of the age);	X	X			
(v) Results of a leak test[18], internal inspection, or other tank system integrity examination such that:	X	X		X	
(A) For nonenterable underground tanks, the assessment must include a leak test that is capable of taking into account the effects of temperature variations, tank end deflection, vapor pockets, and high water table effects[19]; and	N/A	N/A	N/A	N/A	N/A
(B) For other than nonenterable underground tanks and for ancillary equipment, this assessment must include either a leak test, as described above, or other integrity examination, that is certified by an independent, qualified, registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that addresses cracks, leaks, corrosion, and erosion[20].	N/A	N/A	N/A	N/A	N/A
(e) The owner or operator must develop a schedule for conducting integrity assessments over the life of the tank to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The schedule must be based on the results of past integrity assessments, age of the tank system, materials of construction, characteristics of the waste, and any other relevant factors.	X	X	X	X	X
SOW Requirements in Addition to the WAC:					
The assessment shall meet the requirements of TPA Interim Milestone M-045-91I. *"DOE shall provide to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify. The analysis supporting the certification shall be performed in accordance with the requirements identified for analysis in WAC 173-303-640(2) and will include a due diligence review of RPP-10435. IQRPE certification of the SST leak integrity is not required. A work plan and schedule for additional integrity assessment activities will be submitted as a-change package to cover any time period between the end date of the IORPE certification and the end date of the mission."*	X	X	X	X	X

[11] As stated in the Introduction to the Compliance Matrix, every reference to tank systems are just the SSTs themselves.
[12] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[13] SSTs have already been declared unfit for use per DOE Letter 02-OMD-036, so this IAR does not alter this status.
[14] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.
[15] SST tanks are underground tanks and do not meet the requirements of subsection 4 and cannot be entered.
[16] Since the SSTs are classified under previous footnote, the SSTs do not qualify as other tank systems in this subsection.
[17] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.
[18] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I, so there are no leak tests.
[19] Although the SSTs are non-enterable underground tanks, Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[20] This subsection is not applicable since the SSTs are non-enterable underground tanks and ancillary equipment are not fit for use and not included in this assessment.

Table B-3: Structural Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
	(2) Assessment of existing tank system's integrity.			
SST Structural Assessment	(a) For each existing tank system[21], the owner or operator must determine that the tank system is not leaking[22] or is unfit for use[23]. Except as provided in (b) of this subsection[24], the owner or operator must obtain and keep on file at the facility a written assessment reviewed and certified by an independent, qualified registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that attests to the tank system's integrity by January 12, 1988, for underground tanks that do not meet the requirements of subsection (4) of this section and that cannot be entered for inspection[25], or by January 12, 1990, for all other tank systems[26].	See Table B-1	See Table B-1	See Table B-1
	(b) Tank systems that store or treat materials that become dangerous wastes subsequent to January 12, 1989, must conduct this assessment within twelve months after the date that the waste becomes a dangerous waste.[27]	N/A	N/A	N/A

[21] As stated in the Introduction to the Compliance Matrix, every reference to tank systems are just the SSTs themselves.
[22] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[23] SSTs have already been declared unfit for use per DOE Letter 02-OMD-036, so this IAR does not alter this status.
[24] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.
[25] SST tanks are underground tanks and do not meet the requirements of subsection 4 and cannot be entered.
[26] Since the SSTs are classified under previous footnote, the SSTs do not qualify as other tank systems in this subsection.
[27] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.

Table B-3: Structural Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
SST Structural Assessment	(c) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following::	1. Reviewed AORs	1. RPP-RPT-49989, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49990, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type III Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49991, *Single-Shell Tank Integrity Project Analysis of Record Tank to Tank Interaction Study of the Hanford Single-Shell Tanks.* RPP-RPT-49992, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type IV Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49993, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type I Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49994, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record-Single-Shell Tank Integrity Project Analysis of Record.*	See Section 4.12 and Appendix E 1.7.
		2. Reviewed 2002 IAR	2. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	
SST Structural Assessment	(i) Design standard(s), if available, according to which the tank system was constructed;	1. Reviewed 2002 IAR	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	See Section 4.2
SST Structural Assessment	(ii) Dangerous characteristics of the waste(s) that have been and will be handled;	See Table B-4	See Table B-4	See Table B-4
SST Structural Assessment	(iii) Existing corrosion protection measures;	See Table B-5	See Table B-5	See Table B-5
SST Structural Assessment	(iv) Documented age of the tank system, if available (otherwise, an estimate of the age);	1. Reviewed 2002 IAR	1. RPP-10435, 2002, *Single-Shell Tank System Integrity Assessment Report.*	See Section 4.1
SST Structural Assessment	(v) Results of a leak test[28], internal inspection, or other tank system integrity examination such that:	1. Reviewed Tank A-106 Sidewall Core IQRPE Evaluation and Test results.	1. RPP-RPT-58254, *Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project.* RPP-RPT-58116, *Sidewall Core Drilling Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project.*	1. SSTs have structural integrity, see Section 4.8.

[28] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I, so there are no leak tests.

Table B-3: Structural Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
		2. Reviewed Tank C-107 Dome Core IQRPE Report, and test results.	2. RPP-RPT-50934, *Inspection and Test Report for the Removed 241-C-107 Dome Concrete.* RPP-RPT-54564, *Inspection and Test Report for the Removed 241-C-107 Dome Rebar.*	2. SSTs have structural integrity, see Section 4.9.
		3. Reviewed Visual Inspection Reports.	3. RPP-RPT-48194*, Fiscal Year 2010 Visual Inspection Report.* RPP-RPT-51404, *Fiscal Year 2011 Visual Inspection Report*. RPP-RPT-55951 *Fiscal Year 2013 Visual Inspection Report.* RPP-RPT-58239 *Fiscal Year 2014 Visual Inspection Report.* RPP-RPT- 58849 *Fiscal Year 2015 Visual Inspection Report.* RPP-RPT- 59272 *Fiscal Year 2016 Visual Inspection Report.* RPP-RPT-60093 *Fiscal Year 2017 Visual Inspection Report.* RPP-RPT- 60565 *Fiscal Year 2018 Visual Inspection Report Draft.*	3. SSTs have structural integrity, see Section 4.10.
		4. Reviewed Dome Deflection Surveys.	4. RPP-26516, *SST Dome Survey Program.* RPP-RPT-55202, *Dome Survey Report for Hanford Single-Shell Tanks.*	4. SSTs have structural integrity, see Section 4.6.
	(A) For nonenterable underground tanks, the assessment must include a leak test that is capable of taking into account the effects of temperature variations, tank end deflection, vapor pockets, and high water table effects[29]; and	N/A	N/A	N/A
	(B) For other than nonenterable underground tanks and for ancillary equipment, this assessment must include either a leak test, as described above, or other integrity examination, that is certified by an independent, qualified, registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that addresses cracks, leaks, corrosion, and erosion[30].	N/A	N/A	N/A

[29] Although the SSTs are non-enterable underground tanks, Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[30] This subsection is not applicable since the SSTs are non-enterable underground tanks and ancillary equipment are not fit for use and not included in this assessment.

Table B-3: Structural Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
SST Structural Assessment	(e) The owner or operator must develop a schedule for conducting integrity assessments over the life of the tank to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The schedule must be based on the results of past integrity assessments, age of the tank system, materials of construction, characteristics of the waste, and any other relevant factors.	1. Reviewed Expert Panel Recommendations and Conclusions.	1. RPP-PLAN-45082, *Implementation Plan for the Single-Shell Tank Integrity Project.* RPP-RPT-43116, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project.* RPP-ASMT-59981, *Fifth Single-Shell Tank Integrity Project Expert Panel Meeting.*	SSTs have structural integrity. The IQRPE has recommended 16 years for the next IAR. See Section 8 for more information.
		2. Reviewed Tank A-106 Sidewall Core IQRPE Evaluation and Test Results.	2. RPP-RPT-58254, *Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project.* RPP-RPT-58116, *Sidewall Core Drilling Report for the Single-Shell Tank 241-A-106.*	
		3. Reviewed Tank C-107 Dome Core IQRPE Report and Test Results.	3. RPP-RPT-50934, *Inspection and Test Report for the Removed 241-C-107 Dome Concrete.* RPP-RPT-54564, *Inspection and Test Report for the Removed 241-C-107 Dome Rebar.*	
		4. Reviewed Visual Inspection Reports.	4. RPP-RPT-48194, *Fiscal Year 2010 Visual Inspection Report.* RPP-RPT-51404, *Fiscal Year 2011 Visual Inspection Report.* RPP-RPT-55951, *Fiscal Year 2013 Visual Inspection Report.* RPP-RPT-58239, *Fiscal Year 2014 Visual Inspection Report* . RPP-RPT-58849, *Fiscal Year 2015 Visual Inspection Report.* RPP-RPT-59272, *Fiscal Year 2016 Visual Inspection Report.* RPP-RPT-60093, *Fiscal Year 2017 Visual Inspection Report.* RPP-RPT-60565, *Fiscal Year 2018 Visual Inspection Report Draft.*	
		5. Reviewed Dome Deflection Surveys.	5. RPP-26516, *SST Dome Survey Program.* RPP-RPT-55202, *Dome Survey Report for Hanford Single-Shell Tanks.*	
		6. Reviewed AORs.	6. RPP-RPT-49994, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record Single-Shell Tank Integrity Project Analysis of Record.*	

Table B-3: Structural Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
		7. Reviewed 2002 IAR.	7. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	
	SOW Requirements in Addition to the WAC:			
SST Structural Assessment	The assessment shall meet the requirements of TPA Interim Milestone M-045-91I. *"DOE shall provide to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify. The analysis supporting the certification shall be performed in accordance with the requirements identified for analysis in WAC 173-303-640(2) and will include a due diligence review of RPP-10435. IQRPE certification of the SST leak integrity is not required. A work plan and schedule for additional integrity assessment activities will be submitted as a-change package to cover any time period between the end date of the IORPE certification and the end date of the mission."*	1. Reviewed 2002 IAR.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	1. SSTs have structural integrity, see Sections 3.1 and 3.3.
		2. Reviewed Expert Panel Recommendations and Conclusions.	2. RPP-PLAN-45082, *Implementation Plan for the Single-Shell Tank Integrity Project.* RPP-RPT-43116, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project.* RPP-RPT-45921, *Single-Shell Tank Integrity Expert Panel Report.* RPP-RPT-49272, *Fourth Single-Shell Tank Integrity Project Expert Panel Meeting.* RPP-ASMT-59981, *Fifth Single-Shell Tank Integrity Project Expert Panel Meeting August 26-29, 2014.*	2. SSTs have structural integrity, see Section 3.4.
		3. Reviewed AORs.	3. RPP-RPT-49994, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record Single-Shell Tank Integrity Project Analysis of Record.* RPP-11802, *Analysis of Record Summary for Single-Shell Tanks.*	3. SSTs have structural integrity, see Section 4.5 and Appendix E.
		4. Interviewed PNNL on AORs.	4. See Appendix E.	4. SSTs have structural integrity, see Appendix E.
		5. Reviewed Additional Analysis Performed on SSTs.	5. M&D-2054-002-CALC-001, *Seismic Analysis of Hanford Tank 241-C-107 for New 56-Inch-Diameter Dome Penetration.* RPP-CALC-49671, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105.* RPP-CALC-51195, *An Evaluation of Single-Shell Tank 241-C-105 for the Addition of a Large Penetration in the Tank Dome.* RPP-CALC-53887, *SST 241-A-106 Sidewall Coring Structural Analysis Dome Loading and 4-in. Plug Removal from Tank Sidewall.* RPP-PLAN-48753, *Analytical Test Plan for the Removed 241-C-107 Dome Concrete and Rebar.*	5. SSTs have structural integrity, see Sections 4.6 and 4.11.

Table B-3: Structural Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
		6. Reviewed Historic and Current Testing on Concrete and Reinforcing in the SSTs.	6. RHO-C-22, *Strength and Elastic Properties of Concrete from Waste Tank Farms.* RHO-C-40, *Strength and Elastic Properties of 1580-Day Hanford Concrete Cylinders at Room Temperature and 350F.* RHO-C-54, *Effects of Long-Term Exposure to Elevated Temperature on the Mechanical Properties of Hanford Concrete.* RHO-CD-1538, *Waste Tank 241-SX-115 Core Drilling Results.* RHO-RE-CR-2, *Effects of Moisture Loss Due to Radiolysis on Concrete Strength.* RPP-PLAN-50182, *Sampling and Analysis Plan for the Single-Shell Tank Sidewall Coring Project.* RPP-PLAN-50376, *Single-Shell Tank Sidewall Coring Project Sampling and Analysis Work Plan.* RPP-RPT-54764, *Independent Qualified Registered Professional Engineer (IQRPE) Report for Single-Shell Tank 241-A-106 Sidewall Coring Project.7* RHO-CD-1485, *Description of Potential Failure Modes for Single-Shell Waste Tanks.*	6. SSTs have structural integrity, see Sections 4.7, 4.8 and 4.9.
		7. Reviewed Tank Farms Technical Safety Requirements and Current Tank Loading.	7. HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements.*	7. SSTs have structural integrity, see Sections 4.4 and 4.5, and Appendix E.
		8. Reviewed Dome Control Program.	8. RPP-16660, *200 Series Single-Shell Tank Dome Load Capacity (200, B,C,T and U).* RPP-20473, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks.* RPP-16363, *Tank-Specific Allowable Dome Load for Hanford-Site 100-Series Single-Shell Tanks.* RPP-CALC-35333, *Impact of Increasing Tank Radius by One Foot on Dome Load Calculation in RPP-33431, Rev. 0.*	8. SSTs have structural integrity, see Section 4.6.

Table B-3: Structural Compliance (7 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
			TFC-ENG-FACSUP-C-10, *Control of Dome Loading and SSC Load Control.* RPP-19747, *Engineering Management Assessment Dome Load Control Program, FY2004-ENG-M-0011.* RPP-21916, *Engineering Management Assessment of The Tank Farms Dome Load Control Program (FY2004-ENG-M-0163).* RPP-ASMT-27757, *Engineering Management Assessment of the Dome Load Program.* TFC-PLN-142, *Dome Loading Management Plan.*	
		9. Reviewed Visual Inspection Plan.	9. RPP-PLAN-46847, *Visual Inspection Plan for Single-Shell Tanks and Double-Shell Tanks.*	9. SSTs have structural integrity, see Section 4.10.
				In summary, this due diligence review of RPP-10435 is in Section 3.3. Overall RPP-10435 was a very thorough report and did a commendable review of the available information.

Table B-4: Waste Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
	(2) Assessment of existing tank system's integrity.			
SST Waste Compatibility Assessment	(a) For each existing tank system[31], the owner or operator must determine that the tank system is not leaking[32] or is unfit for use[33]. Except as provided in (b) of this subsection[34], the owner or operator must obtain and keep on file at the facility a written assessment reviewed and certified by an independent, qualified registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that attests to the tank system's integrity by January 12, 1988, for underground tanks that do not meet the requirements of subsection (4) of this section and that cannot be entered for inspection[35], or by January 12, 1990, for all other tank systems[36].	See Table B-1	See Table B-1	See Table B-1
	(b) Tank systems that store or treat materials that become dangerous wastes subsequent to January 12, 1989, must conduct this assessment within twelve months after the date that the waste becomes a dangerous waste.[37]	N/A	N/A	N/A
SST Waste Compatibility Assessment	(c) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following:	1. Reviewed previous 2002 IAR for waste compatibility conclusions. 2. Reviewed operating specifications. 3. Reviewed waste inventory reports.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.* 2. OSD-T-151-00013, *Operating Specifications for Single-Shell Waste Storage Tanks.* 3. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018,* Rev. 366.	The chemical compositions of the wastes stored within the SSTs have been kept within acceptable limits so as to limit corrosion of SST materials. No new corrosion mechanisms have been identified since the 2002 IAR. Operating specifications ensure that the waste will continue to be stored, transferred, and monitored to limit effects on SSTs structural integrity.

[31] As stated in the Introduction to the Compliance Matrix, every reference to tank systems are just the SSTs themselves.
[32] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[33] SSTs have already been declared unfit for use per DOE Letter 02-OMD-036, so this IAR does not alter this status.
[34] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.
[35] SST tanks are underground tanks and do not meet the requirements of subsection 4 and cannot be entered.
[36] Since the SSTs are classified under previous footnote, the SSTs do not qualify as other tank systems in this subsection.
[37] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.

Table B-4: Waste Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
SST Waste Compatibility Assessment	(i) Design standard(s), if available, according to which the tank system was constructed;	1. Reviewed design standards of the tank to determine if materials of construction are compatible with the waste.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.* RHO-C-22, *Strength and Elastic Properties of Concretes from Waste Tank Farms.* RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel.*	Direct contact of saltcake with the reinforced concrete tanks is not expected to result in degradation. Liquid waste is expected to find direct paths through the reinforced concrete tanks and not result in degradation capable of structural impact.
SST Waste Compatibility Assessment	(ii) Dangerous characteristics of the waste(s) that have been and will be handled;	1. Determined if materials of construction are compatible with the waste stored in the tanks.	1. RHO-C-22, *Strength and Elastic Properties of Concretes from Waste Tank Farms*.	1 to 3. Direct contact of saltcake with the reinforced concrete tanks is not expected to result in degradation. Water intrusion is insignificant and liquid waste is expected to find direct paths through the reinforced concrete tanks and not result in degradation capable of structural impact.
		2. Reviewed historical waste conditions to determine if tank system conditions affect waste compatibility with materials of construction.	2. RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel*.	
		3. Evaluated if system materials of construction are sufficient to contain the dangerous waste stored in the tanks.	3. See Sections 5 and 7.	
		4. Evaluated waste chemistry within the tanks.	4. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018,* Rev. 366.	4. Estimated tank inventories by constituent obtained from the BBI indicate that tank waste characteristics pose no physical hazards to the SSTs integrity. Aging waste will not change this conclusion, as operating specifications adequately ensure the management of waste characteristics within the tank and also during/after transfers.
		5. Evaluated possible corrosion mechanisms due to water intrusion.	5. See Sections 5 and 7.	5. Water intrusion is insignificant and liquid waste is expected to find direct paths through the reinforced concrete tanks and not result in degradation capable of structural impact.
		6. Evaluated potential for flammable gas formation and design of system to prevent or contain flammable gas explosion.	6. RPP 13033, *Tank Farm Documented Safety Analysis.*	6. Administrative controls are sufficient to ensure a flammable gas event does not occur.

Table B-4: Waste Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
SST Waste Compatibility Assessment	(iii) Existing corrosion protection measures;	See Table B-5	See Table B-5	See Table B-5
SST Waste Compatibility Assessment	(iv) Documented age of the tank system, if available (otherwise, an estimate of the age);	See Table B-3	See Table B-3	See Table B-3
SST Waste Compatibility Assessment	(v) Results of a leak test[38], internal inspection, or other tank system integrity examination such that:	See Tables B-3 and B-5	See Tables B-3 and B-5	See Tables B-3 and B-5
	(A) For nonenterable underground tanks, the assessment must include a leak test that is capable of taking into account the effects of temperature variations, tank end deflection, vapor pockets, and high water table effects[39]; and	N/A	N/A	N/A
	(B) For other than nonenterable underground tanks and for ancillary equipment, this assessment must include either a leak test, as described above, or other integrity examination, that is certified by an independent, qualified, registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that addresses cracks, leaks, corrosion, and erosion[40].	N/A	N/A	N/A
SST Waste Compatibility Assessment	(e) The owner or operator must develop a schedule for conducting integrity assessments over the life of the tank to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The schedule must be based on the results of past integrity assessments, age of the tank system, materials of construction, characteristics of the waste, and any other relevant factors.	1. Determined schedule for future assessments of the waste stored in the tank system.	1. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018,* Rev. 366.	The characteristics of the tank waste, as currently managed, is likely not a driver of the schedule for conducting the next integrity assessment. The IQRPE recommends 16 years for the next IAR. See Section 8 for more information.
	SOW Requirements in Addition to the WAC:			
SST Waste Compatibility Assessment	The assessment shall meet the requirements of TPA Interim Milestone M-045-91I. *"DOE shall provide to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify. The analysis supporting the certification shall be performed in accordance with the requirements*	1. Determine schedule for future assessments of the waste stored in the tank system.	1. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018, Rev. 366.* RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel.*	As the SSTs age, corrosion will eventually breach all of the steel tank liners. The steel liner is non-structural and for the purposes of this report are consider failed, at least locally, such that there is direct exposure of waste to the reinforced concrete tank structure.

[38] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I, so there are no leak tests.
[39] Although the SSTs are non-enterable underground tanks, Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[40] This subsection is not applicable since the SSTs are non-enterable underground tanks and ancillary equipment are not fit for use and not included in this assessment.

Table B-4: Waste Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
	identified for analysis in WAC 173-303-640(2) and will include a due diligence review of RPP-10435. IQRPE certification of the SST leak integrity is not required. A work plan and schedule for additional integrity assessment activities will be submitted as a-change package to cover any time period between the end date of the IORPE certification and the end date of the mission."			Saltcake waste is not expected to attack the reinforced concrete tank upon direct exposure. Laboratory testing of waste simulants in contact with concrete and rebar at elevated temperatures for periods of up to 36 months did not result in either rebar corrosion or concrete degradation.
		2. Reviewed 2002 IAR.	2. RPP-10435, *Single-Shell Tank System Integrity Assessment Report*.	This due diligence review of RPP-10435 is in Section 3.3. Overall RPP-10435 was a very thorough report and did a commendable review of the available information.

Table B-5: Corrosion Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
	(2) Assessment of existing tank system's integrity.			
SST Corrosion Assessment	(a) For each existing tank system[41], the owner or operator must determine that the tank system is not leaking[42] or is unfit for use[43]. Except as provided in (b) of this subsection[44], the owner or operator must obtain and keep on file at the facility a written assessment reviewed and certified by an independent, qualified registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that attests to the tank system's integrity by January 12, 1988, for underground tanks that do not meet the requirements of subsection (4) of this section and that cannot be entered for inspection[45], or by January 12, 1990, for all other tank systems[46].	See Table B-1	See Table B-1	See Table B-1
	(b) Tank systems that store or treat materials that become dangerous wastes subsequent to January 12, 1989, must conduct this assessment within twelve months after the date that the waste becomes a dangerous waste.[47]	N/A	N/A	N/A
SST Corrosion Assessment	(c) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following:	1. Reviewed liner corrosion to see if it indicates a concern with the structural rebar.	1. HNF-EP-0182, 2018, Waste Tank Summary Report for Month Ending June 30, 2018, Rev. 366 RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel.*	Liner is considered not to "exist", that is, is assumed to have failed. Since waste is not aggressive to rebar, SSTs are acceptable for further use.
SST Corrosion Assessment	(i) Design standard(s), if available, according to which the tank system was constructed;	1. Reviewed design of the liner and determine if it was built to protected structure from waste.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	Design when built assumed liner protected structure from waste. Due to evidence of tank leaks, liner is considered not to "exist", that is, is assumed to have failed. Since the liner is non-structural and waste is not aggressive to rebar, SSTs are acceptable for further use.
SST Corrosion Assessment	(ii) Dangerous characteristics of the waste(s) that have been and will be handled;	See Table B-4	See Table B-4	See Table B-4
SST Corrosion Assessment	(iii) Existing corrosion protection measures;	1. Reviewed waste to determine if corrosive.	1. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018, Rev. 366.*	Although liner failure is not a direct structural effect, increased waste exposure to concrete and rebar could, in theory impact the structure. Studies, noted, have indicated concrete and

[41] As stated in the Introduction to the Compliance Matrix, every reference to tank systems are just the SSTs themselves.
[42] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[43] SSTs have already been declared unfit for use per DOE Letter 02-OMD-036, so this IAR does not alter this status.
[44] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.
[45] SST tanks are underground tanks and do not meet the requirements of subsection 4 and cannot be entered.
[46] Since the SSTs are classified under previous footnote, the SSTs do not qualify as other tank systems in this subsection.
[47] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.

Table B-5: Corrosion Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
			RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel.*	rebar were unaffected by long term elevated temperature contact with simulated waste
SST Corrosion Assessment	(iv) Documented age of the tank system, if available (otherwise, an estimate of the age);	See Table B-3	See Table B-3	See Table B-3
SST Corrosion Assessment	(v) Results of a leak test[48], internal inspection, or other tank system integrity examination such that:	1. Reviewed visual inspection reports.	1. RPP-RPT-48194*, Fiscal Year 2010 Visual Inspection Report.* RPP-RPT-51404, *Fiscal Year 2011 Visual Inspection Report*. RPP-RPT-55951, *Fiscal Year 2013 Visual Inspection Report*. RPP-RPT-58239, *Fiscal Year 2014 Visual Inspection Report*. RPP-RPT-58849, *Fiscal Year 2015 Visual Inspection Report*. RPP-RPT-59272, *Fiscal Year 2016 Visual Inspection Report*. RPP-RPT-60093, *Fiscal Year 2017 Visual Inspection Report*. RPP-RPT-60565, *Fiscal Year 2018 Visual Inspection Report Draft*.	Visual inspections show no structural deficiencies, therefore SSTs are acceptable for further use.
	(A) For nonenterable underground tanks, the assessment must include a leak test that is capable of taking into account the effects of temperature variations, tank end deflection, vapor pockets, and high water table effects,[49] and	N/A	N/A	N/A
	(B) For other than nonenterable underground tanks and for ancillary equipment, this assessment must include either a leak test, as described above, or other integrity examination, that is certified by an independent, qualified, registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that addresses cracks, leaks, corrosion, and erosion.[50]	N/A	N/A	N/A

[48] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I, so there are no leak tests.
[49] Although the SSTs are non-enterable underground tanks, Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[50] This subsection is not applicable since the SSTs are non-enterable underground tanks and ancillary equipment are not fit for use and not included in this assessment.

Table B-5: Corrosion Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
SST Corrosion Assessment	(e) The owner or operator must develop a schedule for conducting integrity assessments over the life of the tank to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The schedule must be based on the results of past integrity assessments, age of the tank system, materials of construction, characteristics of the waste, and any other relevant factors.	1. Reviewed waste characteristics for corrosion concerns.	1. HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018, Rev. 366.* RHO-RE-CR-8 P, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel.* OSD-T-151-00013, *Operating Specifications for Single-Shell Waste Storage Tanks.*	Waste and the residual liner prevents inspection of the lower regions of the concrete. Corrosion of the domed area appears negligible. No further corrosion inspections are deemed necessary. Therefore, SSTs are acceptable for further use. The IQRPE has recommended 16 years for the next IAR. See Section 8 for more information.
		2. Reviewed visual inspections.	2. RPP-RPT-48194, *Fiscal Year 2010 Visual Inspection Report.* RPP-RPT-51404, *Fiscal Year 2011 Visual Inspection Report*. RPP-RPT-55951 *Fiscal Year 2013 Visual Inspection Report.* RPP-RPT-58239 *Fiscal Year 2014 Visual Inspection Report.* RPP-RPT- 58849 *Fiscal Year 2015 Visual Inspection Report.* RPP-RPT- 59272 *Fiscal Year 2016 Visual Inspection Report.* RPP-RPT-60093 *Fiscal Year 2017 Visual Inspection Report.* RPP-RPT- 60565 *Fiscal Year 2018 Visual Inspection Report Draft.*	

Table B-5: Corrosion Compliance (4 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
	SOW Requirements in Addition to the WAC:			
SST Corrosion Assessment	The assessment shall meet the requirements of TPA Interim Milestone M-045-91I. *"DOE shall provide to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify. The analysis supporting the certification shall be performed in accordance with the requirements identified for analysis in WAC 173-303-640(2) and will include a due diligence review of RPP-10435. IQRPE certification of the SST leak integrity is not required. A work plan and schedule for additional integrity assessment activities will be submitted as a-change package to cover any time period between the end date of the IORPE certification and the end date of the mission."*	1. Reviewed visual inspection.	1. RPP-RPT-48194, *Fiscal Year 2010 Visual Inspection Report.* RPP-RPT-51404, *Fiscal Year 2011 Visual Inspection Report*. RPP-RPT-55951 *Fiscal Year 2013 Visual Inspection Report.* RPP-RPT-58239 *Fiscal Year 2014 Visual Inspection Report.* RPP-RPT- 58849 *Fiscal Year 2015 Visual Inspection Report.* RPP-RPT- 59272 *Fiscal Year 2016 Visual Inspection Report.* RPP-RPT-60093 *Fiscal Year 2017 Visual Inspection Report.* RPP-RPT- 60565 *Fiscal Year 2018 Visual Inspection Report Draft.*	Visible steel in the dome appears acceptable. Liner is considered not to "exist", that is, is assumed to have failed. Since the liner is non-structural and waste is not aggressive to rebar, SSTs are acceptable for further use.
		2. Reviewed 2002 IAR.	2. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	This due diligence review of RPP-10435 is in Section 3.3. Overall RPP-10435 was a very thorough report and did a commendable review of the available information.

Table B-6: GeoTech Compliance (3 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
	(2) Assessment of existing tank system's integrity.			
SST Geotechnical Assessment	(a) For each existing tank system[51], the owner or operator must determine that the tank system is not leaking[52] or is unfit for use[53]. Except as provided in (b) of this subsection[54], the owner or operator must obtain and keep on file at the facility a written assessment reviewed and certified by an independent, qualified registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that attests to the tank system's integrity by January 12, 1988, for underground tanks that do not meet the requirements of subsection (4) of this section and that cannot be entered for inspection[55], or by January 12, 1990, for all other tank systems[56].	See Table B-1	See Table B-1	See Table B-1
	(b) Tank systems that store or treat materials that become dangerous wastes subsequent to January 12, 1989, must conduct this assessment within twelve months after the date that the waste becomes a dangerous waste.[57]	N/A	N/A	N/A
SST Geotechnical Assessment	(c) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated, to ensure that it will not collapse, rupture, or fail. At a minimum, this assessment must consider the following:	1. Reviewed original soil design parameters.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	Original soil design parameters were appropriate.
		2. Reviewed design parameters in the AORs.	2. RPP-RPT-49989, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49990, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type III Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49991, *Single-Shell Tank Integrity Project Analysis of Record Tank to Tank Interaction Study of the Hanford Single-Shell Tanks.* RPP-RPT-49992, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type IV*	

[51] As stated in the Introduction to the Compliance Matrix, every reference to tank systems are just the SSTs themselves.
[52] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[53] SSTs have already been declared unfit for use per DOE Letter 02-OMD-036, so this IAR does not alter this status.
[54] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.
[55] SST tanks are underground tanks and do not meet the requirements of subsection 4 and cannot be entered.
[56] Since the SSTs are classified under previous footnote, the SSTs do not qualify as other tank systems in this subsection.
[57] WAC 296-173-640(2)(b) does not apply since the waste was hazardous prior to 1988.

Table B-6: GeoTech Compliance (3 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
			Single-Shell Tank Thermal and Operating Loads and Seismic Analysis. RPP-RPT-49993, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type I Single-Shell Tank Thermal and Operating Loads and Seismic Analysis.* RPP-RPT-49994, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record – Single-Shell Tank Integrity Project Analysis of Record.*	
		3. Reviewed intrusion water concerns.	3. See Section 7.	
SST Geotechnical Assessment	(i) Design standard(s), if available, according to which the tank system was constructed;	1. Reviewed soil design parameters.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	Original soil design parameters were appropriate.
SST Geotechnical Assessment	(ii) Dangerous characteristics of the waste(s) that have been and will be handled;	See Table B-4	See Table B-4	See Table B-4
SST Geotechnical Assessment	(iii) Existing corrosion protection measures;	See Table B-5	See Table B-5	See Table B-5
SST Geotechnical Assessment	(iv) Documented age of the tank system, if available (otherwise, an estimate of the age);	See Table B-3	See Table B-3	See Table B-3
SST Geotechnical Assessment	(v) Results of a leak test[58], internal inspection, or other tank system integrity examination such that:	See Tables B-3 and B-5	See Tables B-3 and B-5	See Tables B-3 and B-5
	(A) For nonenterable underground tanks, the assessment must include a leak test that is capable of taking into account the effects of temperature variations, tank end deflection, vapor pockets, and high water table effects[59]; and	N/A	N/A	N/A
	(B) For other than nonenterable underground tanks and for ancillary equipment, this assessment must include either a leak test, as described above, or other integrity examination, that is certified by an independent, qualified, registered professional engineer, in accordance with WAC 173-303-810 (13)(a), that addresses cracks, leaks, corrosion, and erosion60.	N/A	N/A	N/A

[58] Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I, so there are no leak tests.
[59] Although the SSTs are non-enterable underground tanks, Leak Assessment is not part of this IAR per TPA interim milestone M-045-91I.
[60] This subsection is not applicable since the SSTs are non-enterable underground tanks and ancillary equipment are not fit for use and not included in this assessment.

Table B-6: GeoTech Compliance (3 sheets)

Scope	WAC 173-303-640(2) Assessment of Existing Tank System's Integrity	Assessment Activities	Primary Items Assessed	Conclusions
SST Geotechnical Assessment	(e) The owner or operator must develop a schedule for conducting integrity assessments over the life of the tank to ensure that the tank retains its structural integrity and will not collapse, rupture, or fail. The schedule must be based on the results of past integrity assessments, age of the tank system, materials of construction, characteristics of the waste, and any other relevant factors.	1. Reviewed soil design parameters.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report*	SSTs have structural integrity. The IQRPE has recommended 16 years for the next IAR. See Section 8 for more information.
	SOW Requirements in Addition to the WAC:			
SST Geotechnical Assessment	The assessment shall meet the requirements of TPA Interim Milestone M-045-91I. *"DOE shall provide to Ecology, an IQRPE certification of SSTs structural integrity for the remainder of the mission, or for such time as the IQRPE believes he/she can reasonably certify. The analysis supporting the certification shall be performed in accordance with the requirements identified for analysis in WAC 173-303-640(2) and will include a due diligence review of RPP-10435. IQRPE certification of the SST leak integrity is not required. A work plan and schedule for additional integrity assessment activities will be submitted as a-change package to cover any time period between the end date of the IORPE certification and the end date of the mission."*	1. Reviewed 2002 IAR.	1. RPP-10435, *Single-Shell Tank System Integrity Assessment Report.*	This due diligence review of RPP-10435 is in Section 3.3. Overall, RPP-10435 was a very thorough report and did a commendable review of the available information.

APPENDIX C

LIST OF TANKS ASSESSED FOR STRUCTURAL INTEGRITY

Tank Farm	Tank Type	Tank Number	Has Structural Integrity
A	Type IV-B	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
AX	Type IV-C	101	YES
		102	YES
		103	YES
		104	YES
B	Type II	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
B	Type I	201	YES
		202	YES
		203	YES
		204	YES
BX	Type II	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES

Tank Farm	Tank Type	Tank Number	Has Structural Integrity
BX	Type II	108	YES
		109	YES
		110	YES
		111	YES
		112	YES
BY	Type III	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
C	Type II	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
C	Type I	201	YES
		202	YES
		203	YES
		204	YES

Tank Farm	Tank Type	Tank Number	Has Structural Integrity
S	Type III	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
SX	Type IV-A	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
		113	YES
		114	YES
		115	YES

Tank Farm	Tank Type	Tank Number	Has Structural Integrity
T	Type II	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
T	Type I	201	YES
		202	YES
		203	YES
		204	YES
TX	Type III	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
		113	YES
		114	YES
		115	YES
		116	YES
		117	YES
		118	YES

Tank Farm	Tank Type	Tank Number	Has Structural Integrity
TY	Type III	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
U	Type II	101	YES
		102	YES
		103	YES
		104	YES
		105	YES
		106	YES
		107	YES
		108	YES
		109	YES
		110	YES
		111	YES
		112	YES
U	Type I	201	YES
		202	YES
		203	YES
		204	YES

APPENDIX D

FINDINGS, OBSERVATIONS, AND RECOMMENDATIONS

D.1 FINDINGS

Findings are covered in Section 8.0 of this report.

D.2 OBSERVATIONS

This is a compilation of the observations from each of the sections of the report. For additional information, please refer to the respective section.

Section 4: Structural Assessment

- Original design standards for the tanks were appropriate.
- Concrete voids were observed during construction as shown in Figure 4-24 through Figure 4-28. Although those in the pictures were repaired, based on the number of observed void and the construction methodology, it is likely that some voids were located on the interior face of the concrete walls where they could not be observed or repaired. These voids would be insignificant and not reduce the structural integrity of the tanks.
- All 149 single-shell tanks (SSTs) have sufficient structural integrity to not fail, collapse, or rupture under anticipated operational and seismic loading and the tanks meet the requirements of code ACI 349-06, *Code Requirements for Nuclear Safety-Related Concrete Structures*. The maximum demand/capacity ratios for the baseline models were below 0.90 for the walls, haunch, and dome portions of the tanks.
- The analyses of record (AORs) show that the SST slabs are likely cracked and structurally separated from the foundation as a result of the thermal expansion and contraction. However, the AORs further show that the tanks remained stable and did not exceed their capacities when the slabs were removed from the analysis models.
- In addition to the baseline models, the AORs took into account tank-to-tank interaction (TTI) to determine the impact of closely spaced tanks, reviewed tank appurtenances to reflect conditions over the tanks, and performed a limit load analysis to determine the collapse loads.
- The load limit failure analysis showed that the factor of safety against collapse from static concentric surface loading is above 3.0 for Type II, III, and IV tanks. In addition, these failures presented with gross dome deflection (1.5 in. +) that will provide ample opportunity to predict failure prior to collapse with the current Dome Deflection Survey Program. See Appendix E.
- The 149 SSTs have been interim stabilized and the pumpable liquids have been removed.
- The wastes in the SSTs in C Tank Farm and tank S-112 have been retrieved. Therefore, 10% of the SSTs are essentially empty. Although these tanks are retrieved, they still must meet the WAC 173-303-640, "Tank Systems."
- The existing Dome Loading Monitoring Program prevents overloading the tank domes.
- The Dome Deflection Survey Program is to verify the dome deflections every two years or three years depending on the tank status.

- No excessive deflections or settlements that would indicate potential structural issues have been observed.
- The Dome Deflection Survey Program is adequate and is being followed.
- All of the concrete core samples that have been tested have exceeded the originally specified 28-day concrete design strength. In addition, the reinforcing that was tested meets the original yield strength requirements.
- SST visual inspections are scheduled to videotape all the tanks every tank every 10 years. Additional videos for tanks that have some abnormality observed are made.
- Additional analyses as required are performed for tanks that need to have new penetrations cut for retrieval of waste.
- Additional analyses are performed on tanks for larger or usual dome loading conditions that are not covered by RPP-20473, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks* (e.g., postulated equipment drop, large eccentric load, internal pressure pulse, impervious surface barriers), on a case-by-case basis.
- The procedures for structural assessments after a seismic event are outlined in TF-ERP-008, *Emergency Response Procedure 008 Seismic Event Response*, and TFC-ENG-DESIGN-C-30, *Post-Natural Phenomenon Hazard Assessment*.

Section 5: Waste Compatibility Assessment

- The knowledge of waste constituents is sufficient for waste compatibility purposes.
- Hydrogen mitigation and response program are adequate.
- Waste layers were identified in the SSTs that were not compliant with the DST chemistry control limits listed in OSD-T-151-00007, *Operating Specifications for the Double-Shell Storage Tanks*.
- As the SSTs age, corrosion will eventually breach all of the steel tank liners. The steel liner are non-structural and for the purposes of this report are consider failed, at least locally, such that there is direct exposure of waste to the reinforced concrete tank structure.
- Saltcake waste is not expected to attack the reinforced concrete tank upon direct exposure.
- Laboratory testing of waste simulants in contact with concrete and rebar at elevated temperatures for periods of up to 36 months did not result in either rebar corrosion or concrete degradation.
- Any liquid waste that comes into direct contact with the concrete tank is expected to find localized migration paths and is not a concern for the tank's structural integrity. This includes any re-liquification of the waste due to intrusion water.
- Currently, there are 22 SSTs with small surface water intrusions that have been observed during in-tank video inspections, and seven tanks with evidence of past intrusions based on increases in surface pool size, dome interior surface streaking, and other evidence. Volume of intrusion water is insignificant compared to the volume of the tank.
- Re-liquification of the waste due to intrusion water will not create waste that is outside of the waste acceptance criteria, so there are no compatibility concerns with the tank liner.

Section 6: Corrosion Assessment

- Corrosion does not appear to have been a major contributor to leaking of SSTs. The degree of liner, in-tank equipment, and riser corrosion is less than anticipated.
- Although liner failure is not a direct structural effect, increased waste exposure to concrete and rebar could, in theory, impact the structure. Studies, noted earlier, have indicated concrete and rebar were unaffected by long term elevated temperature contact with simulated waste, see Section 5.3.
- Although, for the historical record, it would be of interest to continue visual inspections of the tanks, there is no corrosion reason to do visual inspections. Further visual inspections are only useful for monitoring the concrete structure. Therefore, there are no recommendations for continuing visual inspections solely for liner corrosion
- Of the failed tanks visually inspected, only two (tanks T-111 and TX-114) appear to have significant liner corrosion as noted in Appendix G. Indeed, the leak cause matrix (Table 6-1) suggests the major failures were mostly due to poor liner design, bulging, thermal effects, or other causes with much less effect due to waste chemistry (corrosion). The failed tanks with "significant" waste chemistry effects had little observable corrosion.
- Generally corrosion appears to be localized – pitting or cracking. Large-scale liner failures appear to have been mechanically or thermally induced. The inference is that corrosion would not provide a pathway for sufficient fluid to significantly affect the reinforced concrete tank shell. A major mechanical failure due, say to a bulge, could expose a significant area of concrete to the waste – discounting the protective asphaltic layer.

Section 7: Geotechnical and Hydrogeological Impacts

- The soil design parameters were reasonable in the advanced AORs.
- The seismic design criteria in the AORs was conservative.
- Intrusion of water into the SSTs has been known to occur in recent years.
- Impervious barriers have been installed in the T and TY Tank Farms for the purpose of reducing the driving force for waste plumes under and around the outside of the tanks. Likewise, the impervious barriers were not installed to reduce intrusion water.
- The asphaltic coatings, where present, of the tanks should limit accumulation of intrusion water through the top of the dome concrete. An undamaged asphaltic coating in good initial condition has nearly an unlimited life. Any modifications to tanks need to require repair of this coating.

D.3 RECOMMENDATIONS

Recommendations are covered in Section 8.0 of this report.

D.4 REFERENCES

ACI 349-06, 2006, *Code Requirements for Nuclear Safety-Related Concrete Structures*, American Concrete Institute, Farmington Hills, Michigan.

OSD-T-151-00007, 2017, *Operating Specifications for the Double-Shell Storage Tanks,* Rev. 20, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-20473, 2004, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks,* Rev. 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

TF-ERP-008, 2017, *Emergency Response Procedure 008 Seismic Event Response,* Rev. O-4, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ENG-DESIGN-C-30, 2017, *Post-Natural Phenomena Hazard Assessment,* Rev. A-9, Washington River Protection Solutions, LLC, Richland, Washington.

WAC 173-303-640, "Tank Systems," *Washington Administrative Code,* as amended.

APPENDIX E

ANALYSIS OF RECORDS

TABLE OF CONTENTS

LIST OF TERMS

Acronyms and Abbreviations

3D	three-dimensional
ACI	American Concrete Institute
AOR	analysis of record
ASME	American Society of Mechanical Engineers
BEC	best estimate concrete
BES	best estimate soil
D/C	demand to capacity ratio
DST	double-shell tank
FEA	finite element analysis
FS	factor of safety
HSS	hollow structural section
IAR	integrity assessment report
IBC	International Building Code
IQRPE	Independent Qualified Registered Professional Engineer
LC	load case
MCE	maximum considered earthquake
NQA	Nuclear Quality Assurance
PL	point loading
PNNL	Pacific Northwest National Laboratory
SST	single-shell tank
TOLA	gravity, thermal, and operating loads analysis
TTI	tank-to-tank interaction
UL	uniform loading
V&V	verify and validate
WAC	*Washington Administrative Code*
WRPS	Washington River Protection Solutions, LLC

Units

%	percent
°	degree
°F	degrees Fahrenheit
ft	foot
ft^2	square foot
dia	diameter
gal	gallon
GB	gigabyte
in.	inch
in^2	square inch
kip	kilopound
ksi	kilopound per square inch
lb	pound
psf	pounds per square foot
psi	pounds per square inch

TRADEMARK DISCLOSURE

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E1.0 ANALYSES OF RECORD

E1.1 SCOPE

The purpose of this review is to summarize the various finite element analysis (FEA) evaluations performed on the single-shell tanks (SST). These analyses were done in response to Expert Panel Recommendation SI-1. Additionally, Expert Panel Recommendation SI-6 to develop and model appropriate material mechanic properties was also incorporated in these analyses. Since these analyses used modern analysis techniques and were the most extensive SST structural analyses to date, an in-depth review as part of this integrity assessment report (IAR) was deemed essential as a due diligence activity. This review is to document the types of analyses and to review these analyses for thoroughness and approach. These analyses have been reviewed and approved by industry experts, so this review is not a line-by-line check or a review for accuracy as each analysis of record (AOR) has had this task performed. The relevant documents reviewed for this section are as follows:

- RPP-46442, *Single-Shell Tank Structural Evaluation Criteria*
- RPP-46644, *Single-Shell Tank Integrity Project Analysis of Record – Preliminary Modeling Plan for Thermal and Operating Loads*
- RPP-RPT-49989, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*
- RPP-RPT-49990, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type III Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*
- RPP-RPT-49991, *Single-Shell Tank Integrity Project Analysis Tank to Tank Interaction Study of the Hanford Single-Shell Tanks*
- RPP-RPT-49992, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type IV Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*
- RPP-RPT-49993, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type I Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*
- RPP-RPT-49994, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record-Single-Shell Tank Integrity Project Analysis of Record*.

E1.1.1 Summary of Analyses of Record and Results

For each of the four types of SSTs, a model was created to evaluate the demand of the thermal, operating, and gravity loads on the tanks. These models were created and analyzed with ANSYS 12 for tank types II and III and ANSYS 13 for Types I and IV as well as for the tank-to-tank interaction (TTI) analysis. Separately, each of the SSTs were analyzed for the seismic demands with ANSYS 13. The design loads took into account the original design loads prescribed, bounding overburden soil depths, the IBC 2009, *International Building Code*, seismic criteria, idealized thermal loads based on recordings, and the ACI 349-06, *Code Requirements for Nuclear Safety-Related Concrete Structures*.

Each AOR was subjected to a thorough review and approval process that included internal reviews, client reviews, and external expert reviews until consensus was reached. The expert review was performed by Robert P. Kennedy, PhD of RPK Structural Mechanics and Anestis S. Veletsos, PhD, Professor Emeritus of Rice University.

Based on the design parameters and the induced loads, each of the tanks showed that the capacity to withstand loads exceeded the demand for the dome, haunch, and sidewalls. It was shown, for each tank, that the thermal demands on the slab exceeded the capacity. In each of these instances, the AORs concluded that the failure of the slab did not negatively impact the tanks stability, nor did the failure of the slab cause collapse.

E1.2 SINGLE-SHELL TANK ASSESSMENTS

E1.2.1 Analysis Criteria

For the Type I, II, and III AORs, the analysis parameters were selected in order to capture the most demanding conditions between all of the tanks within the type (e.g., the maximum soil height at the dome occurred at tank C-101 and the maximum temperature occurred in tank C-105 but for the purposes of the analysis both conditions were imposed on the same tanks). The Type IV tanks were comprised of three different designs: A, AX, and S Tank Farm tanks. The difference between the tanks included wall thickness, the dome slope, the strength of the concrete, the reinforcing details, the slab details, thermal histories, and design point loads. Through a combination of bounding conditions and sensitivity studies, analysis parameters were selected. The analysis parameters selected are listed in Table E-1.

Table E-1: Analysis Parameters

Parameter	Type I	Type II	Type III	Type IV
Concrete Strength, f'_c	3 ksi	3 ksi	3 ksi	3 ksi
Rebar Yield Strength, F_y	40 ksi	40 ksi	40 ksi	40 ksi
Height at Center of Dome	26 ft	31 ft	37 ft	44 ft
Inner Diameter	20 ft	75 ft	75 ft	75 ft
Volume	55,000 gal	530,000 gal	758,000 gal	1,000,000 gal
Point Load*	142 kip	200 kip	200 kip	270 kip
Uniform Load	40 psf	40 psf	40 psf	40 psf
Soil Height at Center of Dome	11.45 ft	10 ft	11 ft	7.51 ft
Max Temperature	250 °F	310 °F	300 °F	594 °F
Specific Gravity of Waste	1.7	1.7	1.7	1.7

Reference: RPP-RPT-49989, RPP-RPT-49990, RPP-RPT-49992, RPP-RPT-49993
* Includes weight of the appurtenances on the tank.

Creep is the phenomena where materials will undergo small distortions over time and is typically marked by an elongation and relaxation of internal stresses. For the purposes of this analysis, creep would lower the demand on the tanks. For this reason, the AORs performed analysis cases where creep was considered and was not considered.

Concrete strength is shown to be adversely affected by heat and upon cooling, the strength remains at a degraded level. The gravity model thus performs the thermal evaluation and returns the degraded concrete strength which is then used in the subsequent analyses.

E1.2.2 Methodology

Each type of tank was analyzed by different methods in order to determine the adequacy of the tanks under historical loads with the intent of determining if there were structural concerns. The types of analyses were as follows:

- Gravity, thermal, and operating loads analysis (TOLA)
- Seismic loading
- Combination of the TOLA and seismic results
- Tank-to-tank interaction (TTI)
- Load limit analysis
- Dome buckling analysis
- Appurtenances analysis.

E1.2.3 Gravity, Thermal, and Operating Loads Analysis for Type II, III, and IV Tanks

The TOLA model for the Type II, III, and IV tanks used a 3-dimensional, 2-degree slice of an axisymmetric model (see Figure E-1 through Figure E-4). This model used concrete elements and explicitly modeled the reinforcing in the dome, wall, knuckle, and slab. In the haunch, due to the complexity of the reinforcing, the reinforcing was idealized as strengthened elements that had equivalent properties to the composite reinforced concrete. The tanks were modeled with accurate geometry. Soil was modeled with extreme values intended to bound the range of soil conditions.

Sequence of construction was not considered in the AORs. For instance, in some tanks, the soil was backfilled against the tank side walls prior to dome construction and therefore the walls had a soil preload prior to dome and haunch being constructed. If future AORs are done, this refinement to consider sequence of construction should be considered. Nonetheless, it is anticipated that the sequence of construction would not significantly change the AOR results.

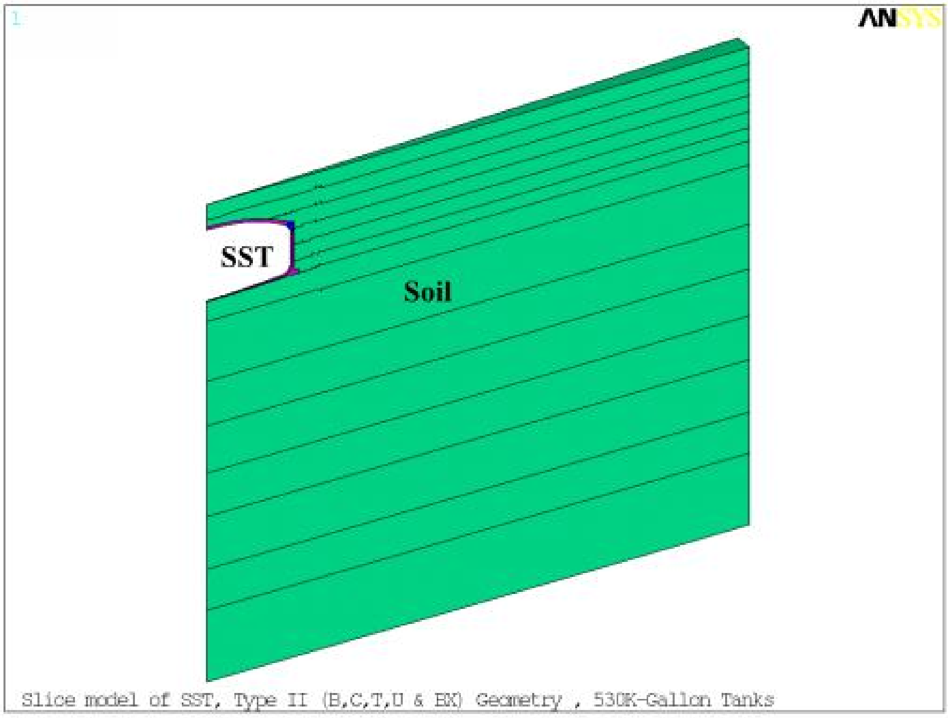

Figure E-1: Isometric View of TOLA Model (RPP-RPT-49989)

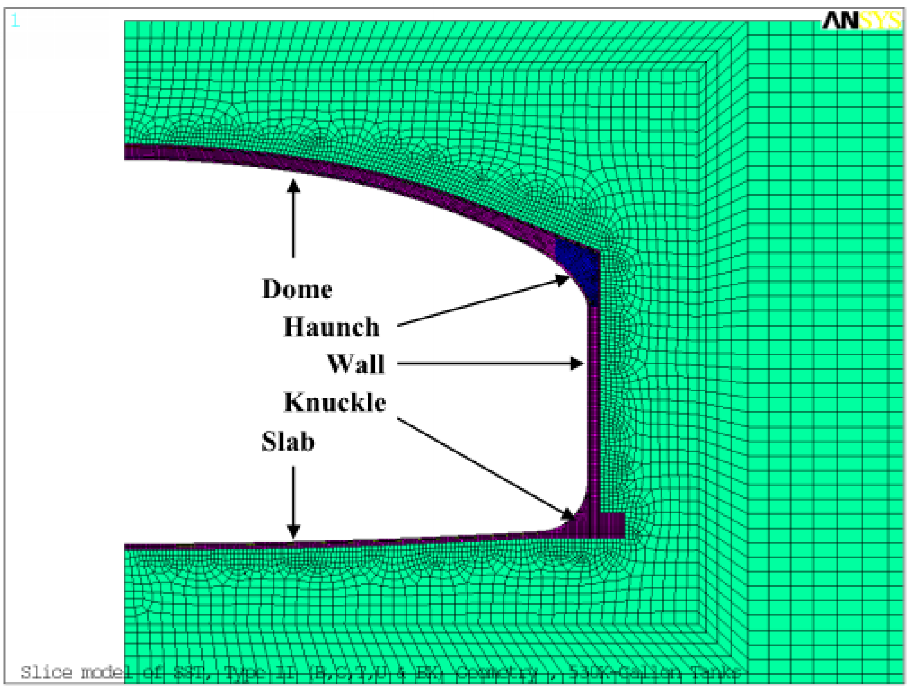

Figure E-2: Enlarged Axisymmetric View of TOLA Tank Model (RPP-RPT-49989)

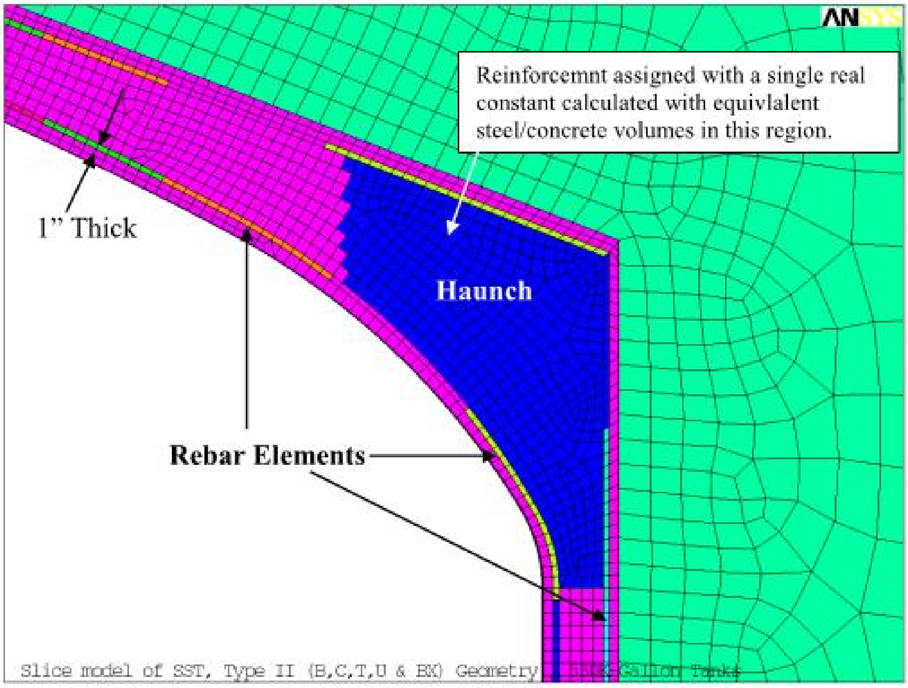

Figure E-3: Haunch Section with Modified Properties (RPP-RPT-49989)

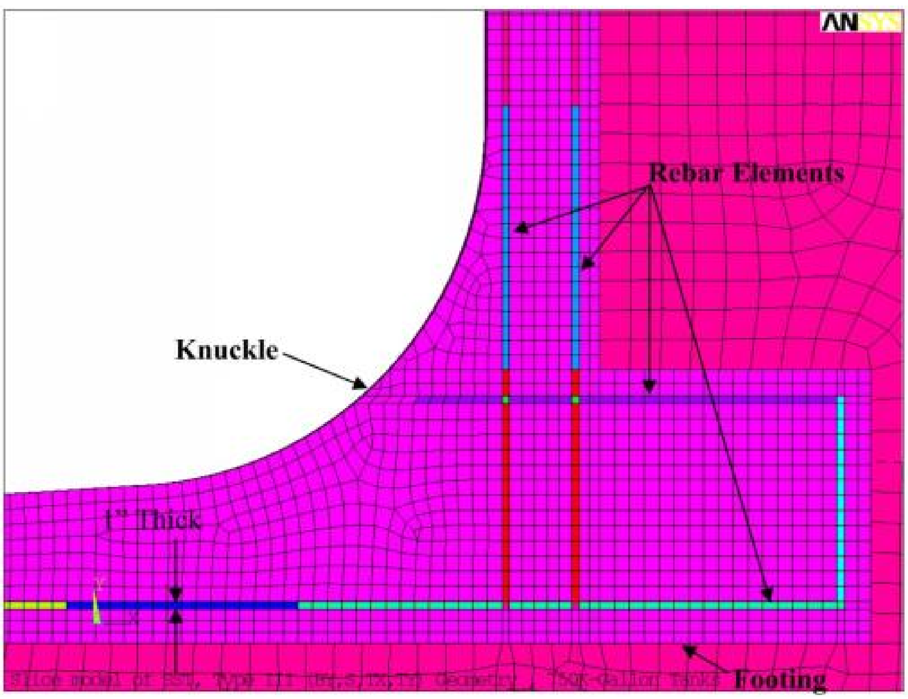

Figure E-4: Knuckle Section (RPP-RPT-49990)

The FEA model used time steps to determine the results. The initial steps were used to take the tanks through their thermal cycles to determine the degraded material properties. Then the loading steps were performed. The thermal histories were taken from recorded data and idealized to simplify the time-steps. The thermal histories were applied with considerations given to the waste height which was also taken from historical measurement data.

After the thermal histories were applied, the mechanical loads and hydrostatic (due to waste height) loads were applied. Finally, the prescribed load combination factors were applied to determine the code level demands. The loads are shown in Table E-1.

The boundary conditions at the face of the elements were consistent with axisymmetric models, the base surface of the soil was constrained against vertical translation, and the vertical surfaces at the extents were constrained against radial movement.

The results of the TOLA analysis showed that during the thermal cycle the slab underwent thermal-radial-expansion followed by radial-contraction which resulted in the stress demand exceeding the stress capacity and, therefore, the slab is likely cracked to the point of structural failure. It was then decided that the TOLA models should be evaluated as if the slab was not present. In each case, it was shown that the tanks remained stable and did not exceed their capacities when the slab was uncoupled under consideration of the TOLA loads.

E1.2.4 Gravity, Thermal, and Operating Loads Analysis for Type I Tanks

The TOLA model for the Type I used a 3-dimensional 180-degree half-symmetry (see Figure E-5 and Figure E-6). The loads, boundary conditions, and model considerations followed the same methodology as for the Type II, III, and IV tanks. The reason the 180-degree model was created in place of the 2-degree model is because each of the tanks has an elaborate hatchway that needed to be captured in the analysis and therefore was explicitly modeled.

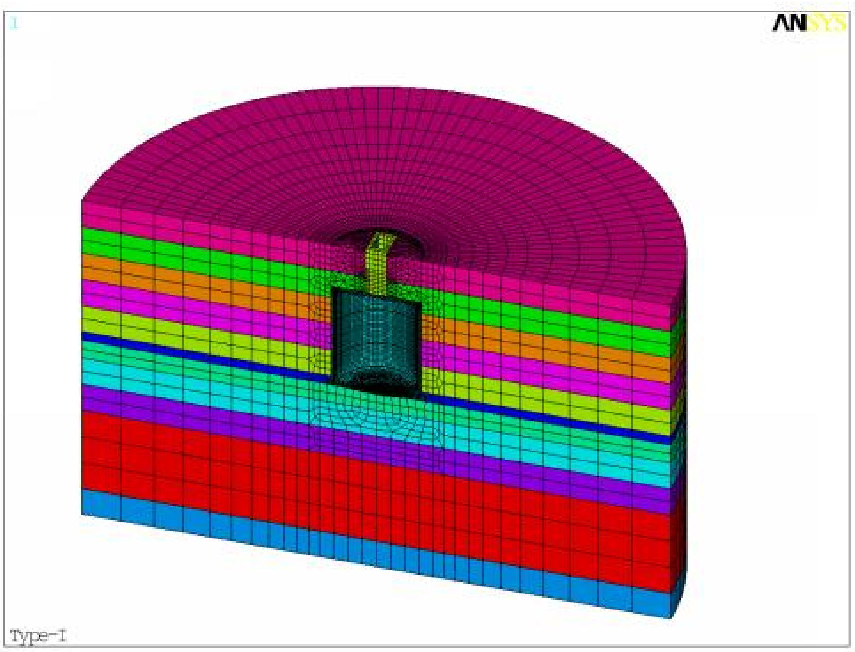

Figure E-5: TOLA Full Model (RPP-RPT-49993)

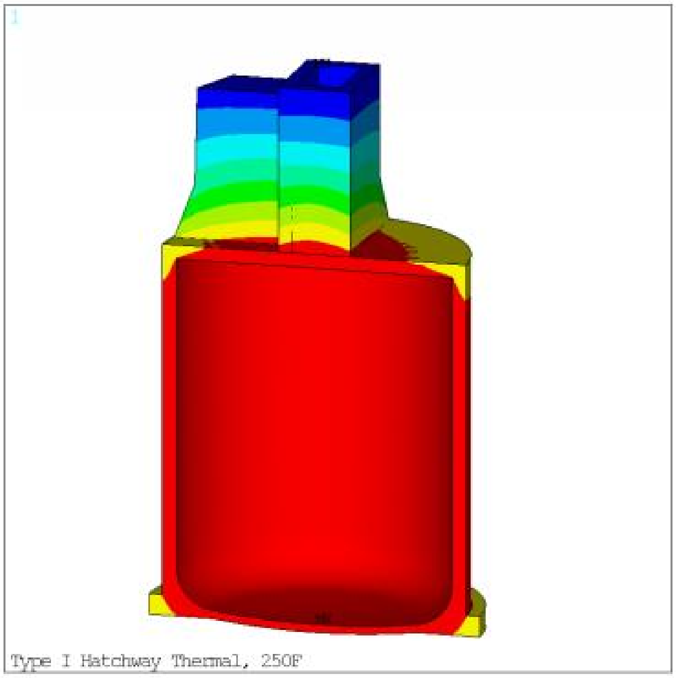

Figure E-6: TOLA Tank Model (RPP-RPT-49993)

E1.2.5 Seismic Analysis

The model used for the seismic analysis was a 180-degree half-symmetry mid-thickness shell model (see Figure E-7 through Figure E-9). The tank was meshed such that there were 9-degree slices, and the length of the elements was approximately equal. Because each element was a representation of a 3-dimensional composite material, each of the elements had to have their stiffness determined in each axis of freedom (i.e., orthotropic elements) with the considerations given for volume of reinforcement, properties of cracked concrete, and degraded concrete (based on the TOLA model). Also, the use of mid-thickness shells presents dimensional irregularities due to the concrete dome, haunch, wall, knuckle, and slab gradually changing thickness along the length.

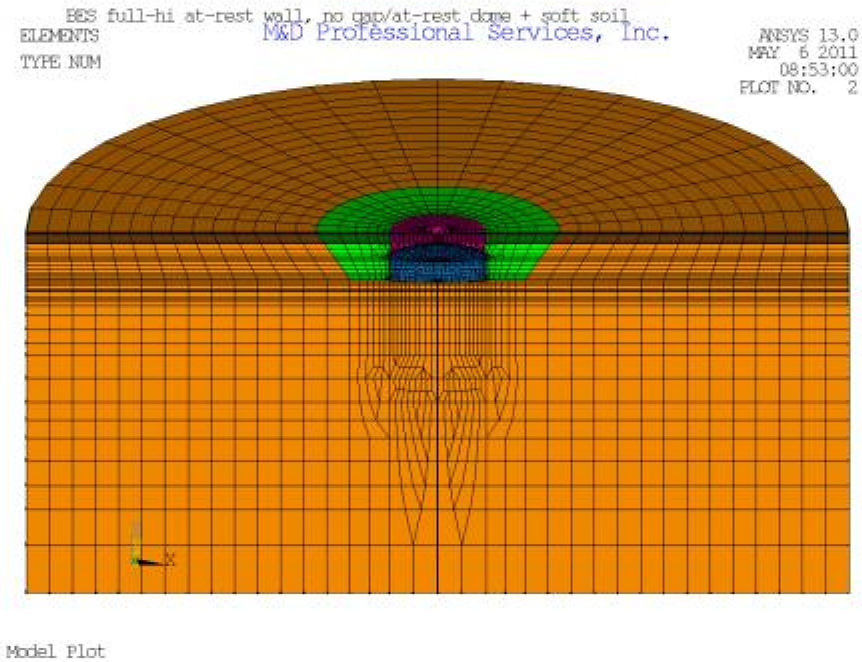

Figure E-7: Full Seismic Model (RPP-RPT-49989)

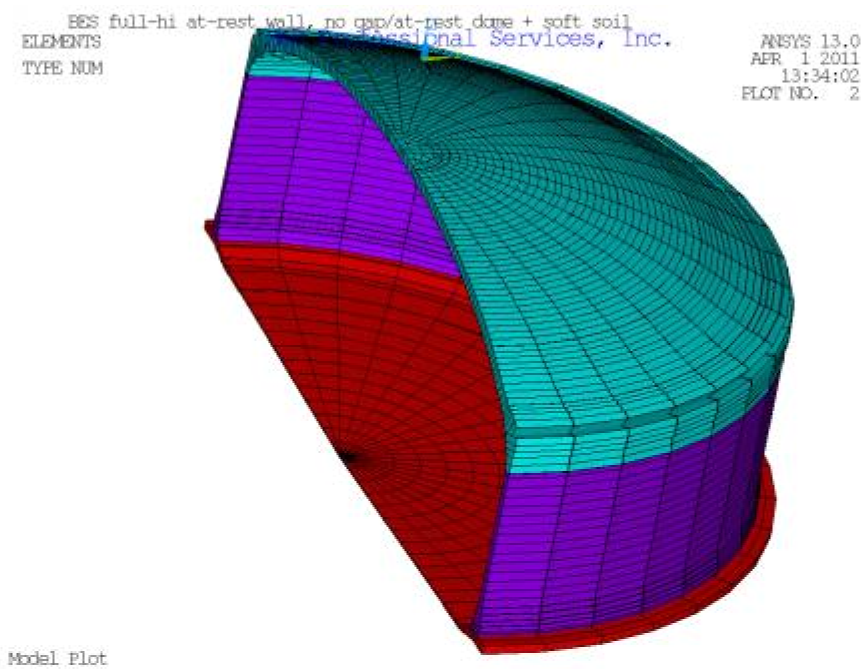

Figure E-8: Seismic Extruded Tank Model (RPP-RPT-49989)

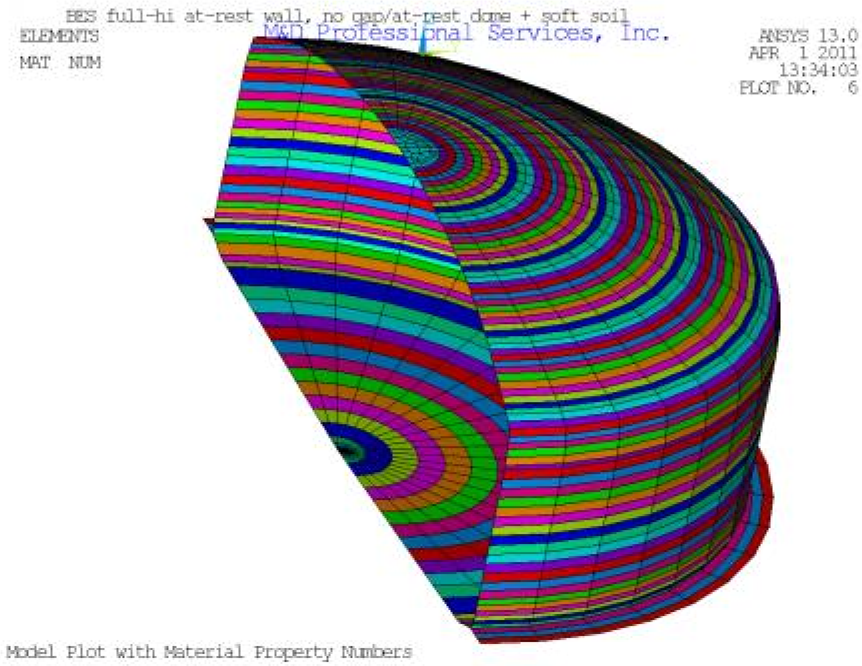

Figure E-9: Seismic Tank Model with Material Properties (RPP-RPT-49989)

The soil was also modeled in layers, and consideration was given to the backfill around the soil. In addition, a phenomena known as soil arching was addressed by either softening soils (Type II AOR) or by using slip planes (the other AORs). Similar to the TOLA model, the extents of the soil boundaries was placed at extreme extents to avoid influencing the tank elements.

To determine the seismic excitation, a spectral response was determined for the site at the ground level. Since these tanks are buried, a soil column model was generated and the base of the soil column was excited until it produced results at the surface which matched the desired response spectrum. Then the model was excited and compared to the desired response, and was scaled up as needed to meet the spectral matching criteria set forth.

The seismic analysis took into account several cases that included changes to waste stiffness and changes to anticipated soil properties.

In order to obtain results from the FEA model, gravitational loading criteria was required to be input into the model. The seismic-only results were extracted using a load case that considered gravity-only loads and a separate case was ran for gravity-and-seismic loading. The gravity-only results were subtracted from the gravity-and-seismic results to produce, in theory, seismic-only results. This was done for each of the 2048 load steps executed in each seismic run and the maximum section forces and moments were captured through time at each meridional section on the tank profile (see Figure 6.7 in RPP-RPT-49989). This is a conservative approach because the maximum forces and moments do not necessarily occur at the same time. As a result, the relationship between the sign of the seismic force and the direction of the moment are also lost. Therefore, through this bounding process, the results of the gravity-only model were actually added and subtracted from the gravity-and-seismic result and the more critical bound was used as the seismic-only results. Again, this is a conservative approach to obtain the seismic results.

E1.2.6 Combined Gravity, Thermal, Operating, and Seismic Analysis

The results of the TOLA model and the seismic model were then combined in the appropriate load combinations to determine the demand capacity ratio of the tank; it should be noted that these combined effects do not take into account tank appurtenances, those effects are addressed in subsequent sections. Since seismic effects can come from any direction and because concrete capacity varies based on a force-moment interaction, the seismic results were combined in four different ways in order to produce the maximum effect. These combinations are as follows:

- (TOLA Force + Seismic Force) and (TOLA Moment + Seismic Moment)
- (TOLA Force + Seismic Force) and (TOLA Moment - Seismic Moment)
- (TOLA Force - Seismic Force) and (TOLA Moment + Seismic Moment)
- (TOLA Force - Seismic Force) and (TOLA Moment - Seismic Moment).

A graphical representation of the process and interaction diagram is shown in Figure E-10.

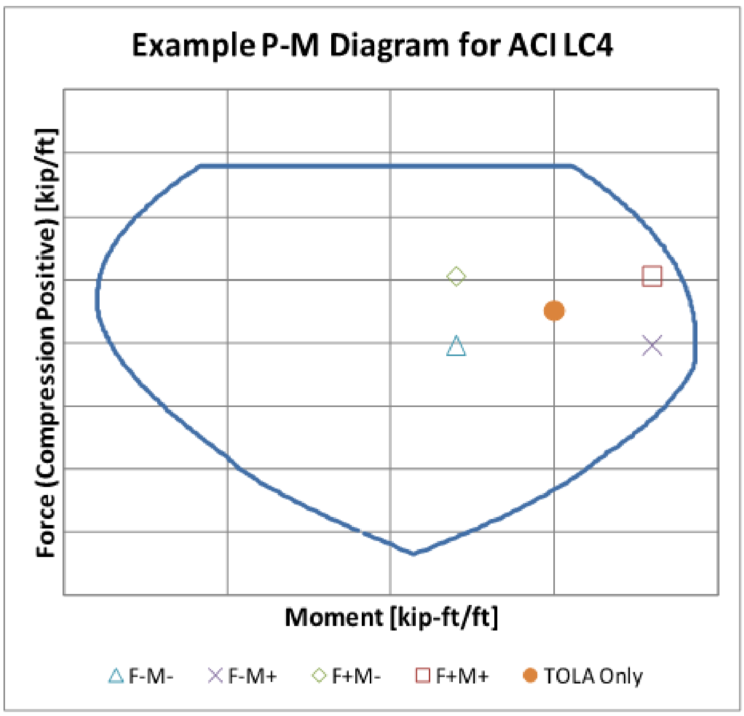

Figure E-10: Example Interaction Diagram with Result Combinations (RPP-RPT-49989)

The maximum combination results in terms of demand/capacity ratio for all load combinations are summarized in Table E-2. Please note the AOR for Type I tanks used the same process to combine the TOLA and seismic loads as the other AORs but the AOR for the Type I tanks did not report the results in tabular form for easy reference; thus, estimates results from 3-dimensional surface plots for the Type I tanks.

Table E-2: Demand/Capacity Ratios for Tanks

Tank	Direction	Dome	Haunch	Wall	Slab
Type I[4]	Meridional[A]	0.40	0.40	0.35	0.25
	Hoop[A]	0.25	0.25	0.25	0.25
	Shear out-of-plane[A,B]	0.30	0.20	1.00	0.30
	Shear in-plane[A,B]	0.40	0.40	0.20	0.20
Type II[1]	Meridional	0.27	0.81	0.46	2.16
	Hoop	0.80	0.56	0.71	0.47
	Shear	0.18	0.32	0.87	1.17
Type III[2]	Meridional	0.24	0.30	0.29	1.85
	Hoop	0.66	0.85	0.51	1.80
	Shear	0.32	0.22	0.46	0.42
Type IV[3]	Meridional	0.30	0.44	0.34	1.13
	Hoop	0.59	0.56	0.36	0.93
	Shear	0.07	0.54	0.50	0.65

Notes:
[A] Type I results in same format. These results were estimated from surface plots.
[B] For the Type I tanks was reported for both

Reference:
[1] RPP-RPT-49989
[2] RPP-RPT-49990
[3] RPT-RPP-49992
[4] RPP-RPT-49993

In summary, all of the tanks were shown to have a D/C ratio less than 1.0, which shows the tanks are adequate for this conservative analysis under the ACI 349-06 design code. Additional analyses were done to consider other loading conditions.

E1.3 TANK-TO-TANK INTERACTION ANALYSIS

The finite element tank models used in the above AORs simulated one tank surrounded by soil. Most of the 75-ft dimeter SSTs are positioned in arrays with a center to center spacing of 102 ft (i.e., separated by more than 50% of the tank radius). However, the Type IV tanks in AX Tank Farm have the closest spacing (as close as 131 in.), which is about 28% of tank radius. Section 6.6 of Brookhaven report BNL-52361 recommended evaluating tank-to-tank interaction effects for tanks that are closer than ½ the tank radius. Thus, the independent reviewers of the Type III tanks

(RPP-RPT-49990) recommended that an analysis be performed in order to determine if tanks showed an increase in demand based on influence from adjacent tanks.

The TTI analysis was performed in a separate AOR with the purpose being to determine the increase in demand associated with influence of an adjacent tank. This analysis took two separate models; one being a single tank and the other being two tanks adjacent to each other. The first analysis was performed on a single tank TOLA model, and was used to determine the model's sensitivity to mesh size in order to optimize computation time without introducing excessive error. After a mesh was determined, single-tank (see Figure E-11 through Figure E-13) and double-tank (see Figure E-14 through Figure E-16) models were created. Each model was created consistent with the previous models (i.e., the same boundary conditions, thermal steps, and modeling strategies).

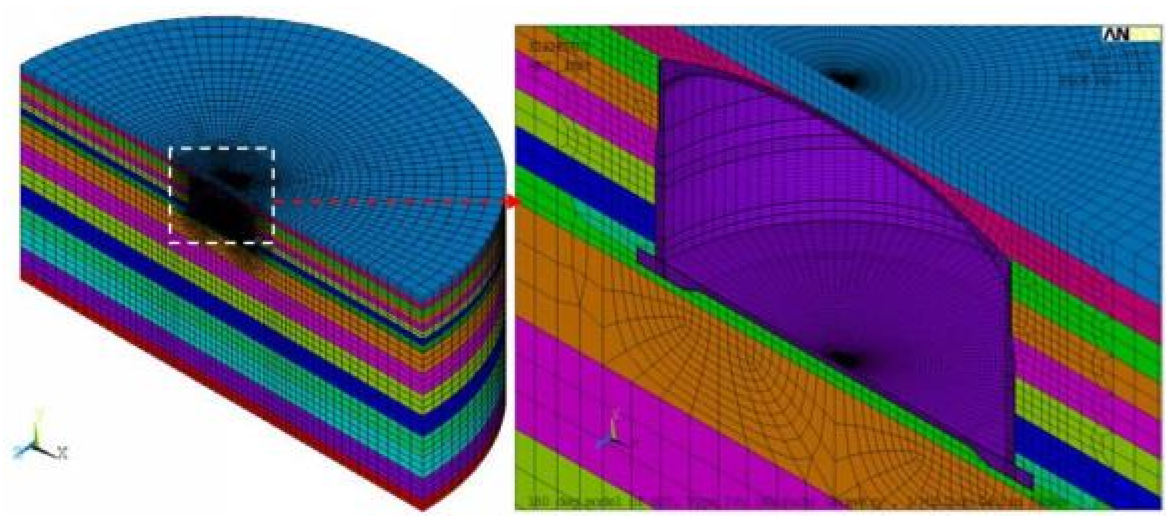

Figure E-11: Single-Tank TOLA Model (RPP-RPT-49991)

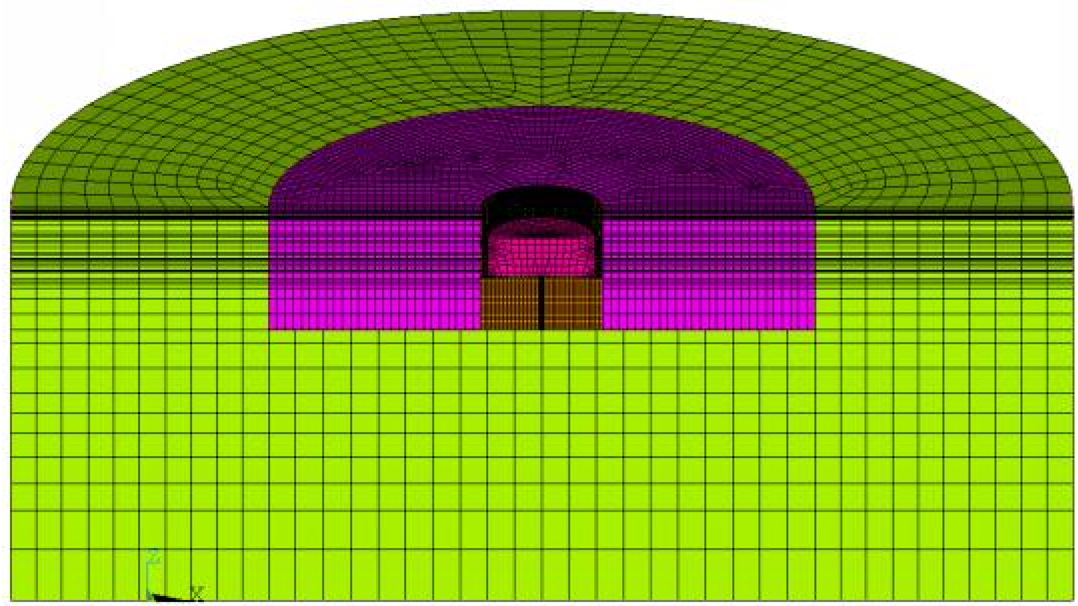

Figure E-12: Single-Tank Seismic Model (RPP-RPT-49991)

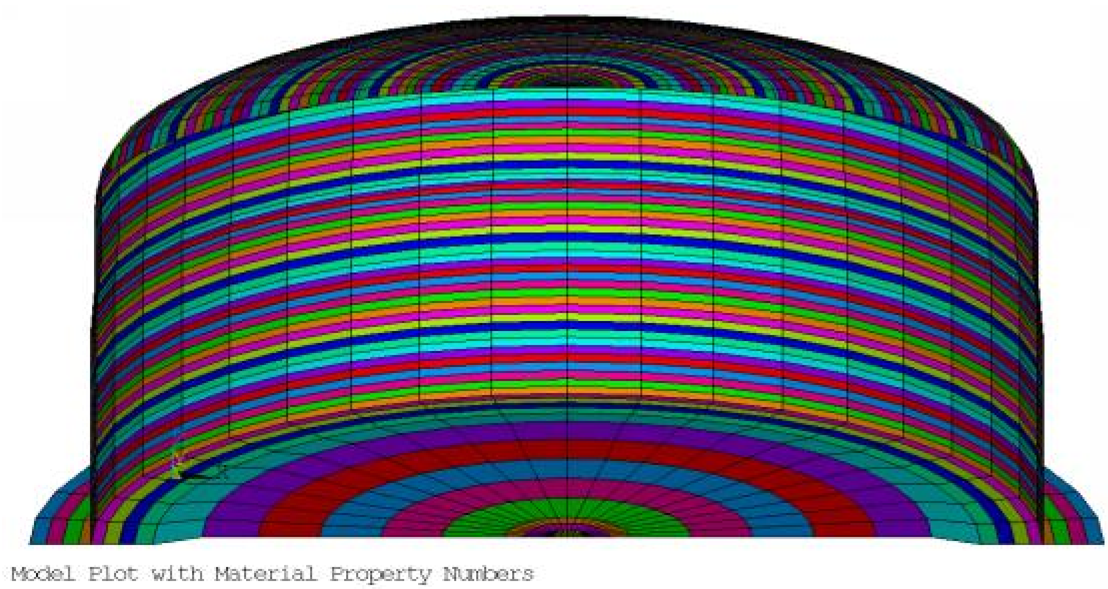

Figure E-13: Seismic Tank Model with Material Properties (similar for Double-Tank) (RPP-RPT-49991)

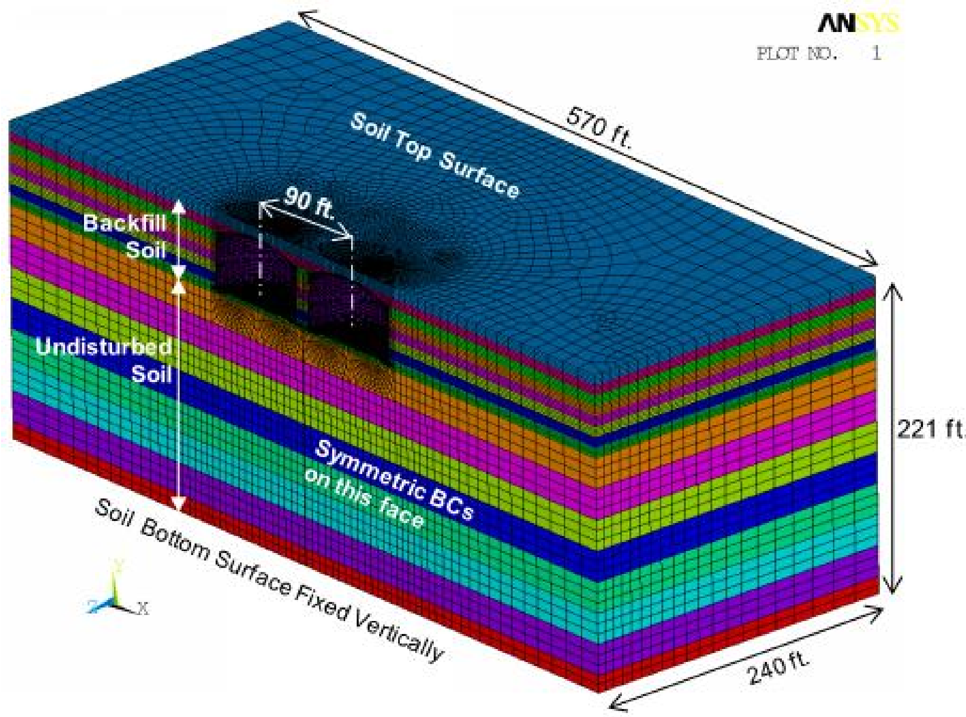

Figure E-14: Double-Tank TOLA Model (RPP-RPT-49991)

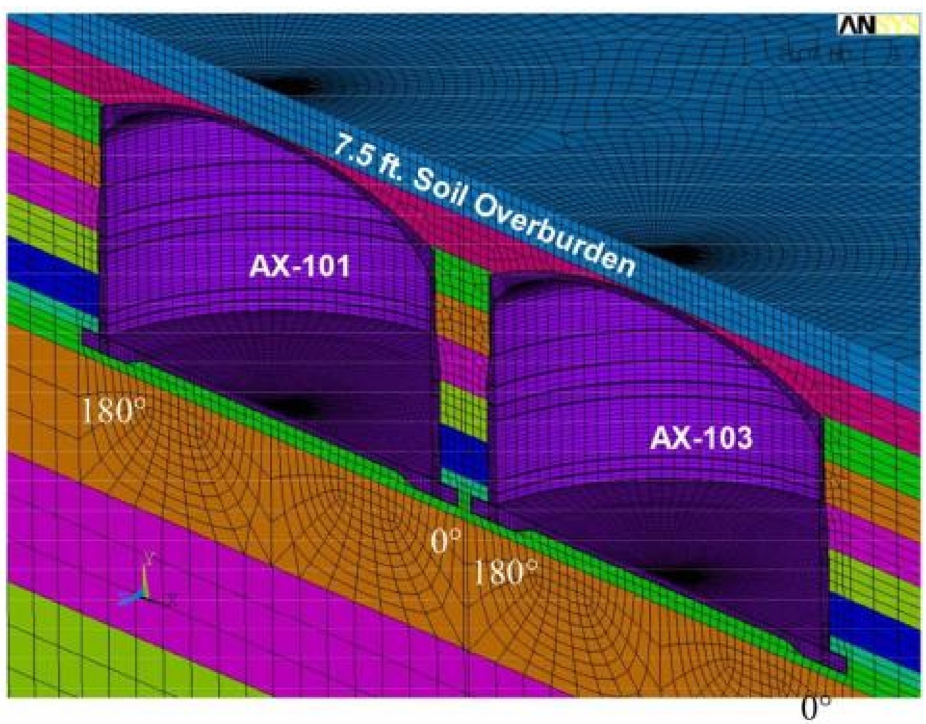

Figure E-15: Enlarged Double-Tank TOLA Model (RPP-RPT-49991)

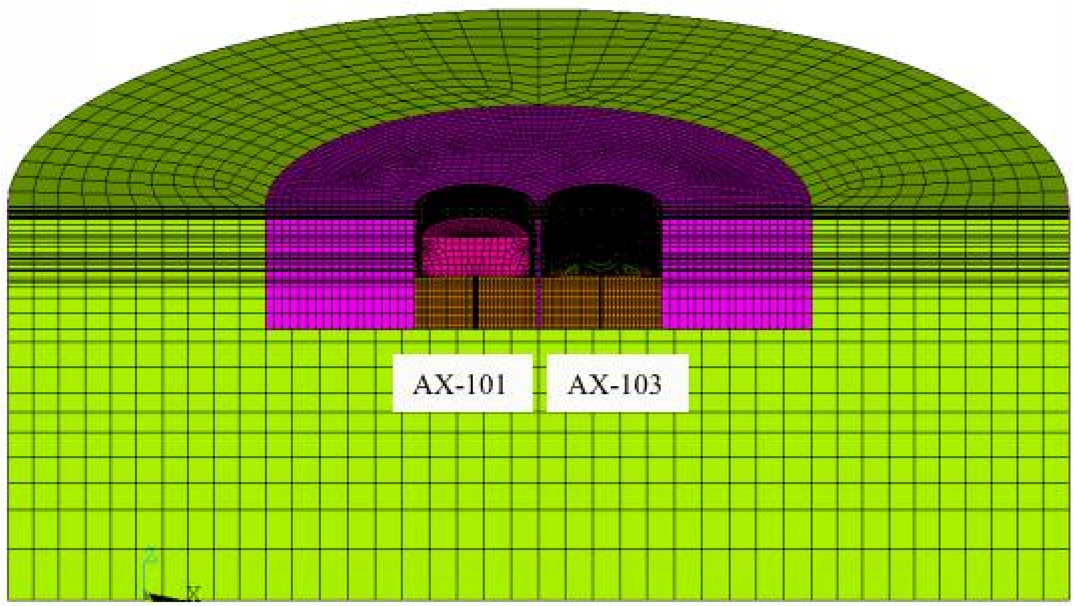

Figure E-16: Double-Tank Seismic Model (RPP-RPT-49991)

It should be noted that the criteria used for the TTI analysis were different than those used in the full Type IV AOR. The criteria are shown in Table E-3. These criteria were selected to better reflect the actual conditions that are present in the locations where the tanks are closely spaced.

Table E-3: Analysis Criteria (RPP-RPT-49991)

Parameter	Type IV TTI
Concrete Strength, f'_c	4 ksi
Rebar Yield Strength, F_y	40 ksi
Height at Center of Dome	44 ft
Inner Diameter	75 ft
Volume	1,000,000 gal
Point Load	612 kip
Uniform Load	40 psf
Soil Height at Center of Dome	7.50 ft
Max Temperature	540 ∘F
Specific Gravity of Waste	1.7

The double-tank model considered conditions with both tanks full of waste, both tanks empty, and one tank full and the other tank empty in order to determine the most critical case. After the TOLA and seismic results were determined, they were combined similarly to what was done in the main tank AORs. The results showed that the increase in demand was typically less than 10% and was localized to areas where the tanks were close. There were locations where the demand increased by as much as 19%, but it should be noted that these locations were in areas where the demand/capacity ratio was low, and therefore deemed to not have a significant impact in the overall determination of the structural adequacy of the SSTs.

Although the TTI analysis was only for the closely spaced Type IV tanks, it was determined that TTI effects would occur for the other tank types. Thus, the results of the TTI analysis were then applied to each of the Tank Types. (Note: Type II and III were retroactively deemed adequate while Types I and IV had not yet been analyzed.) The results of the TTI combined with the main analysis effects are as follows:

- **Type I Tanks** – These tanks were separated by a distance more than three times the tanks radius and therefore deemed to have no influence from adjacent tank loading.
- **Type II Tanks** – The TTI AOR states "no D/C ratios greater than 0.8. Therefore, adjustment for TTI effects will satisfy the ACI evaluation criteria in accordance with [conclusion of adequacy]." It should be noted that this conclusion is not correct as the maximum demand/capacity ratio is 0.87 for shear and could result in a combined TTI demand/capacity ratio greater than 1.0. However, like the Type III tanks, the section with a demand/capacity ratio in excess of 0.80 (D/C = 0.87) was probably at a location where the effects of the TTI were below 0.10 (i.e., 0.87 + 0.10 < 1.0) and therefore adequate.
- **Type III Tanks** – The main AOR showed that for all but one section, the demand/capacity ratios were below 0.80 (i.e., 0.80 + 0.19 < 1.0) and therefore adequate; the one section with a demand/capacity ratio in excess of 0.80 (D/C = 0.85) was at a location where the effects of the TTI were below 0.10 (i.e. 0.85 + 0.10 < 1.0) and therefore adequate.
- **Type IV Tanks** – The combined TTI results showed one location where the demand/capacity ratio exceeded 1.0. This section is where the haunch transitions to the wall. The ACI 349-06 code does allow for shear to be taken at a distance equal to the thickness of the member away from the support because of the crack propagation direction. The AOR states that the adjacent section is within that distance and so the demand capacity ratio of the adjacent section is evaluated. It should be noted that the ACI 318-08 commentary of this same section (ACI 349-08 R11.1.3.1) emphasize two things for this assumption to be valid: (1) stirrups are required across the distance and (2) a tension force exists in the longitudinal reinforcement at the face of the support. Both of these conditions are met. At this adjacent section, the combined effects are reported as 0.61. Additionally, the loading of these tanks is strictly controlled and 1.7 load factor for the applied surface loads is overly conservative for this application.

In summary, this AOR analysis determined that TTI effects applied to Type II, III, and IV tanks and determined that all the tanks were satisfactory.

E1.4 LOAD LIMIT ANALYSIS

The load limit analysis, also referred to as a collapse margin assessment, was performed to determine the load that would cause the collapse of the tank structure. The procedure is based on the ASME Boiler and Pressure Vessel Code and describes an approach where load and displacement are graphed together. The graph of this relationship is linear to a point and then undergoes greater displacement to a point and then tends to undergo another portion of linear behavior (see Figure E-17). ASME prescribes criteria for the calculation of these points.

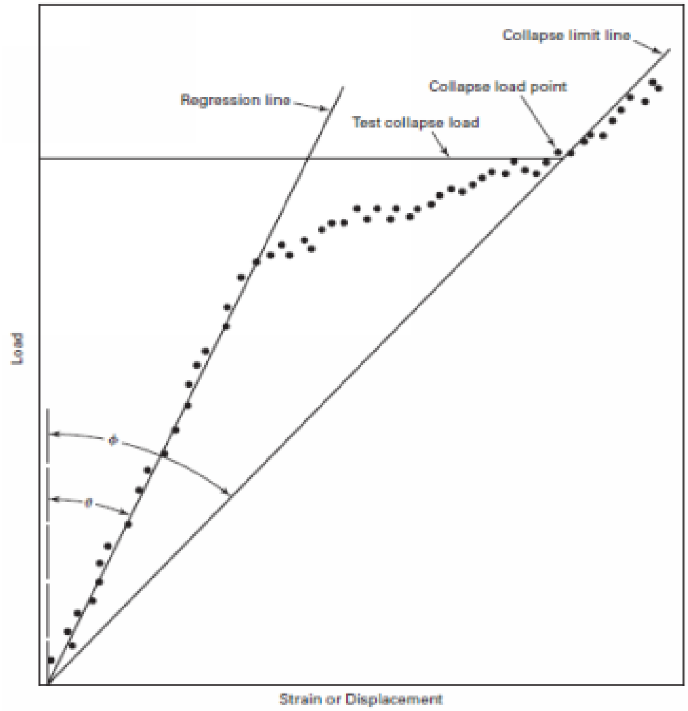

Figure E-17: ASME Collapse Load Criteria (RPP-46442)

The load limit is performed by using the SST models with load combinations that use unfactored loads. The analysis takes into account the changing of geometry as large deflections were anticipated and the loading was incrementally increased until the dome offers little or no resistance. The collapse load was determined for both a point load at the center of the dome on a 20-ft diameter (similar to the point load for the TOLA model) and for a uniform load applied at the top of soil.

In the evaluation criteria document (RPP-46442), the factor of safety specified from the following equation:

$$\frac{U_L}{U_C} + \frac{P_L}{P_C} = \frac{1}{FS}$$

where:

U_L is the uniform load that produces an equivalent deflection as the deflection produced from the soil over the dome in the baseline analysis.
U_C is the uniform load measured at collapse.
P_L is the point load applied at the center of the tank in the baseline analysis.
P_C is the point load measured at collapse.
FS is the factor of safety.

It was determined that the desired factor of safety be a minimum of 3.0.

The factor of safety was then modified in the AORs to be the following equation:

$$FS = \frac{L_C + L_E}{L_E}$$

where:

L_C is the applied load, at collapse, for either a uniform load or a point load.
L_E is the load that produces an equivalent deflection as the deflection produced from the soil over the dome in the baseline analysis.

The load limit models used the similar methodology as the TOLA models. The models did use a simplified thermal history, fewer soil property conditions, and fewer concrete condition properties.

The results for the load limit analysis are summarized in Table E-4. Please note that for Types II, III, and IV tanks multiple conditions and cases were investigated and this table represents the minimum factor of safeties; the Type I tanks only considered one case.

Table E-4: Factor of Safety Against Collapse

Tank	FS for Uniform Loading	FS for Point Load Loading
Type I	1.8	2.1
Type II	4.7	5.5
Type III	5.0	6.3
Type IV	5.2	7.2

References: RPP-RPT-49989, RPP-RPT-49990, RPP-RPT-49992, RPP-RPT-49993.

With regard to the results in Table E-4, it should be noted for Types II, III, and IV tanks considered a total of four cases for consideration for each uniform loading (UL) and point loading (PL) conditions. For the Type II tanks, the cases were:

- 10 ft of overburden soil with lower bound concrete properties (FS UL = 4.7, FS PL = 5.5)
- 10 ft of overburden soil with best estimate soil properties (FS UL = 5.3, FS PL = 6.4)
- 5.8 ft of overburden soil with lower bound concrete properties (FS UL = 7.3, FS PL = 8.3)
- 5.8 ft of overburden soil with best estimate soil properties (FS UL = 8.3, FS PL = 9.6).

For the Type III tanks, the cases were:

- 11 ft of overburden soil with lower bound concrete properties (FS UL = 5.0, FS PL = 6.3)
- 11 ft of overburden soil with best estimate soil properties (FS UL = 5.3, FS PL = 7.1)
- 6.85 ft of overburden soil with lower bound concrete properties (FS UL = 6.3, FS PL = 9.2)
- 6.85 ft of overburden soil with best estimate soil properties (FS UL = 6.7, FS PL = 10.4).

For the Type IV tanks, the cases were:

- 7.51 ft of overburden soil with lower bound concrete properties (FS UL = 5.2, FS PL = 7.2)
- 7.51 ft of overburden soil with best estimate soil properties (FS UL = 6.1, FS PL = 7.1)
- 6.22 ft of overburden soil with lower bound concrete properties (FS UL = 6.0, FS PL = 8.3)
- 6.22 ft of overburden soil with best estimate soil properties (FS UL = 7.3, FS PL = 8.4).

In summary, Table E-4 shows that the tanks have adequate collapse margin based on lower bound material properties. Using less conservative parameters show even greater factors of safety against collapse. Tested material properties are listed in Section 4.0 of the main text of this report and have been above design compressive strength.

E1.5 BUCKLING ANALYSIS

A buckling analysis was conducted on each of the tank types. An in-depth explanation is given in the AORs on the procedure for investigating the dome buckling capacity. It should be noted that the AOR reviewers noted that they did not have expertise in this buckling analysis area and therefore did not comment on that section of the AOR reports; similarly, this review has no comments on the process or results. Per Appendix L of RPP-RPT-49989, Larry Julyk of Becht Engineering (previously M&D Professional Services) performed the ASME NQA-1 review of the concrete shell and dome buckling analysis. It is our belief that these buckling analyses were very thorough and theoretical beyond typical reviewer expertise. Additionally, the AOR reports were reviewed and approved by industry experts Robert P. Kennedy, PhD of RPK Structural Mechanics and Anestis S. Veletsos, PhD, Professor Emeritus of Rice University.

E1.6 APPURTENANCES ANALYSIS

The appurtenance models were models that were ran in order to determine how the penetrations and/or pits affected the results of the tank AORs as this had not been considered in previous analyses. The appurtenances are not fit for use and are thus not included in this IAR. So, the appurtenances themselves are not assessed, just their effects on the tank structures. In addition to the pits and penetrations considered in the AORs, the tanks were evaluated for the impact of tank-to-tank piping, fill line piping, small diameter penetrations (less than 12-in.), and ancillary equipment; for each of these smaller items, it was determined their impact was negligible.

It should be noted that the Type I tanks did not have a specific appurtenance model, as the appurtenances (mainly the hatchway) were deemed integral with the tank and therefore were part of the base model.

For Type II, III, and IV tanks, each of the seismic appurtenance models used 180-degree shell models similar to the baseline models; the TOLA models continued to use 3-dimensional elements but utilized larger slices while still taking advantage of axisymmetric symmetry. For the Type II tanks, a 45-degree slice was used as a conservative approximation of symmetry (see Figure E-18 and Figure E-19), for the Type III tanks, a 90-degree section was used (see Figure E-20 and Figure E-21), and the Type IV tanks used 180-degree model (see Figure E-22 and Figure E-23).

Each of the appurtenance models followed the modeling techniques as the baseline models. They used a 3-dimensional TOLA model, a shell element seismic model, the same boundary conditions, and loading conditions. The thermal histories were further simplified, and the meshes were typically coarser in an effort to manage computational time. For appurtenance models, the heaviest pits and largest openings were considered. It should be noted, for the Type II tanks, the largest opening in any tank (55-in. diameter) was not considered as this penetration was analyzed separately and is described in Section 4.11.2 of the main text of this report.

For the Type II appurtenance models, the effects of the appurtenances are localized, and beyond the local effects, the demand closely matches the baseline results. In the wall near the appurtenance, the demand/capacity ratio peaks at 1.07. The author concludes that their seismic forces are 10 to 30% conservative, so they accepted the results as adequate.

Similar to the Type II, the Type III appurtenance model demonstrates that the only impact the appurtenances seem to have is localized, and otherwise the model closely matched the baseline model. Unlike the Type II analysis, in this Type III appurtenance analysis, the demand/capacity ratio does not exceed 1.0.

The Type IV appurtenance model showed that the haunch produced a demand/capacity ratio of 1.02 near the appurtenance. Otherwise, there was more variation between the baseline and the appurtenance model than shown in the Type II or III models, but the demand/capacity ratio did not exceed 1.0. The author then concludes that the tank is adequate due to the conservatism in the model.

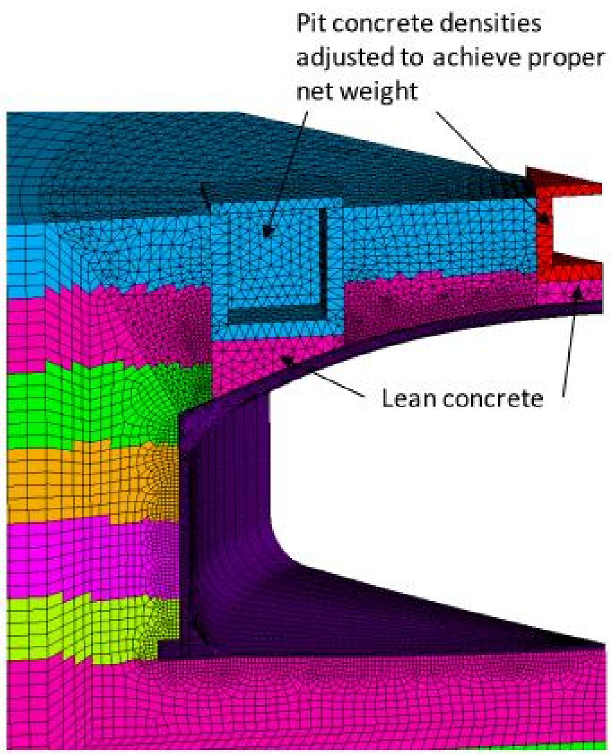

Figure E-18: Type II TOLA Appurtenance Model (RPP-RPT-49989)

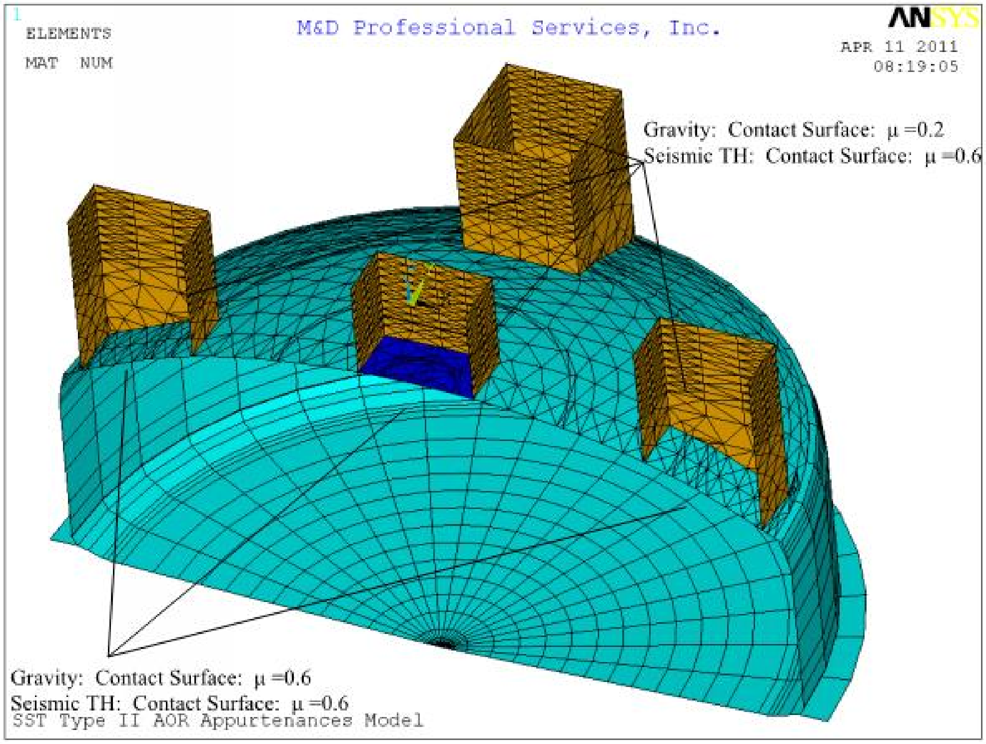

Figure E-19: Type II Seismic Appurtenance Model (RPP-RPT-49989)

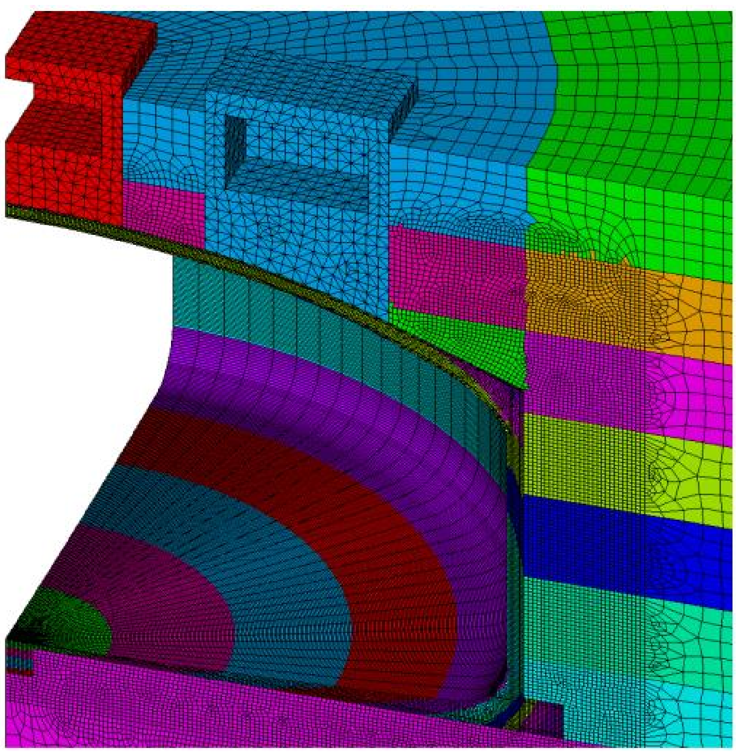

Figure E-20: Type III TOLA Appurtenance Model (RPP-RPT-49990)

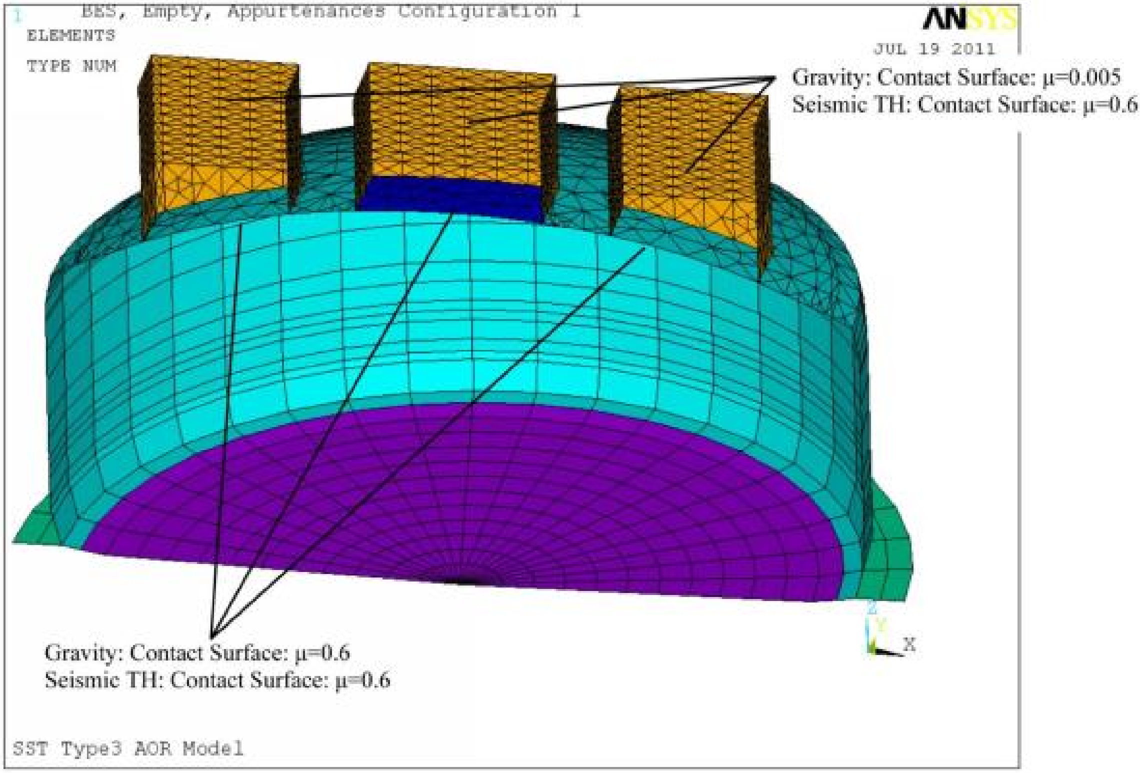

Figure E-21: Type III Seismic Appurtenance Model (RPP-RPT-49990)

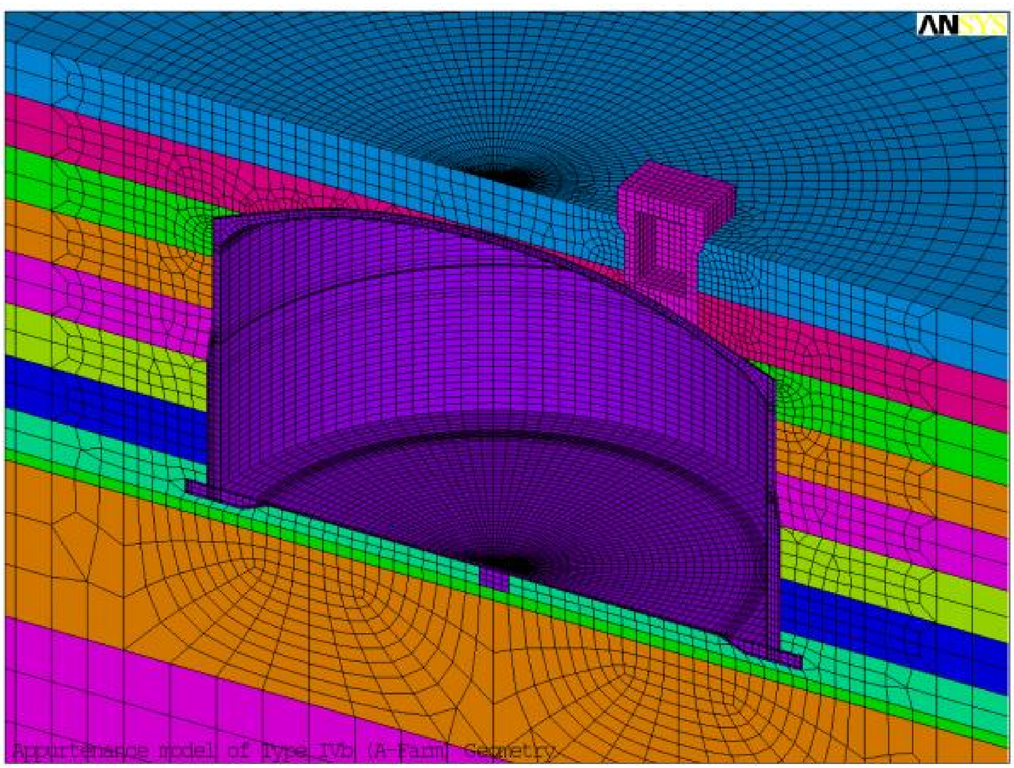

Figure E-22: Type IV TOLA Appurtenance Model (RPP-RPT-49992)

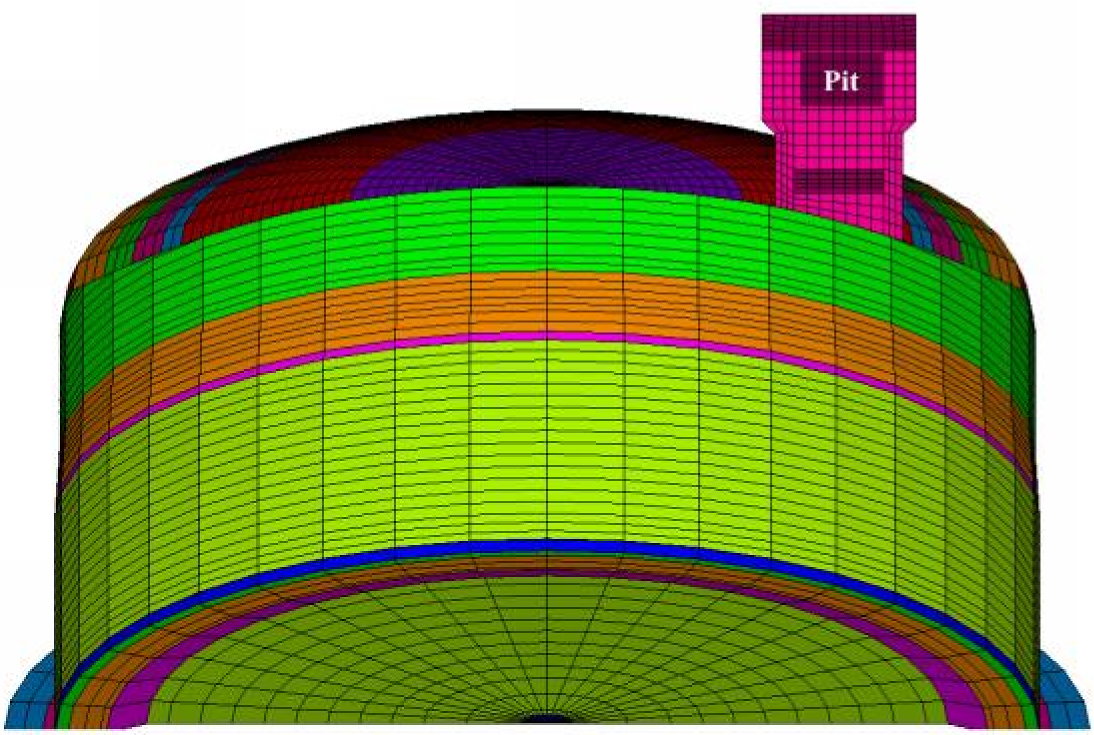

Figure E-23: Type IV Seismic Appurtenance Model (RPP-RPT-49992)

E1.7 CONCLUSIONS

These AORs used modern analysis methods (i.e., FEA) and were reviewed by an expert panel to ensure accuracy of results and thoroughness of analysis. The analyses were conservative in material properties, soil loads, thermal histories, waste levels, and appurtenance loads. Seismic loads were applied. Additionally, tank-to-tank interaction, tank buckling, and appurtenance effects were modeled. The analyses also determined a conservative collapse load for each tank. What can be seen from reviewing these AORs is that they were performed competently and with thoroughness to conclude that the tanks have sufficient structural integrity to not fail, collapse, or rupture under anticipated operational and seismic loading, and that the tanks meet the requirements of the ACI-349-06.

In conclusion:

- The tanks have sufficient structural integrity to not fail, collapse, or rupture under anticipated operational and seismic loading and that the tanks meet the requirements of the ACI-349-06 code. The maximum demand/capacity ratios for the baseline models were below 0.90 for the walls, haunch, and dome portions of the tanks.
- AORs show that the SST slabs are likely cracked and structurally separated from the foundation as a result of the thermal expansion and contraction. However, the AORs further show that the tanks remained stable and did not exceed their capacities when the slabs were removed from the analysis models.

- Tank-to-tank interaction typically adds less than a 10% increase in demand. In areas of the tanks that are closest to each other, the increase in demand can be as much as 19%. Considering the TTI effects, Type II and IV tanks may present localized demand/capacity ratios that exceed 1.0 by less than 10%. It should be noted that the load factors in ACI 349-06 are conservative considering that these tanks are strictly controlled and monitored in terms of dead and live loading. Additionally, the material properties considered in these AORs are conservative in that they are significantly lower than the material properties that have been determined through modern testing (see Section 4.0 of the main text of this report).
- The load limit failure analysis showed that the factor of safety against collapse from static concentric surface loading is above 3.0 for Type II, III, and IV tanks. In addition, these failures presented with gross dome deflection (1.5-in. +) which will provide ample opportunity to predict failure prior to collapse with current dome deflection survey program.
- The sequence of construction was not addressed in the AORs (i.e., the soil was back filled against the walls prior to wall construction).
- Additional analyses are performed on for tanks for larger or usual dome loading conditions that are not covered by RPP-20473, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks* (e.g., postulated equipment drop, large eccentric load, internal pressure pulse), on case-by-case basis.

Based on our review and the conclusions drawn herein we have generated the following recommendations for future AORs:

- When additional AORs are performed, consider modifying the modeling techniques to address the following issues:
  - Use the most up-to-date evaluation method that is available to consider the relative stiffness and yielding characteristics of the reinforcing steel, the concrete, and the surrounding soil
  - Consider evaluating the seismic load combinations with the other loads in the same analysis model
  - Consider separating the tank from the slab when evaluating the seismic forces on the tank
  - Consider sequence of construction for applying soil loads in the model
  - Analysis should consider all current loading criteria (e.g., dead, live, seismic) at the time of analysis.

E1.8 REFERENCES

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RPP-46442, 2010, *Single-Shell Tank Structural Evaluation Criteria,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-46644, 2010, *Single-Shell Tank Integrity Project Analysis of Record-Preliminary Modeling Plan for Thermal and Operating Loads*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-49989, 2011, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-49990, 2011, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type III Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

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RPP-RPT-49992, 2014, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type IV Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

RPP-RPT-49993, 2014, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type I Single-Shell Tank Thermal and Operating Loads and Seismic Analysis*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

RPP-RPT-49994, 2015, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record-Single-Shell Tank Integrity Project Analysis of Record*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

E2.0 ANALYSES OF RECORD QUESTIONS AND ANSWERS

The review of the AOR documents (RPP-RPT-49989, RPP-RPT-49990, RPP-RPT-49991, RPP-RPT-49992, RPP-RPT-49993, and RPP-RPT-49994) is included in Section E1.0. The AORs were produced by Pacific Northwest National Laboratory (PNNL). During the course of this IAR, several questions were generated relevant to the AORs. As a due diligence follow-up on that review, these questions were asked of WRPS. WRPS contracted with PNNL to assist with answering these questions. On the following pages:

- The IQRPE questions are listed, followed by
- The PNNL response, and then
- The IQRPE closing comments.

E2.1 QUESTION 1

IQRPE Question: A 2% exceedance in 50 years was used for the seismic criteria. Since these structures are of high importance and expected to last until 2067+, is this reasonable for these structures and why?

PNNL Response: The tanks are classified as PC-2 structures which determines the required mean annual frequency of exceedance of 4×10^{-4} (2% exceedance in 50 years, equivalent to a 2500 year return period). From the Type IV report, "The SSTs are categorized as and evaluated as Performance Category 2 (PC-2) structures, and DOE-STD-1020-2002, Section 2 (DOE 2002), requires that the ground motions for PC-2 shall be developed following the 2000 International Building Code (IBC) requirements. The Tank Operations Contractor standard (TFC-ENG-STD-06) recognizes *Washington Administrative Code* (WAC) 51-50-003, which adopted the 2009 IBC at the time that the structural evaluation criteria for the SSTs were developed (Johnson et al. 2010).

Consistent with Johnson et al. (2010), IBC (2009), and DOE (2002), the MCE ground motions are defined as the ground motions with a mean annual frequency of exceedance of 4×10^{-4} (2% probability of exceedance in 50 years). In this analysis, the site-specific design response spectra for the SST facilities site uses the Rohay and Reidel (2005) Hanford Waste Treatment and Immobilization Plant design spectra as a reasonable assessment of the current state of knowledge of the hazard levels at the 200 East and 200 West Areas. The 2005 spectra are conservative relative to data documented in Geomatrix (2007), but this choice was made to protect against the chance that Hanford seismic hazard levels could be increased in the near future. The dynamic seismic model evaluated a range of soil properties, and evaluated tanks with and without waste during a seismic event using degraded concrete properties as determined in TOLA. A separate seismic model evaluated the effects of tank appurtenances."

Additional analysis at a later date in the cleanup mission may be required to update the SST AOR.

IQRPE Closing Comments: We concur with the PNNL response. These structures are PC-2 and the required mean annual frequency of exceedance of 4×10^{-4} (2% exceedance in 50 years) is appropriate. Additionally, the AOR analyses show that seismic is not the controlling load condition, so there is an additional margin of capacity.

E2.2 QUESTION 2

IQRPE Question: RPP-46442 Sections 2.8.1 and 2.8.2 suggest that equipment drops and flammable gas ignition may need to be investigated; was this performed separately or was this determined to not be a concern?

PNNL Response: The statement was included to specify what was not evaluated in this analysis. No additional analysis were performed.

IQRPE Closing Comments: RPP-46442 Section 2.8.1 states “A postulated equipment drop shall be evaluated on a case-by-case basis for any equipment used either over or within the SSTs. The analysis shall consider the effect of the equipment drop on the SST structural integrity during installation and removal of equipment.” Loading of tanks is controlled by the dome load limits of RPP-20473, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks*.

In addition, RPP-46442 Section 2.8.2 states “The postulated ignition of hydrogen/flammable gases that may be released periodically from the waste could result in an internal pressure pulse within the primary tank. The time history of the pressure pulse shall be characterized on a case-by-case basis considering the estimated inventory of flammable gases within the tank of interest.” Based on Section 6.0, postulated ignition of hydrogen/flammable gases is not anticipated as discussed in Section 5.

Therefore, for larger or usual dome loading conditions that are not covered by RPP-20473, such as a postulated equipment drop or an internal pressure pulse, analysis shall be done on case-by-case basis.

E2.3 QUESTION 3

IQRPE Question: In RPP-46644 Section 5.1.1.3 it is found that the rate at which the temperature changes plays a large role in the stress undergone by the tank. It appears that when the data was missing for long time periods that the temperature was linearly increased between the two measurements. Is this a reasonable assumption or should there have been consideration of the temperature increasing quickly then leveling off?

PNNL Response: Identifying reasonable yet conservative thermal transients from historical temperature data was one of the challenging aspects of performing the SST AORs. The preliminary analysis evaluated maximum temperature, cycling, and temperature rise time of the waste and its effect on forces, moments, shear and cracking. Page 5.1 of RPP-46644 states that “unlike the double-shelled tanks (DSTs), the SSTs were not subjected to regularly scheduled thermal cycling operations.” Page 5.5 of RPP-46644 states that cracking is more a function of the highest temperature rather than number of cycles. The SST AORs conservatively applied waste temperatures directly to the tank surface up to the liquid level rather than assuming a bulk temperature and convective heat transfer coefficient. The models included transient radiation heat transfer from the waste surface to the dome to calculate the dome temperatures. Also the analyses represented in Figures 5.15 through 5.18 assumed the high temperature of the sludge/solids extended across the entire floor to the walls of the tank. Additional analysis on page 5-12 of RPP-46644 states “Similar analysis with a hot spot diameter of 50-ft instead of the uniform solids temperature did not yield [a] significant difference in forces and moments for 36 and 13 Fahrenheit-degrees/day, except for the tank slab or hot spot region. It can be concluded that if the temperature rise was restricted to the hot spot region, then the rate of temperature rise does not have a significant impact on the tank load distribution. However, in general, the rate of temperature rise appears to have a significant effect."

A later, detailed review of waste temperature data was conducted during the Type IV AOR (2013-2014). Section 3.2.2 of RPP-RPT-49992 presents temperature data for the AX Tank Farm tanks where an array of thermocouple trees was positioned inside the tank and thermocouple wells were cast into the walls of the tank (see Figures 3.7 and 3.8 of RPP-RPT-49992). Compilation of the AX temperatures showed a hot spot in the center of the tank floor (up the 540 °F) with much lower temperatures in the lower wall (<250 °F). In addition, the wall temperature at the waste surface was higher than at the bottom of the wall, consistent with convective recirculating flow in a boiling tank (Figure 3.11 of RPP-RPT-49992). Therefore, it is likely that steep temperature gradients (of the center sludge/solids) did not result in high temperatures of the tank walls, which caused the results in Chapter 5 of the RPP-46644 preliminary analysis. The SST summary report (RPP-RPT-49994) references tank A-106 side-wall core testing (Misiak 2014) that showed high concrete compressive strengths, well above the 3-ksi design strength throughout the height of the wall core. The current sound condition of the concrete supports the conclusion that the walls remained at much lower temperatures (consistent with the ~250 °F boiling temperature of the waste supernate) than the maximum measured temperature of 596 °F (at the bottom center of the sludge layer).

The Type II AOR applied the temperature history in Figure 1 and found that the calculated tank temperatures were similar to the bounding temperatures of the previous tank C-106 analysis. Both the Type III and Type IV thermal transients begin with steep temperature ramps to the highest temperature recorded for each tank type (Figures 2 and 3) to ensure that the maximum amount of concrete degradation was included in the analysis.

<u>IQRPE Closing Comments:</u> The question has been thoroughly answered, so we concur with the PNNL response.

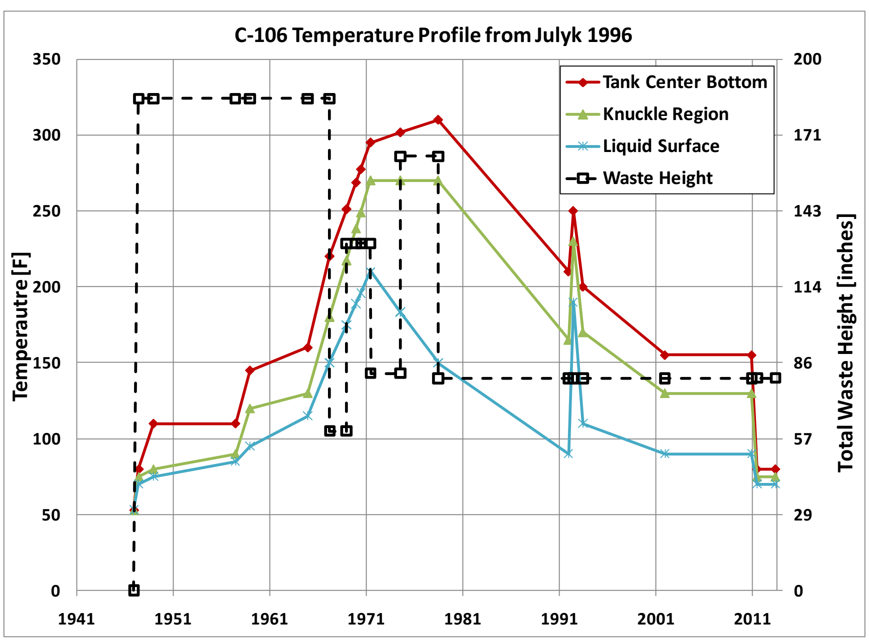

Figure 1: Type-II Temperature and Waste Height History

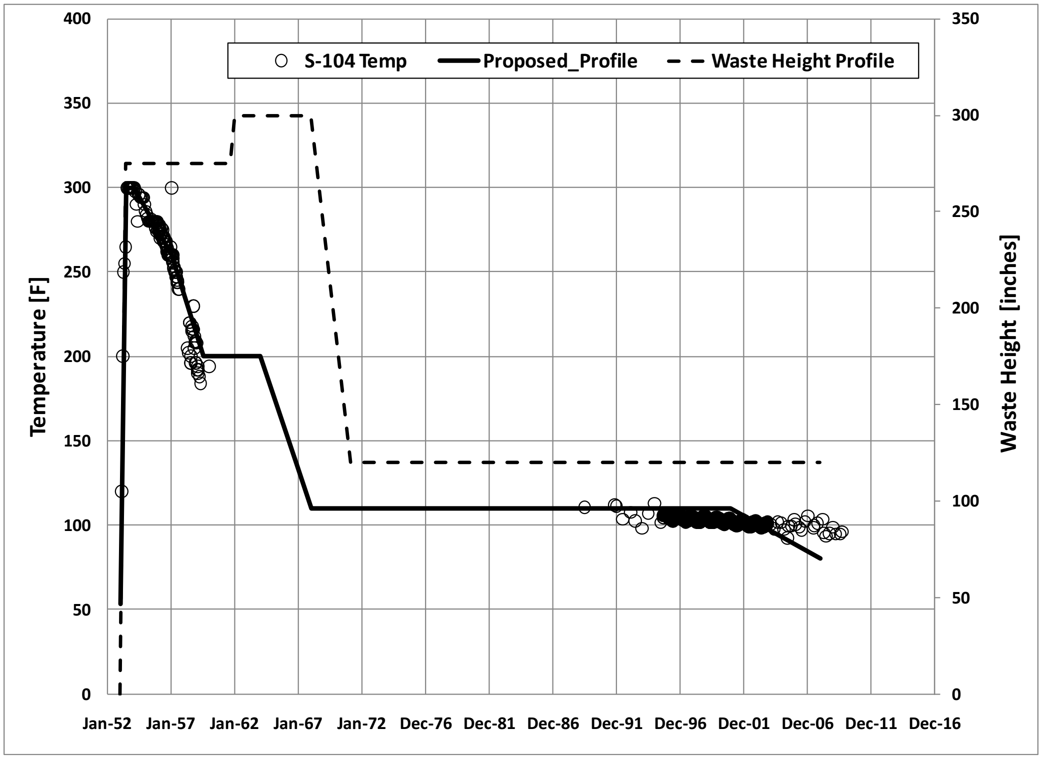

Figure 2: The Peak Temperature History Profile and Waste Height Profile Used for Detailed Analysis of the Type III Tanks

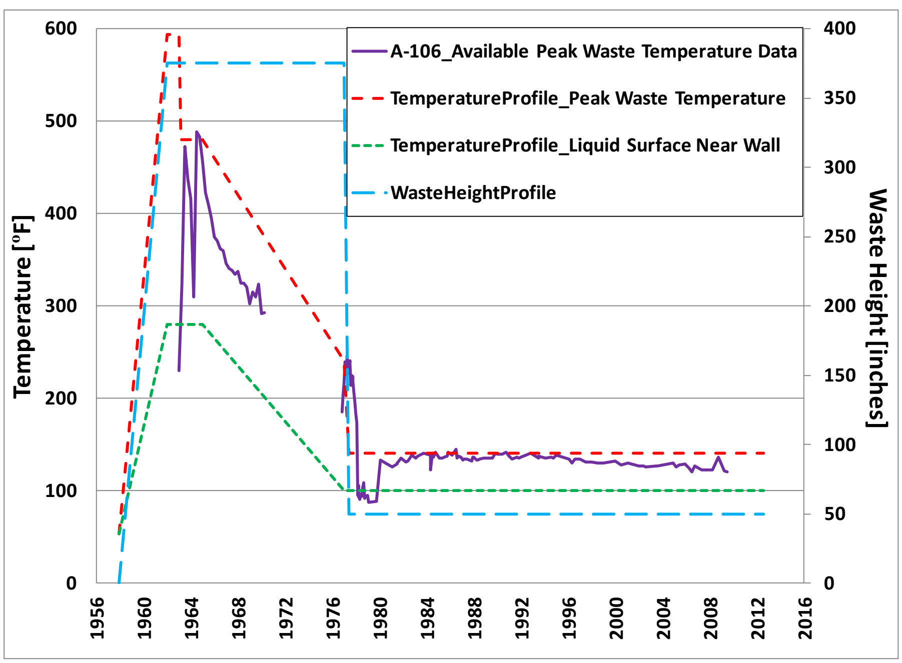

Figure 3: Bounding Type-IV A-Farm Waste Temperature (°F) and Waste Height (inches) Histories Used in the AOR

E2.4 QUESTION 4

IQRPE Question: With the availability of high-end computing, why wasn't a half-symmetry 3D element model used for analysis forgoing the need for a TOLA model and a seismic model?

PNNL Response: There are several factors that determined the analysis approach taken in the SST AOR, including the decision to decouple the TOLA and seismic analyses. Overall, the two models were designed for very different purposes. Combining them was not practical, even with today's software and computers.

The ANSYS commercial finite element software was used for the SST AOR because it has the required solution methods (thermal plus static and dynamic structural), material models, and it has been V&V'ed for NQA-1 analysis. While PNNL has massively parallel computers, the ANSYS code is not structured to use that capability. ANSYS uses an implicit finite element solution method which has limited parallel processing capability. Realizing that, the SST AOR project purchased high-end work station computers in 2010 with lots of memory, fast processors and fast disks to perform most efficiently with the analyses ahead. ANSYS was then V&V'ed on these specific processors at PNNL and Becht (previously M&D) for the SST AORs.

There are many differences between the TOLA and seismic solutions which supported splitting the analyses. The TOLA model focused on evaluating the potential degraded condition of the tank reinforced concrete. The model includes the following details that make the analysis highly nonlinear:

- Temperature dependent concrete stiffness, strength, creep, crushing, and cracking,
- Elastic-plastic rebar,
- Pressure dependent Drucker-Prager soil yield model, and
- Contact between the soil and the concrete tank.

The TOLA loads are axi-symmetric so the 2° slice model was appropriate. This also allowed concentrating the analysis on the detailed layers of reinforcement at the specific locations in the tank sections. The TOLA 2° slice models typically required 1 GB of memory, generated 53 GB results files, and 7 hours of computer time per run. The TOLA model run times were long because of the concrete and rebar detail, thermal degradation, creep, etc. Multiplying by 90 for a 180° analysis would have made this intractable with no increase in detail or accuracy of results.

The seismic analysis used elastic material properties for the soil and concrete, contact between the soil and concrete, and it was performed in the time domain, running 2048 loadsteps. The concrete elastic properties were degraded based on the TOLA thermal analysis. This typically required 4 Gb of memory, generated 50 Gb results files, and up to 250 hours (largest model: Lower Bound Soil with 5 CPU cores) of computer time for each run. The seismic run times are long because of the number of soil elements, contact interfaces, and the number of loadsteps. That includes the economies of transitioning to shell elements for the tank with the stiffnesses degraded for high temperature exposure. To conserve disk space, the output files were also reduced to only the results needed to model checking and load combination in the TOLA plus seismic load analyses. Including the details of the TOLA model in the seismic model would have made it intractable.

Splitting the TOLA and seismic analyses also allowed PNNL and Becht to work in parallel; PNNL applying its expertise in thermal/structural analysis and Becht its expertise in seismic soil structure interaction analysis of the buried tanks.

IQRPE Closing Comments: As was demonstrated in later analysis, courser meshes did not negatively impact results. If structural failures or other structural concerns develop, a new finite element analysis should be conducted to find the extent that a tank can be damaged and still be structurally sound. This is similar to the Expert Panel Recommendation SI-9. If and when this analysis is done, the tank type with the highest reported D/C (demand to capacity) ratio should undergo a more thorough analysis to validate the results of the previous AORs. Ideally, this new analysis would be a 180° 3D element model that takes into account tank-to-tank interaction, accurate appurtenance layouts, accurate dome/wall penetrations, separation of the slab from the wall, seismic and TOLA loading, and any other criteria that potentially would affect the D/C ratio.

E2.5 QUESTION 5

IQRPE Question: Why wasn't load eccentric of the point load considered? Couldn't this produce higher demands in the side walls? *RPP-CALC-51994 performs this kind of check and determines that with load eccentricity the D/C ratio for through wall shear increased and resulted in lower allowable loads (see page 3.13).*

PNNL Response: The concentric concentrated load conditions were specified by the client. The weights of all structures and equipment above the dome were conservatively concentrated in a 20-ft diameter circle. Load eccentricity could concentrate the load somewhat in the wall coinciding with the direction of the eccentricity. Studies beyond the SST AOR performed concrete shell buckling analyses where load eccentricity was considered on the dome of tank C-105 with a 55-in. penetration in the dome center (RPP-CALC-51195). The analysis showed that the dome critical buckling load increased as the load moved toward the wall. This occurred because the dome section thickness increases and the concentrated load at the surface spreads out over a larger area as the soil depth to the dome surface increases at locations away from the dome apex.

IQRPE Closing Comments: While the dome buckling load may increase, it was shown in RPP-CALC-51994 that the maximum allowed eccentrically applied load did decrease due to the increase in side wall shear demand. Even so, loading of tanks is controlled by the dome load limits of RPP-20473, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks*, which provides adequate limits on dome loading.

Therefore, for larger or unusual dome loading conditions that are not covered by RPP-20473, such as a large eccentric loads, analysis shall be done on case-by-case basis.

E2.6 QUESTION 6

IQRPE Question: The TOLA model considered separation from the slab, why was the seismic model similarly not considered for this case?

PNNL Response: Review of the Type II AOR report (RPP-RPT-49989 Chapter 8, Static Model Results) shows that shear in the slab at the footing was the concern under factored static loads (ACI-349 Load Case 1) which initiated the slab removal study. Subsequent review of Chapter 9, Seismic Analysis Results, shows that the seismic plus static loads analysis also has shear D/Cs greater than 1.0. Looking back, it would have been more complete to reevaluate the seismic model with the slab detached. Currently one could review the shear demands and capacities of the LC-1 and LC-4 load cases and scale the differential settlements from the static analysis as an estimate of the static plus seismic response with the slab detached. Doubling the calculated 0.041-in.

displacement offset across the gap (between slab and footing) would still be less than 1/3 of the 0.25-in. nominal liner thickness.

IQRPE Closing Comments: We agree with PNNL that, in hindsight, the slab should have been detached in the seismic model. Doubling the 0.041-in. displacement does not directly relate to the effect of detaching the slab on the D/C ratio under seismic load combinations. So, the effect of detaching the slab is unknown. However, since the D/C ratio for seismic load combinations is less than other load combinations, and the critical stresses occur in different locations for seismic load combinations, no additional analysis is needed. If future seismic analysis is performed, it should consider detachment of the slab in the model.

E2.7 QUESTION 7

IQRPE Question: For the results of the TOLA model, the reinforcing shows negative stress. Does this mean that the compressive force is being carried by the reinforcing? The concern is whether or not the rebar is alleviating compressive load in the concrete? Would it have been more appropriate to model the rebar as tension-only (RPP-RPT-49990 Figure 8.20)?

PNNL Response: The rebar was not explicitly modeled in the AOR. ANSYS SOLID65 elements employ a smeared rebar fraction assuming a perfect bond between concrete and rebar. The rebar was allowed to carry partial compression up to the concrete crushing strength. The rebar is a small fraction of the overall cross-section of tank structure. One could go back and specifically check the load carried by rebar compared to concrete.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

E2.8 QUESTION 8

IQRPE Question: In the axisymmetric model (RPP-RPT-49989, Figure 8.3), is the knuckle section 26 or 28? I believe it is section 26 now, but the labels are not shown well in any of the figures. In addition, if I am wrong and the knuckle is section 28, then there are some additional issues that need to be addressed.

PNNL Response: The bottom of the wall is section 26. The lower end of the radiused knuckle is section 28 where it transitions to the slab.

IQRPE Closing Comments: Question has been thoroughly answered, so we concur with the PNNL response.

E2.9 QUESTION 9

IQRPE Question: Were the gravity results of the shell model and the axisymmetric model compared to ensure that the model was producing similar results? *As an aside, RPP-CALC-51994 Section 3.5 discusses such a comparison and shows that the models produced maximum demands in different sections.*

PNNL Response: Yes they were compared and they gave similar results. The results were presented in team review meetings but were not included in the reports.

IQRPE Closing Comments: In RPP-CALC-51994 Section 3.5 there are discrepancies between the shell and 3D element models in both the magnitude of stresses and location of peak stresses for the gravity load condition. It is known that this model is not one of the ones used for the tank AORs but it does highlight that the differing models can produce different results. Although the differences are not quantified, we accept the PNNL evaluation that the differences were minor such that the different models provided similar results. Additionally, the D/C ratios showed a significant margin.

E2.10 QUESTION 10

IQRPE Question: In the seismic model, the elements appear to have large aspect ratios (RPP-RPT-49989 Figure 6.6). Is this figure not showing the elements?

PNNL Response: Yes, Figures 6.5 and 6.6 show the finite element mesh. The elements at the outer radii (in the dome, wall, and footing/slab) have aspect ratios that appear to be over five. This was necessary to reduce the model size and still provide sufficient mesh resolution in the tank cross-section to capture the axial and bending response of the tank profile.

IQRPE Closing Comments: During the meeting to discuss these questions and responses, PNNL presented that new FEA techniques have led to a reduction in potential errors based on element aspect ratio. The question has been thoroughly answered, so we concur with the PNNL response.

E2.11 QUESTION 11

IQRPE Question: The seismic model produces 400 psf uplift at the soil surface under dead load only in RPP-RPT-49989 Figure 6.29. Can you explain these results and why they are acceptable?

PNNL Response: 0.4 kip/ft^2 is approximately zero for the contour range used in Figure 6.29. The finite element code first calculates the nodal forces and displacements in the soil, then the stresses at the internal integration points, and finally extrapolates the integration point stresses to approximate the nodal stresses at the surface. The nine stress contours on Figure 6.29 range from -36.4 to 0.4 kip/ft^2, with the red contour from -3.69 to 0.40 kip/ft^2. Zero is within the red contour. The 0.4 kip/ft^2 maximum value is shown locally in the soil at the left side of the tank dome. If finer contours were chosen with one ending at 0.0, we expect that most of the surface would be at zero, and the 0.40 kip/ft^2 value would be evident and localized.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

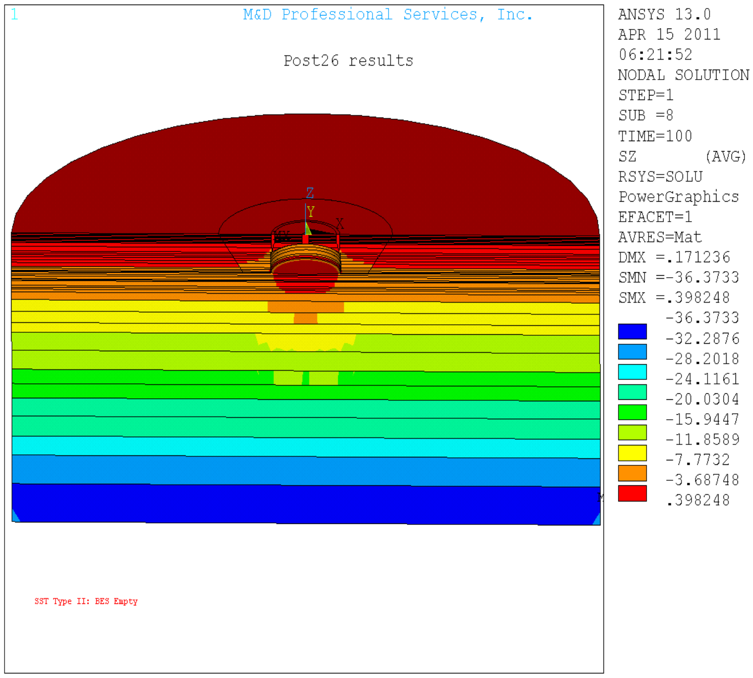

Figure 6.29: SST Type II Seismic Model BES: Soil Stresses (kip/ft^2) – Vertical Component

E2.12 QUESTION 12

IQRPE Question: The soil pressure at the side walls produces odd at rest pressure results against the tank side walls (see RPP-RPT-49989 Figure 6.12). Appendix H discusses these results as a function of geometry of the tank. Was this phenomena also shown in the axisymmetric model or only the shell model? With a well-defined phenomenon as pressure increase along depth of soil it is odd to see a wave like distribution of soil pressure. Has this type of pressure distribution been observed/measured in real world tests?

PNNL Response: Figure 6.12 shows the approximated soil pressures from the 180° seismic model. Appendix H is the axisymmetric static model, which is actually a 3D wedge (with symmetric boundary conditions) because the STIF65 concrete elements are 3D. The waviness of Figure 6.12 is an artifact of the finite element modeling approximation. We don't expect that real-world tests would show similar behavior.

The finite element models (with compacting soil, flexible wall stiffness, and soil-to-tank frictional contact) required tuning and checking to ensure that they approximate the expected at-rest soil pressure. In reality, the tanks were built on compacted soil, and the surrounding soil was backfilled and compacted in lifts. The models are built with all soil surrounding the tanks and then gravity is applied to all components. Model tuning included reducing the friction coefficient to prevent wall drag-down during the gravity step. The seismic models also tuned the side-wall contact stiffnesses to better approximate the expected linear soil pressure distribution. Appendix H presents a soil pressure study of the static model requested by the external reviewer. Additional forces were applied to the tank wall to enforce the expected linear at-rest pressure distribution. This case gave ACI-349 D/C ratios that were very similar to the baseline case with the nonlinear initial pressure distribution resulting from the combination of gravity, soil compression, and sidewall flexing. Appendix H showed the changing nonlinear soil pressures for the different load combinations. The conclusion was that the results were reasonable and understandable.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

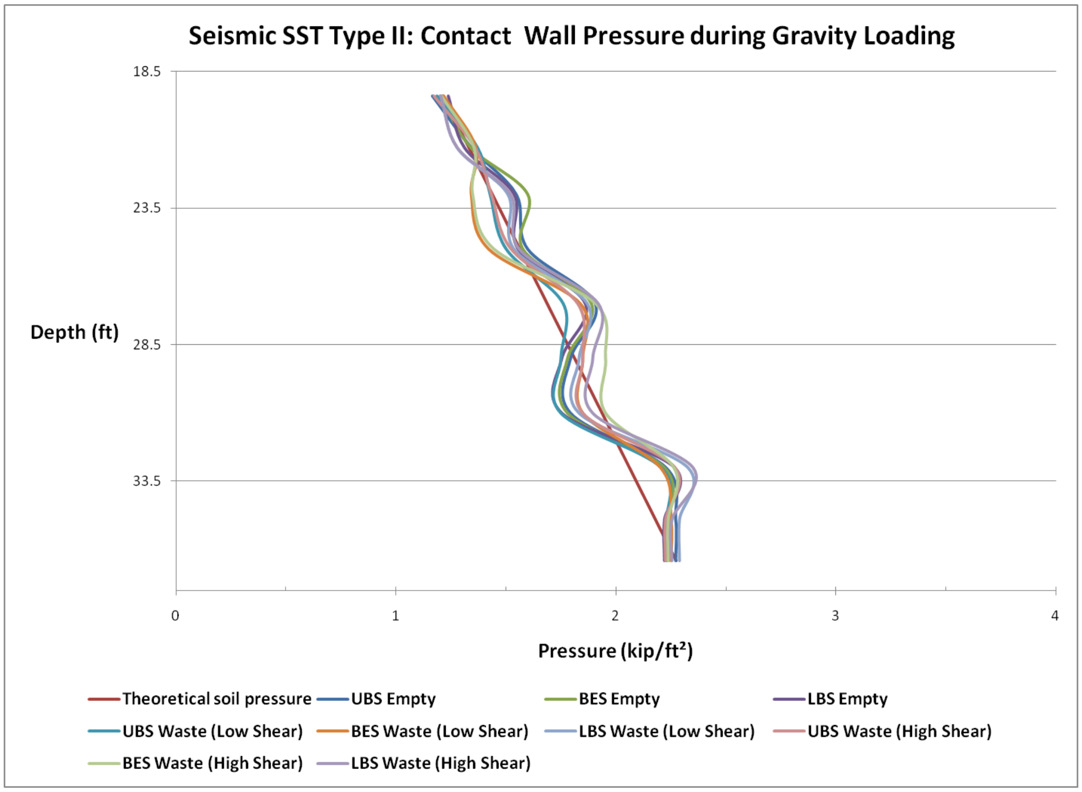

Figure 6.12: Seismic Model Soil/Concrete Contact Element Normal Pressure for At-Rest Calibration – Gravity Only

E2.13 QUESTION 13

IQRPE Question: In RPP-RPT-49989, the seismic model used soft areas of soil to address soil arching. In RPP-RPT-49990, the seismic model used slip planes to address the same phenomena. How do each of these methods impact results and why is one method superior to the other? Why were different strategies used for similar tanks?

PNNL Response: The elastic soil in the seismic model must include some mechanism to prevent the soil from arching over the tank dome. The slip planes or "soil rings" method more freely applies the deadweight soil load to the dome while maintaining full horizontal load transfer through the soil. This was a minor improvement that was devised between the Type II and Type III AORs. It was carried into the Type IV and Type I analyses as well.

IQRPE Closing Comments: On the issue of soil arching, the magnitude of the change from Type II and Type III models is not quantified in the AORs. Based on adequate D/C ratios, we concur with the PNNL response.

E2.14 QUESTION 14

IQRPE Question: In the load-displacement response graphs for the limit analysis, what causes the non-linear behavior in each of the graphs (RPP-RPT-49989 Figure 11.11)? Based on RPP-46442 Figure 4.5, it seems that this behavior is similar to the ASME collapse load but the collapse limit line is not shown in the plots so it is difficult to discern.

PNNL Response: The nonlinear slope change in RPP-RPT-49989 Figure 11.11 load/deflection curve results from extensive cracking in the dome and the haunch concrete. The slope change is more pronounced for the local limit load cases than the uniform limit load cases.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

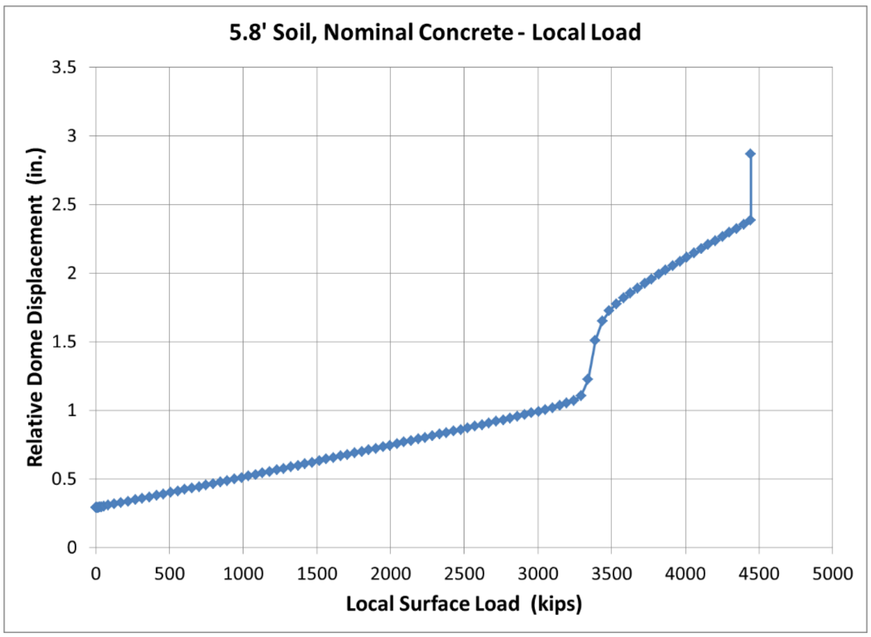

Figure 11.11: Load-Displacement Response of Nominal Concrete Under 5.8 ft of Soil with Local Load

E2.15 QUESTION 15

IQRPE Question: For reference, RPP-RPT-49989 Figure 10.44 shows a localized exceedance of shear capacity (D/C=1.07) in adjacent elements at the top of the wall. The reviewer says to average the shear stress over a distance 4× the wall thickness. In the discussion, it is mentioned that even doing this still leaves the area over capacity (D/C=1.06). It is stated that the seismic demands are 10-30% conservative in general, but that is not reflected at each location. It is also stated that the combination of appurtenances is not present in any single Type II tank. Those considerations could give credence to the argument that the tank is conservatively analyzed. But, the tank-to-tank interaction is not taken into account, which was stated can increase the demand by 10-20%. Why was the model then not revised to better reflect the actual conditions of a tank (or 2) to then present results that show the tank was under stressed?

PNNL Response: The tank-to-tank interaction study of the Type-IV AX Tank Farm tanks was completed in 2014, three years after the Type II AOR. The summary report reviewed the Type II AOR for tank-to-tank interaction effects, but it inadvertently did not review the appurtenance analysis. Further analysis of the Type II appurtenance study with some of the stacked conservatisms removed (i.e., 10-30% conservative seismic accelerations, upper-bound combined pit configurations, 10-ft soil overburden) would likely show shear demands below capacity in the haunch-to-wall transition. Additional background information is provided below:

Figure 8.18 Factored static loads, BES+BEC, no creep, shows shear peak D/C=0.52 at section 19.

Figure 10.9 Appurtenance model, factored static loads, BES+BEC, no creep, shows shear peak D/C~0.55 at section 19.

Figure 10.33 Concrete tank through-wall shear – BES, HSS waste comparison with and without appurtenances (seismic only),

- No appurtenances, shear = 3.4 kip/ft at section 17, shear = 1.9 kip/ft at section 19
- With appurtenances, shear = 7.4 kip/ft at section 16, shear = 2.3 kip/ft at section 19.

Table 8.1 Tank-to-tank recommended adjustment factors.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

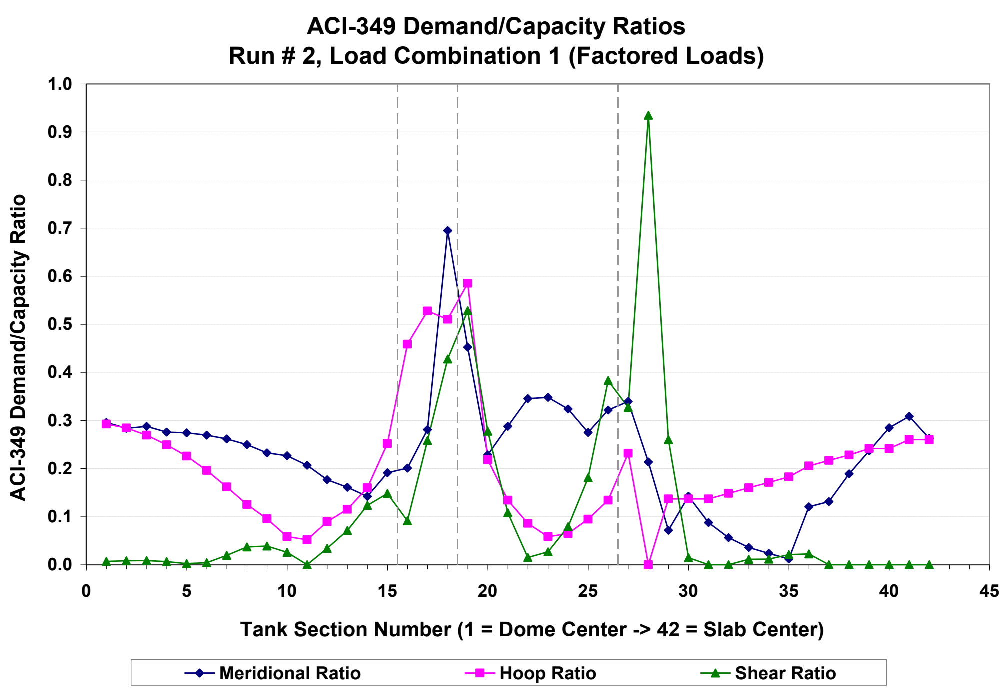

Figure 8.18: Run 2, ACI D/C Ratios for LC1, BES + BEC, No Creep

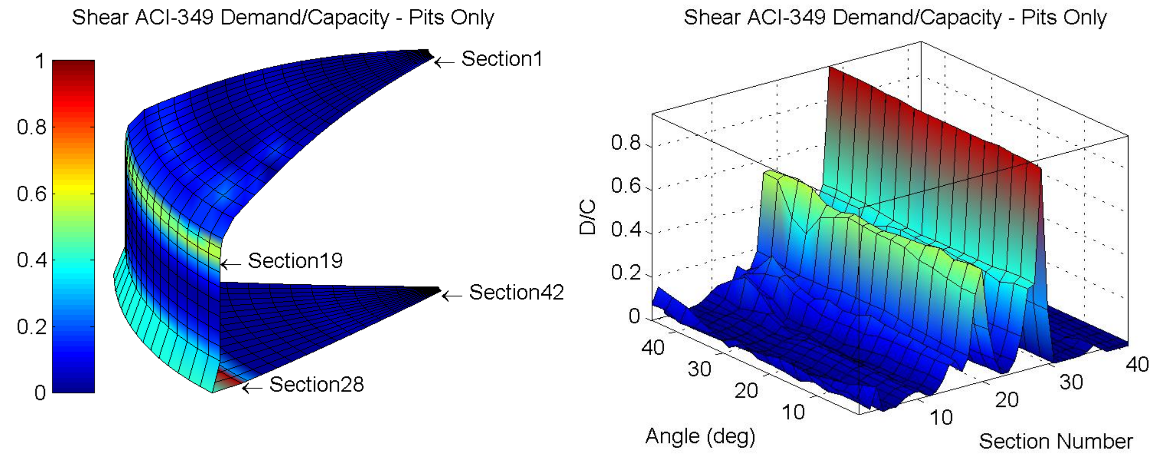

Figure 10.9: Pits-Only LC1 D/C Ratios in Shear (top), Meridional (middle), and Hoop (bottom), BES + BEC, No Creep

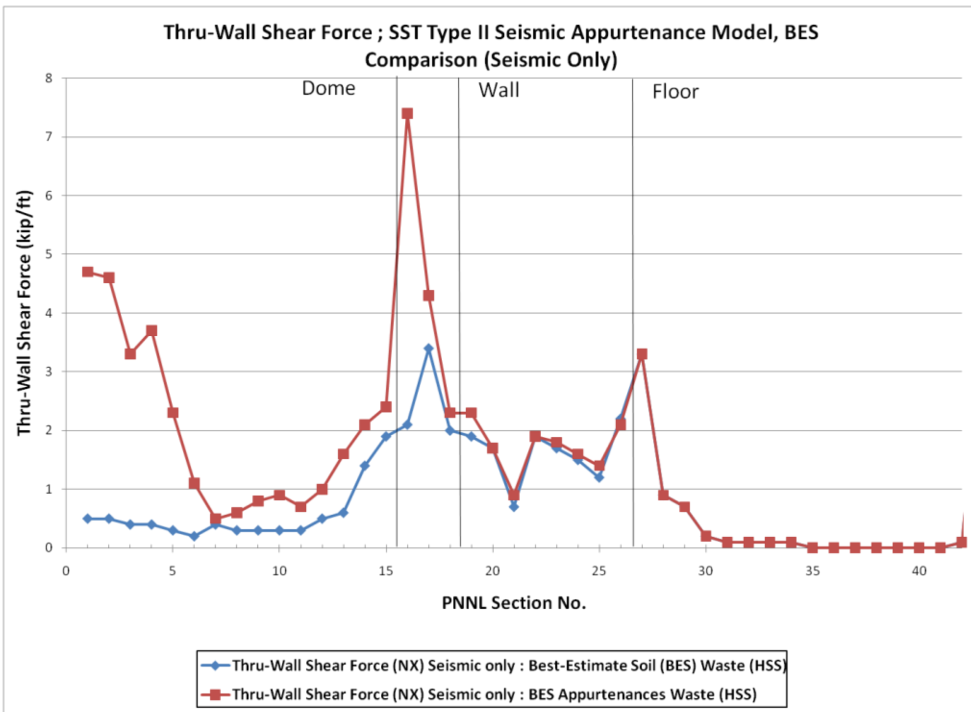

Figure 10.33: Concrete Tank Through-Wall Shear – BES, HSS Waste Comparison with and without Appurtenances (Seismic Only)

Table 8.1. TTI D/C Ratio Adjustments for Specific Load Evaluations, Loading Directions, and Tank Regions (RPP-RPT-49991)

Load Evaluation	Loading Direction	Tank Region	Max TTI D/C	Single Tank D/C	D/C Scale Factor	Suggested ΔD/C
Peak Temperature	Meridional	Bottom of Wall	0.43	0.29	1.48	**+0.14**
	Through-Wall Shear	Bottom of Wall	0.41	0.22	1.86	**+0.19**
LC1	Through-Wall Shear	Haunch	0.34	0.20	1.70	**+0.14**
LC4	Meridional	Top of Wall	0.46	0.31	1.48	**+0.15**
	Through-Wall Shear	Haunch	0.33	0.22	1.50	**+0.11**

E2.16 QUESTION 16

IQRPE Question: Who reviewed the buckling analysis? The reviewers stated, "Neither of the reviewers has sufficient expertise to comment on the details of the buckling report," (RPP-RPT-49989, pg A.24, comment on Chapter 12).

PNNL Response: Larry Julyk of Becht (previously M&D Professional Services) performed the NQA-1 review of the concrete shell buckling analysis (see Appendix L of RPP-RPT-49989). No further external review was conducted.

IQRPE Closing Comments: Based on our reviews, we do not anticipate any buckling type failures. If structural failures or other structural concerns develop, a new finite element analysis should be conducted to find the extent that a tank can be damaged and still be structurally sound. This is similar to the Expert Panel Recommendation SI-9. If and when this analysis is done, the tank type with the highest reported D/C (demand to capacity) ratio should undergo a more thorough analysis to validate the results of the previous AORs. In conjunction with that finite element analysis, this buckling analysis should be reviewed and/or redone.

E2.17 QUESTION 17

IQRPE Question: Was the deflection of the dome calculated during the seismic evaluation? More specifically, is dome deflection an adequate indicator of pre-collapse? What is dome deflection under dead+seismic and under dead? In addition, what are deflections at the haunch?

PNNL Response: There are some deflection values included in the dome limit load analyses. The models calculate dome deflection through the application of gravity and all other loads. Dome deflection under dead + seismic and dead alone were not reported. No haunch deflections were reported.

As part of additional feedback on this topic, PNNL wrote:

> Let's put this in perspective using some numbers from the Type II buckling analysis (Appendix L of RPP-RPT-49989):

Vertical force supported at the wall mid-height with 10 ft of soil at dome apex = 13,000,000 lb

Wall area = 76 ft dia x π × 1 ft thick = 239 ft^2

Wall compressive stress = 54,448 lb/ft^2 = 378 lb/in^2

Concrete Degraded Elastic Mod. = 2,900,000 psi

Midwall strain = 378 psi / 2,900,000 psi = 1.3E-4

Wall height (footing to haunch) = 209 in.

Deflection of haunch relative to footing = 209 in. × 1.3E-4 = 0.027 in.

Therefore the modeled wall deflections will be extremely small. The limit load analysis estimates that the dome deflection relative to the haunch is about 0.3 inch with 10 ft of soil at the dome apex, which is also a small dimension. The bottom line is that if the dome deflection program measures any real deflection (i.e., greater than the measurement uncertainty), then it will be significant.

IQRPE Closing Comments: It is the IQRPE's recommendation that any future AORs meeting the criteria listed in Expert Panel Recommendation SI-9 include some points along the base of the wall and the corresponding top of the haunch and wall mid-height as well as the center of the tank dome where deflections are calculated. Although unlikely based on PNNL's response, the intent of this deflection output is to determine if there is deflection in the sidewall of the tank will it be measurable at the top of the tank. It is recommended that this evaluation also consider what the maximum size and number of localized holes are allowed prior to failure of the tank system.

E2.18 QUESTION 18

IQRPE Question: WRPS is performing visual inspections inside the tanks; will this detect failure (such as cracking) and where?

PNNL Response: Hoop direction cracks on the inside of the dome are not expected because the meridional stresses are compressive at the inside surface. Cracks in the meridional direction maybe be present (and stable) due to tensile hoop stresses in the outer ~50% of the radius. Any measurable increase in crack width over time or due to additional loads would be concerning. Even the formation of small cracks (on the order of 1/16 in. wide) would signal significant structural degradation as would measurable dome deflections of ~0.25 in. or greater.

The following is from RPP-RPT-43116, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project*:

3.0 CONFIRMATION OF TANK STRUCTURAL INTEGRITY

3.1 OBSERVATIONS CONCERNING THE CURRENT CONDITION OF TANKS

3.1.1 Observations Concerning Current Conditions of Concrete Domes

Surveys have been conducted on all of the SSTs approximately every two (2) years since the early 1980s. A maximum allowable decrease in the dome elevation of 0.24 inches, relative to the baseline measurement, has been specified as the acceptable limit for SSTs. Analytical studies summarized in Section 6.4 of Abatt (2002) indicate a safety factor of approximately 3.0 or larger against dome collapse for the in-situ soil overburden load. An evaluation of the safety factor as a function of the increase in dome deflection over initial baseline measurements was conducted on Tank 241-C-106. This evaluation indicated a safety factor of approximately 2.5 for an additional downward deflection of 0.24 inch, and approximately 2.0 for an additional deflection of 0.48-in. Thus, adequate safety margin exists if dome deflections do not increase more than 0.48-in. Remote visual inspections of the underside of the SST concrete domes does not indicate signs of concrete cracking, rust stains, or spalling of the concrete. One would not expect concrete cracks on the underside of the dome except possibly in the haunch area. Cracks in excess of 1/16-in. wide would indicate tensile yielding of the reinforcing steel (rebar). Cracks in excess of 1/8-in. wide are of significant structural concern. Rust stains or spalling of concrete indicate rebar corrosion.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

E2.19 QUESTION 19

IQRPE Question: In RPP-RPT-49993 (Type I tanks) it is noted in the body that the load limit factor-of-safety is approximately 2 unless concrete crushing is considered to be acceptable. When crushing is permitted, the FS is slightly less than the desired FS=3.0. Both the report and the reviewer make the comment that further analysis may be required to determine an acceptable FS. Has that been performed? If not is it planned to be performed or has it been deemed acceptable in other ways? In addition, why is concrete crushing deemed to be acceptable here?

PNNL Response: No additional analysis has been performed. Concrete crushing is not deemed to be acceptable. The limit load analysis uses concrete crushing as an estimate of the onset of structural instability. These loads that result in concrete crushing are way beyond the ACI design limits. The intent of the limit load analysis is to show a large margin between the actual loads and what the tanks could support before collapse.

IQRPE Closing Comments: RPP-RPT-49993 states “While the tank limit load analysis, as conservatively applied, it did not demonstrate the desired safety factors of the evaluation criteria, it does demonstrate additional margin nearly equal to the applied loads. Additional more refined analysis is recommended if the need for an over-tank concentrated loads arises.” Per Table 10.1 of RPP-RPT-49993, the limit load was 813 kips minimum. The allowable applied load under the dome load without further analysis is 142 kips per RPP-16660. Therefore, there is ample safety factor limits on dome loading of the Type I tanks.

If in the future, a larger applied load is needed over the Type I tanks, then a new AOR shall be generated to show that the tank is capable of supporting the specified and precise new load in addition to the existing and sustained loads. Depending on the duration of the new load, a load factor other than 1.7 might be justifiable for “Short-Term” loading. In addition, seismic may not need to be evaluated concurrently as the load is temporary, well controlled, and for a short duration.

E2.20 QUESTION 20

IQRPE Question: Can the load case “Peak Temperature” be better described as this case is critical to the analysis? The only reference says that all ACI load factors are set to 1.0. That also appears to be ACI-349 LC4 though. For reference, see RPP-RPT-49989 Figures 8.17 and 8.19.

PNNL Response: The tanks were evaluated at peak temperature with load factors equal to 1.0 to ensure that no rebar yielding, concrete crushing, or section shear failure was predicted that would invalidate the continuum behavior inherently assumed by the finite element models. The purpose of the peak temperature evaluation should have been clearly described in the AOR reports. The peak temperature evaluation is not a required ACI-349 load case.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

E2.21 QUESTION 21

IQRPE Question: More so in RPP-RPT-49993, it appears that a single model should have been used for TOLA and seismic as the TOLA model was a half-symmetry model as well as the seismic model. Why were these analyses modeled separately?

PNNL Response: RPP-RPT-49993 presents the analysis of record of the small 55,000 gal, Type I tanks. Because of the smaller size (and smaller finite element models) this might seem to be a case for using one finite element model for both the TOLA and seismic analyses. However, all of the points presented in the question 4 response still apply. Further, this was the last of the four AORs, so not a good time to change the analysis approach.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

E2.22 QUESTION 22

IQRPE Question: In RPP-CALC-51195 (55 in. penetration in tank C-105) the model is based on the Type II model, the same thermal cycle is used. Why was the peak temperature case not run? This case showed the slab failing in RPP-RPT-49989 model (which this model re-uses) but the slab is not shown to exceed capacity in any of the cases considered.

PNNL Response: As stated in Response [20], the peak temperature evaluation was a check to ensure the finite element model assumptions were not invalidated by section failure. This was shown in RPP-RPT-49989 so it was not repeated in RPP-CALC-51195. RPP-CALC-51195 focused more on the change in structural response of the dome to the presence of the new penetration. RPP-CALC-51195 shows the D/C ratios increase by a factor of two near the post construction hole, but do not change at sections away from the hole. Additional detailed working stress evaluations were performed very near the cut surfaces of the hole to ensure the dome sections were still adequate where the rebars were cut.

IQRPE Closing Comments: The question has been thoroughly answered, so we concur with the PNNL response.

E2.23 IQRPE SUMMARY OF ANALYSES OF RECORD QUESTIONS AND ANSWERS

The ability to interview and correspond with PNNL and WRPS on the AORs was extremely helpful in our assessment of the AORs. Being modern FEAs, the AORs conservatively show that the tanks are structurally adequate to the criteria of the ACI 349-06 code.

APPENDIX F
WASTE COMPATIBILITY

Table F-1: Waste Compatibility Matrix (11 sheets)

Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
A-101	Sound		331	37	0	3	328	1/1/2017
A-102	Sound	Water Intrusion	40	9	2	0	38	1/7/2015
A-103	Sound		388	86	10	2	376	6/1/2017
A-104	Assumed Leaker		25	0	0	25	0	2/1/2015
A-105	Assumed Leaker		37	0	0	37	0	1/1/2016
A-106	Sound		79	9	0	50	29	4/1/2016
AX-101	Sound		320	44	0	2	318	1/1/2018
AX-102	Sound		31	0	1	6	24	4/1/2018
AX-103	Sound		104	22	0	8	96	1/1/2017
AX-104	Sound		5	0	0	5	0	4/1/2018
B-101	Assumed Leaker		104	20	0	28	76	1/1/2016
B-102	Sound		31	7	4	0	27	1/1/2016
B-103	Assumed Leaker		52	10	0	1	51	1/1/2016
B-104	Sound		369	45	0	309	60	1/1/2016
B-105	Assumed Leaker		289	20	0	28	261	1/1/2016
B-106	Sound		117	8	1	116	0	4/1/2017

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Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
B-107	Assumed Leaker		156	23	0	84	72	5/1/2017
B-108	Sound		85	19	0	27	58	8/1/2017
B-109	Sound		123	23	2	50	71	10/1/2016
B-110	Assumed Leaker		244	27	0	244	0	1/1/2016
B-111	Assumed Leaker		220	23	5	215	0	1/1/2017
B-112	Assumed Leaker		33	2	2	14	17	1/1/2016
B-201	Assumed Leaker	Water Intrusion	29.3	5	0.3	29	0	7/1/2016
B-202	Sound	Water Intrusion	29	4	2	27	0	8/1/2016
B-203	Assumed Leaker		50	5	1	49	0	8/1/2016
B-204	Assumed Leaker		50	5	2	48	0	8/1/2016
BX-101	Assumed Leaker	Water Intrusion	52	4	9	43	0	9/1/2016
BX-102	Assumed Leaker		89	0	0	89	0	5/1/2018
BX-103	Sound	Water Intrusion	73	4	11	62	0	10/1/2016
BX-104	Sound		97	4	4	93	0	1/1/2017

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Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
BX-105	Sound		70	4	0	42	28	1/1/2017
BX-106	Sound		38	4	0	10	28	5/1/2017
BX-107	Sound	Water Intrusion	344	37	0	344	0	11/1/2017
BX-108	Assumed Leaker		30	4	0	30	0	1/1/2017
BX-109	Sound		189	25	0	189	0	7/1/2017
BX-110	Assumed Leaker	Water Intrusion	212	35	6	65	141	10/1/2016
BX-111	Assumed Leaker		124	6	0	30	94	1/1/2016
BX-112	Sound		158	9	0	158	0	1/1/2017
BY-101	Sound		365	24	0	37	328	1/1/2016
BY-102	Sound	Water Intrusion	316	40	0	0	316	1/1/2016
BY-103	Assumed Leaker	Water Intrusion	412	55	0	9	403	1/1/2016
BY-104	Sound		401	44	0	43	358	7/1/2017
BY-105	Assumed Leaker		477	47	0	48	429	1/1/2017
BY-106	Assumed Leaker		429	37	0	30	399	8/1/2016
BY-107	Assumed Leaker		274	42	0	16	258	9/1/2016

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Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
BY-108	Assumed Leaker		221	33	0	44	177	10/1/2016
BY-109	Sound	Water Intrusion	296	37	0	23	273	11/1/2017
BY-110	Sound		348	20	0	44	304	1/1/2017
BY-111	Sound		399	14	0	0	399	7/1/2017
BY-112	Sound		287	24	0	2	285	6/1/2017
C-101	Assumed Leaker	Retrieval Complete	5.5	Retrieved to limit of first and second retrieval technologies 9/25/2013				4/23/2015
C-102	Sound	Retrieval Complete	15.5	Retrieval completed 11/30/2015				3/16/2016
C-103	Sound	Retrieval Complete	2.5	Retrieval completed 8/23/2006				3/1/2017
C-104	Sound	Retrieval Complete	1.9	Retrieval completed 8/17/2012				4/1/2018
C-105	Assumed Leaker	Tank in Retrieval	1.5	Retrieval in progress				3/1/2018
C-106	Sound	Retrieval Complete in Review	2.8	Retrieval completed 12/31/2003				5/1/2017

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Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
C-107	Sound	Retrieval Complete	10	Retrieved to limit of third retrieval technology 9/30/14				5/1/2017
C-108	Sound	Retrieval Complete	3.4	Retrieved to limit of modified sluicing technology 3/22/2012				4/1/2018
C-109	Sound	Retrieval Complete	2	Retrieved to limit of modified sluicing technology 9/12/2012				4/1/2018
C-110	Sound	Retrieval Complete	2.1	Retrieval completed 10/30/13				5/1/2018
C-111	Sound	Retrieval Complete	4.9	Retrieval completed 8/29/2016				4/4/2017
C-112	Sound	Retrieval Complete	10	Retrieval completed 5/29/2014				3/3/2015
C-201	Assumed Leaker	Retrieval Complete	0.14	Retrieval completed 3/23/2006				10/1/2016
C-202	Assumed Leaker	Retrieval Complete	0.15	Retrieval completed 8/11/2005				1/1/2017
C-203	Assumed Leaker	Retrieval Complete	0.14	Retrieval completed 3/24/2005				1/1/2017

Table F-1: Waste Compatibility Matrix (11 sheets)

Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
C-204	Assumed Leaker	Retrieval Complete	0.14	Retrieval completed 12/11/2006				1/1/2017
S-101	Sound		350	45	0	235	115	8/1/2017
S-102	Sound		93	5	2	22	69	1/1/2017
S-103	Sound		230	45	1	9	220	8/1/2017
S-104	Assumed Leaker		283	49	0	132	151	11/1/2017
S-105	Sound		508	42	0	2	506	4/1/2017
S-106	Sound	Water Intrusion	451	26	0	0	451	8/1/2017
S-107	Sound		358	42	0	328	30	10/1/2017
S-108	Sound		541	4	0	5	536	5/1/2016
S-109	Sound		533	16	0	13	520	7/1/2017
S-110	Sound		387	30	0	91	296	11/1/2017
S-111	Sound		401	42	0	72	329	4/1/2016
S-112	Sound	Retrieval Complete	2.7	Retrieval completed 3/2/2007				9/1/2017
SX-101	Sound	Water Intrusion	416	44	0	141	275	6/1/2018
SX-102	Sound	Water Intrusion	342	37	0	55	287	4/1/2015
SX-103	Sound		599	40	0	80	519	11/1/2017
SX-104	Sound		433	48	0	70	363	8/1/2017
SX-105	Sound		376	39	0	63	313	11/1/2017

Table F-1: Waste Compatibility Matrix (11 sheets)

Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
SX-106	Sound	Water Intrusion	399	37	0	0	399	4/1/2016
SX-107	Assumed Leaker		96	7	0	96	0	7/1/2015
SX-108	Assumed Leaker		79	0	0	79	0	10/1/2017
SX-109	Assumed Leaker		241	0	0	66	175	7/1/2015
SX-110	Sound		58	0	0	49	9	7/1/2015
SX-111	Assumed Leaker		117	11	0	97	20	10/1/2015
SX-112	Assumed Leaker		77	6	0	77	0	10/1/2015
SX-113	Assumed Leaker		22	0	0	22	0	10/1/2015
SX-114	Assumed Leaker		158	30	0	127	31	7/1/2015
SX-115	Assumed Leaker		4	0	0	4	0	7/1/2015
T-101	Assumed Leaker	Water Intrusion	94	16	2	37	55	6/1/2016
T-102	Sound	Formal Leak Assessment	30	3	11	19	0	7/1/2016

Table F-1: Waste Compatibility Matrix (11 sheets)

Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
T-103	Assumed Leaker		26	4	3	23	0	1/1/2016
T-104	Sound		310	31	0	310	0	7/1/2016
T-105	Sound		92	5	0	92	0	7/1/2016
T-106	Assumed Leaker		21	0	0	21	0	5/1/2016
T-107	AssumedLeaker	Water Intrusion	166	34	5	161	0	4/1/2016
T-108	Assumed Leaker		15	4	0	7	8	7/1/2016
T-109	Assumed Leaker		98	11	0	0	98	4/1/2018
T-110	Sound		370	48	1	369	0	7/1/2016
T-111	Assumed Leaker	Active Leak / Water Intrusion	424	38	0	424	0	7/1/2017
T-112	Sound		62	4	7	55	0	8/8/2017
T-201	Sound	Water Intrusion	31	4	2	29	0	5/1/2016
T-202	Sound		19	3	0	19	0	6/1/2016
T-203	Sound		36	5	0	36	0	5/1/2016
T-204	Sound		36	5	0	36	0	5/1/2016
TX-101	Sound		87	7	0	73	14	11/1/2017
TX-102	Sound		213	27	0	2	211	7/1/2015
TX-103	Sound		144	18	0	0	144	10/1/2015

Table F-1: Waste Compatibility Matrix (11 sheets)

Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
TX-104	Sound		67	9	1	33	33	2/1/2017
TX-105	Assumed Leaker		600	25	0	11	589	2/1/2018
TX-106	Sound		391	37	0	5	386	5/1/2018
TX-107	Assumed Leaker		27	7	0	0	27	7/1/2015
TX-108	Sound		118	8	0	6	112	10/1/2015
TX-109	Sound		359	6	0	359	0	12/1/2017
TX-110	Assumed Leaker		462	14	0	37	425	10/1/2015
TX-111	Sound		359	10	0	43	316	10/1/2015
TX-112	Sound		627	26	0	0	627	8/8/2017
TX-113	Assumed Leaker		634	18	0	88	546	4/1/2017
TX-114	Assumed Leaker		522	17	0	4	518	10/1/2015
TX-115	Assumed Leaker		544	25	0	8	536	10/1/2015
TX-116	Assumed Leaker		565	21	0	66	499	4/1/2017
TX-117	Assumed Leaker		626	10	0	29	597	1/1/2018
TX-118	Sound		248	31	0	0	248	1/1/2018

Table F-1: Waste Compatibility Matrix (11 sheets)

Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
TY-101	Assumed Leaker		105	2	0	59	46	5/1/2016
TY-102	Sound	Water Intrusion	70	13	9	0	61	10/1/2016
TY-103	Assumed Leaker		152	23	0	101	51	7/1/2016
TY-104	Assumed Leaker		42	4	1	41	0	7/1/2016
TY-105	Assumed Leaker		231	12	0	231	0	7/1/2016
TY-106	Assumed Leaker		13	1	0	13	0	1/1/2017
U-101	Assumed Leaker		23	4	0	23	0	7/1/2016
U-102	Sound	Water Intrusion	353	37	6	43	304	1/1/2017
U-103	Sound		418	33	1	12	405	2/1/2017
U-104	Assumed Leaker		84	0	0	45	39	4/1/2017
U-105	Sound	Water Intrusion	350	44	0	32	318	3/1/2017
U-106	Sound		165	36	2	0	163	10/1/2017
U-107	Sound		277	32	0	16	261	12/1/2017
U-108	Sound		428	46	0	29	399	1/1/2018
U-109	Sound		401	47	0	32	369	2/1/2017

Table F-1: Waste Compatibility Matrix (11 sheets)

Tank (241-)	Tank Leak Integrity	Tank Status	Total Waste (kgal)	Drainable Interstitial Liquid (kgal)	Supernatant Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
U-110	Assumed Leaker		183	16	0	183	0	11/1/2017
U-111	Sound	Water Intrusion	219	31	0	26	193	4/1/2016
U-112	Assumed Leaker		43	4	0	43	0	1/1/2018
U-201	Sound		5	1	1	4	0	7/1/2016
U-202	Sound		5	0	1	4	0	7/1/2016
U-203	Sound		3	0	1	2	0	7/1/2016
U-204	Sound		3	0	1	2	0	7/1/2016

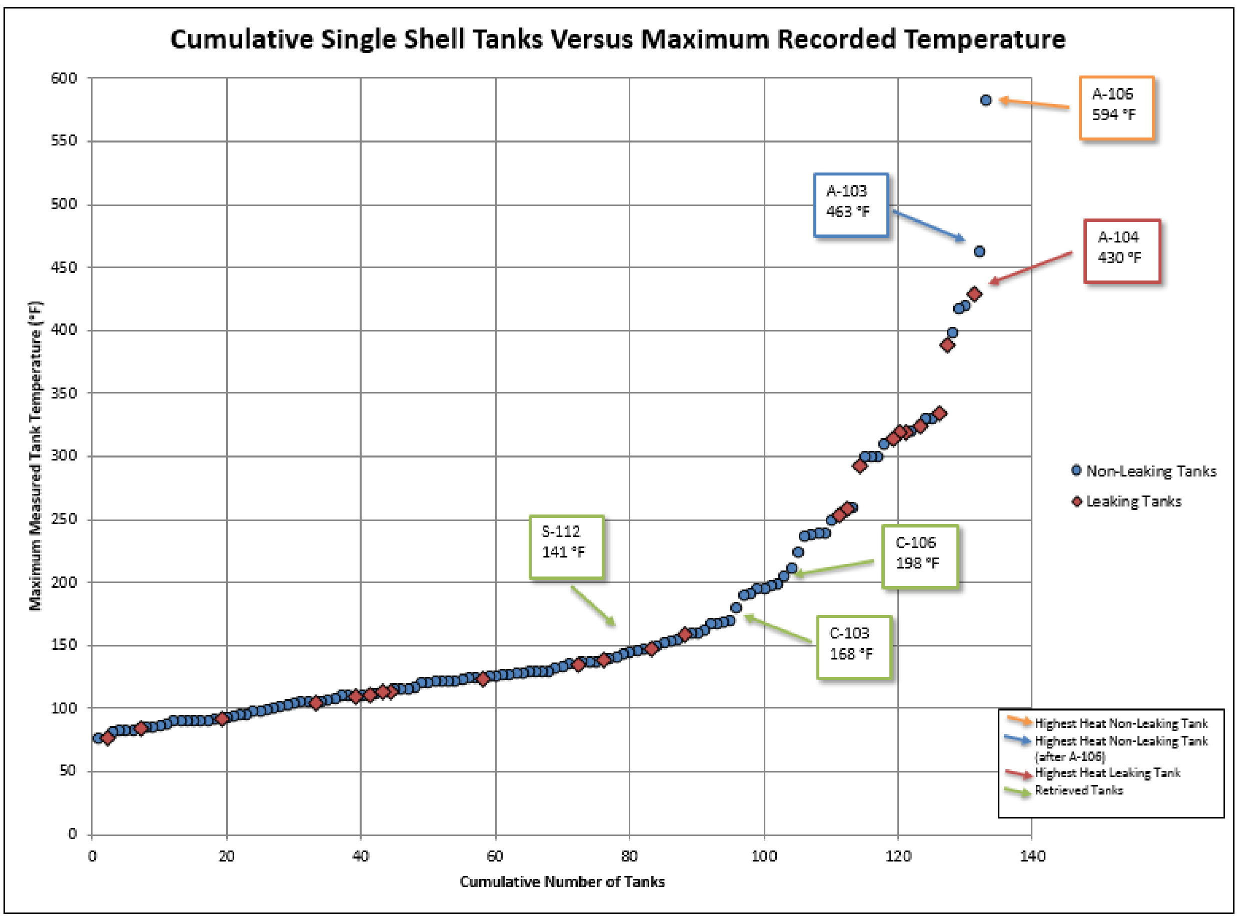
APPENDIX G
CORROSION

COMPARISON OF ASSUMED LEAKING TANKS

Although leaking is not directly investigated as part of this Single-Shell Tank (SST) Structural Integrity Assessment Report, leaking tanks are looked at to see if there is any indications of structural concern. For example, some tanks had very high temperatures.

As shown in Figure G-1, there does not appear to be a correlation between leaker tanks and temperature. Table G-1 shows length of time non-leaker tanks exceeded 200 °F, the point where it is postulated that temperature starts to cause degradation of concrete. Figure G-2 also illustrates non-leaker tanks with prolonged periods of elevated temperatures.

The visual inspections noted corrosion information for the liner, in-tank equipment, and risers. Other information recorded by the visual inspections is cracking and any distress factors. Table G-2 lists the most severe corrosion condition observed in the most recent visual inspection by tank, organized in alphabetical order of tanks. Tanks which have not been visually inspected are also included in the table, but there is no data. Table G-3 shows the same information sorted by sound/assumed leaker tanks first and then by alphabetical order.



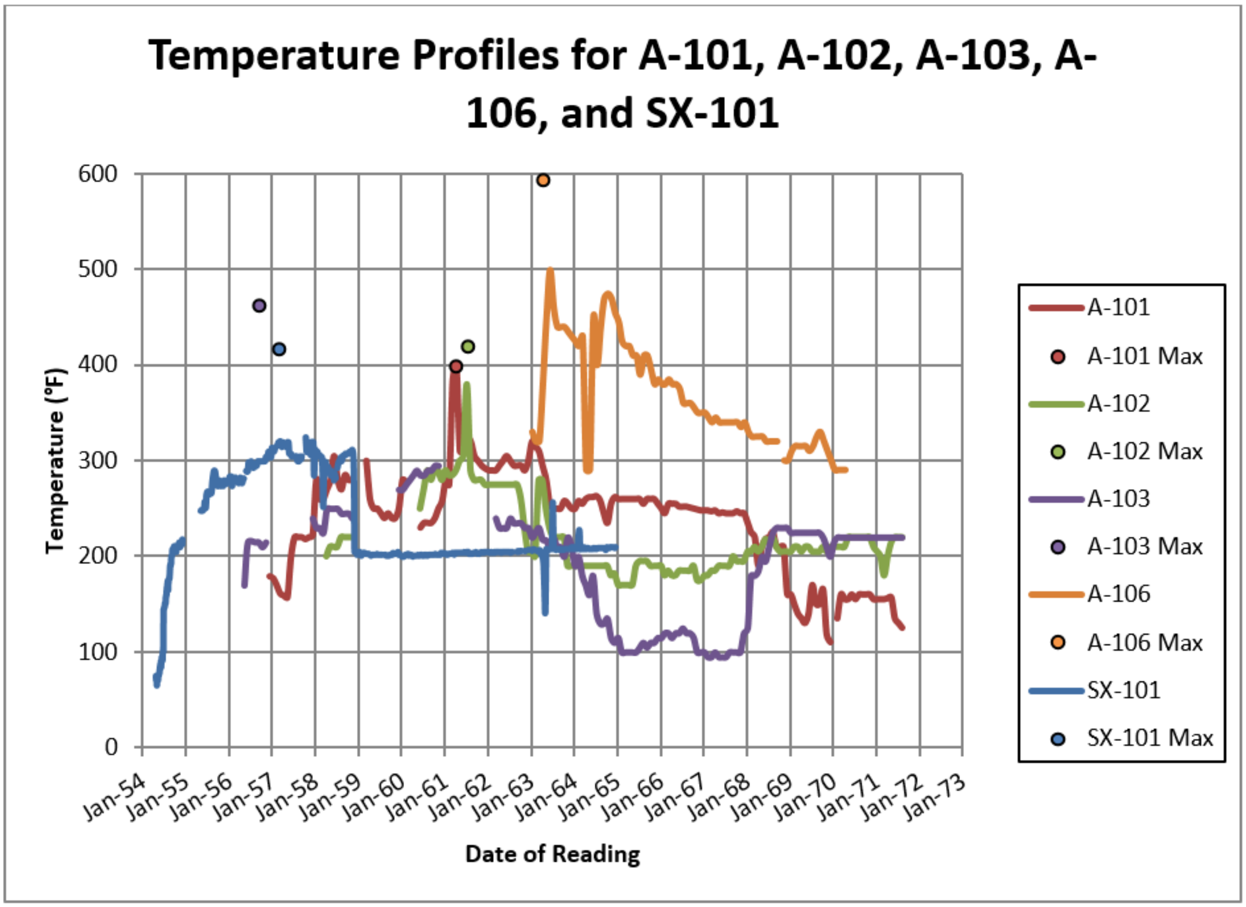
Reference: RPP-49300, 2011, *Data Quality Objectives for Single-Shell Tank Sidewall Coring Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Figure G-1: Leaker SSTs and Temperature

Table G-1: Non-Leaker SSTs with Elevated Temperatures

Non-Leakers			
Tank	**Max. Temp. (°F)**	**Months ≥ 200 °F**	**Months ≥ 300 °F**
A-106	594	87	81
A-103	463[3]	91	3+
A-102	420	93	3
SX-101	417[3]	117	22
A-101	399	130	17

Reference: RPP-49300, 2011, *Data Quality Objectives for Single-Shell Tank Sidewall Coring Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.



Reference: RPP-49300, 2011, *Data Quality Objectives for Single-Shell Tank Sidewall Coring Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Figure G-2: Non-Leaker SSTs with Prolonged Elevated Temperatures

Table G-2: Visual Inspection Information of SSTs Sorted Alphabetically (5 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
A-101[5]	2015		X				X				X					Sound
A-102[4]	2014	X					X					X				Sound
A-103[3,4]	2013/2014		X				X				X					Sound
A-104[7]	2017	X				X				X						Assumed Leaker
A-105[1,7]	2010/2017	X				X				X						Assumed Leaker
A-106[1]	2010	X				X				X						Sound
AX-101[2]	2011	X				X				X						Sound
AX-102[1]	2010	X				X				X						Sound
AX-103[2]	2011	X				X				X						Sound
AX-104[2]	2011	X				X				X						Sound
B-101[6]	2016			X			X				X					Assumed Leaker
B-102[1]	2010	X				X				X						Sound
B-103																Assumed Leaker
B-104[8]	2018		X			X				X				X		Sound
B-105[8]	2018	X					X				X			X		Assumed Leaker
B-106[2]	2011	X				X				X	X					Sound
B-107																Assumed Leaker
B-108																Sound
B-109[4]	2014		X				X				X					Sound
B-110																Assumed Leaker
B-111																Assumed Leaker
B-112																Assumed Leaker
B-201[6]	2016			X				X				X		X		Assumed Leaker
B-202[4]	2014			X			X				X					Sound
B-203[3]	2013			X			X				X					Assumed Leaker
B-204[3]	2013			X			X				X				X	Assumed Leaker
BX-101[3]	2013		X					X				X				Assumed Leaker
BX-102[7]	2017		X				X				X					Assumed Leaker
BX-103[3]	2013		X					X				X				Sound
BX-104																Sound

Table G-2: Visual Inspection Information of SSTs Sorted Alphabetically (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
BX-105																Sound
BX-106[5]	2015		X				X				X					Sound
BX-107[7]	2017		X				X				X					Sound
BX-108																Assumed Leaker
BX-109		X	X			X				X						Sound
BX-110[3]	2013				X	X				X						Assumed Leaker
BX-111[4]	2014		X				X				X					Assumed Leaker
BX-112																Sound
BY-101[3]	2013			X			X				X				X	Sound
BY-102[3]	2013		X				X				X					Sound
BY-103[4]	2014	X				X				X						Assumed Leaker
BY-104																Sound
BY-105[6]	2016		X				X				X					Assumed Leaker
BY-106[4]	2014			X		X						X				Assumed Leaker
BY-107																Assumed Leaker
BY-108																Assumed Leaker
BY-109[7]	2017		X			X				X						Sound
BY-110[1,5]	2010/2015			X			X				X					Sound
BY-111[3]	2013		X				X				X					Sound
BY-112																Sound
C-101[2]	2011	X				X					X					Assumed Leaker
C-102																Sound
C-103																Sound
C-104																Sound
C-105																Assumed Leaker
C-106																Sound
C-107																Sound
C-108																Sound
C-109																Sound
C-110[1]	2010	X				X				X						Sound

Table G-2: Visual Inspection Information of SSTs Sorted Alphabetically (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
C-111																Sound
C-112[2]	2011	X					X				X					Sound
C-201																Assumed Leaker
C-202																Assumed Leaker
C-203																Assumed Leaker
C-204																Assumed Leaker
S-101[1]	2010	X				X				X						Sound
S-102																Sound
S-103[1]	2010	X				X				X						Sound
S-104 [1,7]	2010/2017		X			X					X					Assumed Leaker
S-105[6]	2016	X				X				X						Sound
S-106[4]	2014	X				X				X				X		Sound
S-107[8]	2018		X			X				X						Sound
S-108[1,5]	2010/2015		X			X					X					Sound
S-109[3]	2013	X					X				X				X	Sound
S-110																Sound
S-111[3]	2013	X					X				X					Sound
S-112																Sound
SX-101[1,8]	2010/2018	X					X				X					Sound
SX-102[4]	2014		X			X				X						Sound
SX-103[8]	2018	X				X				X						Sound
SX-104[5]	2015		X				X				X					Sound
SX-105[8]	2018	X				X				X						Sound
SX-106[3]	2013	X					X				X					Sound
SX-107[2]	2011	X				X				X						Assumed Leaker
SX-108																Assumed Leaker
SX-109																Assumed Leaker
SX-110[7]	2017		X				X				X					Sound
SX-111																Assumed Leaker
SX-112																Assumed Leaker

Table G-2: Visual Inspection Information of SSTs Sorted Alphabetically (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
SX-113[8]	2018		X				X				X			X		Assumed Leaker
SX-114																Assumed Leaker
SX-115																Assumed Leaker
T-101[4]	2014		X					X				X			X	Assumed Leaker
T-102[2,4]	2011/2014	X				X				X						Sound
T-103																Assumed Leaker
T-104[7]	2017		X				X				X					Sound
T-105[7]	2017	X	X				X				X					Sound
T-106[7]	2017	X	X			X				X						Assumed Leaker
T-107[6]	2016			X			X				X					Assumed Leaker
T-108																Assumed Leaker
T-109[7]	2017		X			X				X						Assumed Leaker
T-110[6]	2016			X			X				X					Sound
T-111[3,4,5,6,7]	2013/2014 2015/2016 2017				X			X				X				Assumed Leaker
T-112[2,6]	2011/2016			X		X					X					Sound
T-201[4]	2014		X				X				X					Sound
T-202																Sound
T-203[3]	2013			X			X				X					Sound
T-204[3]	2013			X				X				X				Sound
TX-101[2]	2011	X				X				X						Sound
TX-102																Sound
TX-103[6]	2016		X				X				X					Sound
TX-104[2]	2011	X				X				X						Sound
TX-105[8]	2018	X				X				X						Assumed Leaker
TX-106[8]	2018	X				X				X						Sound
TX-107																Assumed Leaker
TX-108[5]	2015		X				X				X					Sound
TX-109[8]	2018		X			X				X				X		Sound

Table G-2: Visual Inspection Information of SSTs Sorted Alphabetically (6 sheets)

Tank	Year Inspected													Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
TX-110																Assumed Leaker
TX-111[6]	2016		X				X				X					Sound
TX-112[3]	2013		X			X				X						Sound
TX-113[6]	2016	X				X					X					Assumed Leaker
TX-114[5]	2015		X			X				X						Assumed Leaker
TX-115[5]	2015	X				X				X						Assumed Leaker
TX-116[6]	2016			X			X				X					Assumed Leaker
TX-117[5]	2015		X				X				X					Assumed Leaker
TX-118[8]	2018	X				X				X				X		Sound
TY-101																Assumed Leaker
TY-102[4]	2014		X			X				X					X	Sound
TY-103[5]	2015		X			X				X						Assumed Leaker
TY-104																Assumed Leaker
TY-105[3]	2013		X			X				X				X		Assumed Leaker
TY-106																Assumed Leaker
U-101																Assumed Leaker
U-102[6]	2016		X				X				X			X		Sound
U-103[8]	2018		X			X					X			X		Sound
U-104[1]	2010	X				X				X						Assumed Leaker
U-105[6]	2016		X			X				X					X	Sound
U-106[2]	2011	X				X				X						Sound
U-107[7]	2017	X				X				X						Sound
U-108																Sound
U-109																Sound
U-110																Assumed Leaker
U-111[3,4]	2013/2014			X			X				X			X		Sound
U-112																Assumed Leaker
U-201																Sound
U-202																Sound
U-203																Sound

Table G-2: Visual Inspection Information of SSTs Sorted Alphabetically (6 sheets

Tank	Year Inspected													Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
U-204																Sound

References:

[1] RPP-RPT-48194, Rev. 00
[2] RPP-RPT-51404, Rev. 00
[3] RPP-RPT-55951, Rev. 00
[4] RPP-RPT-58239, Rev. 00
[5] RPP-RPT-58849, Rev. 00
[6] RPP-RPT-59272, Rev. 00
[7] RPP-RPT-60093, Rev. 00
[8] RPP-RPT-60565, Rev. 00

Table G-3: Visual Inspection Information of SSTs Sorted by Sound/Assumed Leaker Tank (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
A-101[5]	2015		X				X				X					Sound
A-102[4]	2014	X					X					X				Sound
A-103[3,4]	2013/2014		X				X				X					Sound
A-106[1]	2010	X														Sound
AX-101[2]	2011	X				X				X						Sound
AX-102[1]	2010	X				X				X						Sound
AX-103[2]	2011	X				X				X						Sound
AX-104[2]	2011	X				X					X					Sound
B-102[1]	2010	X				X				X						Sound
B-104[8]	2018		X			X				X				X		Sound
B-106[2]	2011	X				X				X	X					Sound
B-108																Sound
B-109[2]	2011		X				X				X					Sound
B-202[4]	2014			X			X				X					Sound
BX-103[3]	2013		X					X				X				Sound
BX-104																Sound
BX-105																Sound
BX-106[5]	2015		X				X				X					Sound
BX-107[7]	2017		X				X				X					Sound
BX-109		X	X			X				X						Sound
BX-112																Sound
BY-101[3]	2013			X			X				X				X	Sound
BY-102[3]	2013		X				X				X					Sound
BY-104																Sound
BY-109			X			X				X						Sound
BY-110[1,5]	2010/2015			X		X					X					Sound
BY-111[3]	2013		X				X				X					Sound
BY-112																Sound
C-102																Sound
C-103																Sound

Table G-3: Visual Inspection Information of SSTs Sorted by Sound/Assumed Leaker Tank (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
C-104																Sound
C-106																Sound
C-107																Sound
C-108																Sound
C-109																Sound
C-110[1]	2010	X				X				X						Sound
C-111																Sound
C-112[2]	2011	X					X				X					Sound
S-101[1]	2010	X				X				X						Sound
S-102																Sound
S-103[1]	2010	X				X				X						Sound
S-105[6]	2016	X				X				X						Sound
S-106[4]	2014	X				X				X				X		Sound
S-107[8]	2018		X			X				X						Sound
S-108[1,5]	2010/2015		X								X					Sound
S-109[3]	2013	X					X				X				X	Sound
S-110																Sound
S-111[3]	2013	X					X				X					Sound
S-112																Sound
SX-101[1,8]	2010/2018	X					X				X					Sound
SX-102[4]	2014		X			X				X						Sound
SX-103[8]	2018	X				X				X						Sound
SX-104[5]	2015		X				X				X					Sound
SX-105[8]	2018	X				X				X						Sound
SX-106[3]	2013	X					X				X					Sound
SX-110[7]	2017		X				X				X					Sound
T-102[2,4]	2011/2014	X				X				X						Sound
T-104[7]	2017		X				X				X					Sound
T-105[7]	2017	X	X				X				X					Sound

Table G-3: Visual Inspection Information of SSTs Sorted by Sound/Assumed Leaker Tank (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
T-110[6]	2016			X			X				X					Sound
T-112[2,6]	2011/2016			X		X					X					Sound
T-201[4]	2014		X				X				X					Sound
T-202																Sound
T-203[3]	2013			X			X				X					Sound
T-204[3]	2013			X				X				X				Sound
TX-101[2]	2011	X				X				X						Sound
TX-102																Sound
TX-103[6]	2016		X				X				X					Sound
TX-104[2]	2011	X				X				X						Sound
TX-106[8]	2018	X				X				X						Sound
TX-108[5]	2015		X				X				X					Sound
TX-109[8]	2018		X			X				X				X		Sound
TX-111[6]	2016		X				X				X					Sound
TX-112[3]	2013		X			X				X						Sound
TX-118[8]	2018	X				X				X				X		Sound
TY-102[4]	2014		X			X				X					X	Sound
U-102[6]	2016		X				X				X			X		Sound
U-103[8]	2018		X				X				X			X		Sound
U-105[6]	2016		X			X				X					X	Sound
U-106[2]	2011	X				X				X						Sound
U-107[7]	2017	X				X				X						Sound
U-108																Sound
U-109																Sound
U-111[3,4]	2013/2014			X			X				X			X		Sound
U-201																Sound
U-202																Sound
U-203																Sound
U-204																Sound

Table G-3: Visual Inspection Information of SSTs Sorted by Sound/Assumed Leaker Tank (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
A-104[7]	2017	X				X				X						Assumed Leaker
A-105[1,7]	2010/2017	X				X				X						Assumed Leaker
B-101[6]	2016			X			X				X					Assumed Leaker
B-103																Assumed Leaker
B-105[8]	2018	X					X				X			X		Assumed Leaker
B-107																Assumed Leaker
B-110																Assumed Leaker
B-111																Assumed Leaker
B-112																Assumed Leaker
B-201[6]	2016			X				X				X		X		Assumed Leaker
B-203[3]	2013			X			X				X					Assumed Leaker
B-204[3]	2013			X			X				X				X	Assumed Leaker
BX-101[3]	2013		X					X				X				Assumed Leaker
BX-102[7]	2017		X				X				X					Assumed Leaker
BX-108																Assumed Leaker
BX-110[3]	2013				X	X				X						Assumed Leaker
BX-111[4]	2014		X				X				X					Assumed Leaker
BY-103[4]	2014	X				X				X						Assumed Leaker
BY-105[6]	2016		X				X				X					Assumed Leaker
BY-106[4]	2014			X		X						X				Assumed Leaker
BY-107																Assumed Leaker
BY-108																Assumed Leaker
C-101[2]	2011	X				X					X					Assumed Leaker
C-105																Assumed Leaker
C-201																Assumed Leaker
C-202																Assumed Leaker
C-203																Assumed Leaker
C-204																Assumed Leaker
S-104 [1,7]	2010/2017		X			X					X					Assumed Leaker
SX-107[2]	2011	X				X				X						Assumed Leaker

Table G-3: Visual Inspection Information of SSTs Sorted by Sound/Assumed Leaker Tank (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
SX-108																Assumed Leaker
SX-109																Assumed Leaker
SX-111																Assumed Leaker
SX-112																Assumed Leaker
SX-113[8]	2018		X				X				X			X		Assumed Leaker
SX-114																Assumed Leaker
SX-115																Assumed Leaker
T-101[4]	2014		X					X				X			X	Assumed Leaker
T-103																Assumed Leaker
T-106[7]	2017	X	X			X				X						Assumed Leaker
T-107[6]	2016			X			X				X					Assumed Leaker
T-108																Assumed Leaker
T-109[7]	2017		X			X				X						Assumed Leaker
T-111[3,4,5,6,7]	2013/2014 2015/2016 2017				X			X				X				Assumed Leaker
TX-105[8]	2018	X				X				X						Assumed Leaker
TX-107																Assumed Leaker
TX-110																Assumed Leaker
TX-113[6]	2016	X				X					X					Assumed Leaker
TX-114[5]	2015		X			X				X						Assumed Leaker
TX-115[5]	2015	X				X				X						Assumed Leaker
TX-116[6]	2016			X			X				X					Assumed Leaker
TX-117[5]	2015		X								X					Assumed Leaker
TY-101																Assumed Leaker
TY-103[5]	2015		X			X				X						Assumed Leaker
TY-104																Assumed Leaker
TY-105[3]	2013		X			X				X				X		Assumed Leaker
TY-106																Assumed Leaker
U-101																Assumed Leaker

Table G-3: Visual Inspection Information of SSTs Sorted by Sound/Assumed Leaker Tank (6 sheets)

Tank	Year Inspected	Liner				In-Tank Equipment				Riser				Dome		Tank Status
		Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Negligable to Mild	Moderate	Severe	Very Severe	Observed Cracks	Distress Factor	
U-104[1]	2010	X				X				X						Assumed Leaker
U-110																Assumed Leaker
U-112																Assumed Leaker

References:

[1] RPP-RPT-48194
[2] RPP-RPT-51404
[3] RPP-RPT-55951
[4] RPP-RPT-58239
[5] RPP-RPT-58849
[6] RPP-RPT-59272
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RPP-49300, 2011, *Data Quality Objectives for Single-Shell Tank Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

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RPP-RPT-51404, 2012, *Fiscal Year 2011 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

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RPP-RPT-60565, 2018, *Fiscal Year 2018 Visual Inspection Report for Single-Shell Tanks,* DRAFT, Washington River Protection Solutions, LLC, Richland, Washington.

APPENDIX H

DOCUMENTS REVIEWED BY SUBJECT MATTER EXPERTS

DOCUMENTS REVIEWED BY SUBJECT MATTER EXPERTS

This appendix is provided as a list of all documents reviewed by the Independent Qualified Registered Professional Engineer (IQRPE) and subject matter experts (SME) in the preparation of this integrity assessment report (IAR). The documents actually referenced in the document are listed in Section 9 and also in this appendix. As part of a due diligence review for this IAR, the IQRPE and SMEs did a research effort to ensure that the boundaries of the scope were encompassed and exceeded. As evidenced by this appendix, far more documents were reviewed than actually referenced. Even documents from before the 2002 IAR were reviewed. The far right column are documents that were reviewed as part of this IAR but not referenced.

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
00-OSD-175, Letter, Clifford E. Clark, Office of Regulatory Liaison, U.S. Department of Energy, to Michael A. Wilson, Department of Ecology, State of Washington, *Transmittal of Administrative Orders No. 00NWPKW-1250 and No. 00NWPKW-1251 Action 5 Reported,* dated December 23, 2002.	X		
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0301190, 2000, Letter, Dan Silver, Department of Ecology, letter to R. French, Keith Klein and Mary P. Delozier, Office of River Protection) *Failure to Comply with Major Milestone M-32 of the Tri-Party Agreement; Administrative Order No. United States Department of Energy 00NWPKW-1250*, dated June 2000.			X
06-TPD-042, 2006, Letter, Roy J. Schepens, Office of River Protection, U.S. Department of Energy, to Jane Hedges, Nuclear Waste Program, State of Washington, Department of Ecology, *Completion of Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-48-07 Requirements for Isolation, Stabilization, and Monitoring of Double-Shell Tank System Components,* dated July 11.			X
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10-TPD-026, 2010, Letter, Charboneau, Office of River Protection, U.S. Department of Energy, to Jeffrey Lyon, Department of Ecology, State of Washington, *Submittal of the Washington State Department of Ecology (Ecology)-U.S. Department of Energy (DOE Interim Barrier Selection Criteria in Accordance with Proposed Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-045-92,* dated March 24.			X

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
16-TF-0071, 2016, Letter, Mark A. Lindholm, Washington River Protection Solutions, LLC and Kevin W. Smith, Office of River Protection, U.S. Department of Energy, to Alexandra K. Smith, Department of Ecology, Washington State, *Waste Designation for 241-AZ-301 Condensate,* dated July 5.			X
24904, 1984, Letter, Michael J. Lawrence, U.S. Department of Energy, to Paul G. Lorenzini, Rockwell Hanford Operations, *Waste Management Programmatic Change,* dated July 10.			X
40 CFR 265.191, "Assessment of Existing Tank System's Integrity," *Code of Federal Regulations*, as amended.			X
40 CFR 265.196, "Response to Leaks or Spills and Disposition of Leaking or Unfit-for-Use Tank Systems," *Code of Federal Regulations*, as amended.			X
40 CFR 265.197, "Closure and Post-Closure Care," *Code of Federal Regulations*, as amended.			X
7G410-JKE/MJR-007-005, 2007, Internal Memorandum from J.K. Engeman and M.J. Rodgers to G.P. Duncan and D.J. Washenfelder, CH2M HILL Hanford Group, Inc., *Evidence of Annulus Moisture Accumulation in Tanks 241-AY-101 and 241-AY-102,* dated February 8.			X
ACI 201.1R-08, 2008, *Guide for Conducting a Visual Inspection of Concrete in Service,* American Concrete Institute, Farmington Hills, Michigan.			X
ACI 318, 1951, *Building Code Requirements for Structural Concrete (ACI 318-51),* American Concrete Institute, Farmington Hills, Michigan.			X
ACI 318, 2014, *Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14),* American Concrete Institute, Farmington Hills, Michigan.	X		
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ARH-1105-DEL, 1969, *Monthly Report 200 Areas Operation June 1969,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-1106-DEL, 1969, *Monthly Report 200 Areas Operation July 1969,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-1109-DEL, 1969, *Monthly Report 200 Areas Operation October 1969,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-1496, 1970, *Review of Storage Tank Integrity*, Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-1845, 1970, *Design Criteria Waste Concentrate Facilities for the 241-T and 241-B Farm Complexes,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-2035, 1971, *Investigation and Evaluation of 102-BX Tank Leak,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-2874, 1973, *241-T-106 Tank Leak Investigation,* Atlantic Richfield Hanford Company, Richland, Washington.			X

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
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ARH-CD-427, 1975, *Criteria-Waste Tank Dome Evaluation Surveys,* Atlantic Richfield Hanford Company, Richland, Washington.	X		
ARH-LD-127, 1976, *Geology of the 241-AX Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
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ARH-LD-129, 1976, *Geology of the 241-B Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-130, 1976, *Geology of the 241-BX Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-131, 1976, *Geology of the 241-BY Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-132, 1976, *Geology of the 241-C Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-133, 1976, *Geology of the 241-C Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
ARH-LD-134, 1976, *Geology of the 241-SX Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-135, 1976, *Geology of the 241-T Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-136, 1976, *Geology of the 241-TX Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-137, 1976, *Geology of the 241-TY Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-LD-138, 1976, *Geology of the 241-U Tank Farm,* Atlantic Richfield Hanford Company, Richland, Washington.			X
ARH-R-43, 1970, *Management of Radioactive Wastes Stored in Underground Tanks at Hanford,* Rev. 2, Atlantic Richfield Hanford Company, Richland, Washington.	X		
ARH-R-45, 1969, *Interim Summary Report Stress and Strength Analysis for Waste Tank Structures,* Atlantic Richfield Hanford Company, Richland, Washington.	X		
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ARH-ST-111, 1975, *Compilation of Hanford Corrosion Studies,* Atlantic Richfield Hanford Company, Richland, Washington.	X		
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Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
ASME D449/D449M, *Standard Specification for Asphalt Used in Dampproofing and Waterproofing,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.			X
ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications.*	X		
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ASTM A185-61T, *Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete,* American Society for Testing Materials, West Conshohocken, Pennsylvania.		X	
ASTM A283/A283M – 13, *Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.			X
ASTM A285/A285M – 12, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.			X
ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.	X		

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
ASTM A615/A615M, *Standard Specification Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.	X		
ASTM D173/D173M, *Standard Specification for Bitumen-Saturated Cotton Fabrics Used in Roofing and Waterproofing,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.			X
ASTM D41-41, *Standard Specification for Asphalt Primer Used in Roofing, Dampproofing and Waterproofing,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.		X	
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DeWitt, R.D. and R.J. Sloat, 1959, *The Self-Concentration of High Level PUREX Wastes in the Hot Semiwork Waste Concentrator,* General Electric Hanford Atomic Products Operations, Richland, Washington.			X
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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
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Ecology, EPA, and DOE, 2011, *Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement(Change Package M-45-10-01,* as amended, State of Washington Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.	X		
FFS-ENG-02-0604, 2004, *Integrity Assessment Report Slurry Vessel for C-200 Series Tank Retrieval,* CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
Frankel et al. 2002, *Documentation for the 2008 Update of the United States National Seismic Hazard Maps,* U.S. Geologic Survey (USGS) National Seismic Hazard Mapping Project (NSHMP).	X		
General Electric, 1951, *REDOX Technical Manual,* General Electric Company, Hanford Works, Richland, Washington.			X
H-14-020813, 2015, *241-C Waste Transfer WRS P&ID C-105 MARS Retrieval Sheet 25,* Rev. 02, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-020813, 2018, *241-C Waste Transfer WRS P&ID C-107 MARS Retrieval Sheet 35,* Rev. 8, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
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H-14-021824, 2017, *Raw Water Portable Eqpt O&M P&ID Distribution Manifolds,* Rev. 14, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
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H-14-107695, 2009, *Large Riser Details Sheets 1-5,* Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-107696, 2009, *Pad Structural Details,* Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-107697, 2010, *Large Riser Installation Sequence,* Rev. 1, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-107698, 2010, *Riser Plug and Anchor Plate Details,* Rev. 1, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-107928, 2016, *Mars P&ID Bulk Retrieval System,* Rev. 4, U.S. Department of Energy, Office of River Protection Richland, Washington.			X
H-14-107928, 2016, *Mars P&ID Bulk Retrieval System,* Rev. 6, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-109470, 2011, *Drawing Tree 241-C-105 Large Riser Installation,* Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-109471, 2011, *241-C-105 Large Riser Site Plan,* Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-109472, 2011, *Large Riser Details,* Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-14-109473, 2011, *Pad Structural Details,* Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
H-14-109478, 2012, *C-105 Heel Pit Removal and Large Riser Installation Sequence,* U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
H-2-1313, 1950, *75 Foot Tank Steel Plate Details,* Rev. 4, General Electric Co., Hanford Works, Richland, Washington.			X
H-2-1318, 1949, *75 Foot Tank Nozzle & Piping Det's,* Rev. 2, Hanford Engineer Works, Richland, Washington.			X
H-2-1774, 1949, *General Layout Waste Disposal Facility 241-S,* Rev. 6, General Electric Co., Hanford Works, Richland, Washington.		X	
H-2-1783, 1949, *75 Foot Composite Storage Tank Sections,* Rev. 3, Hanford Engineer Works, Richland, Washington.	X		
H-2-1785, 1951, *75 Foot Tank Base Footing & Wall Reinforcing,* Rev. 1, Hanford Engineer Works, Richland, Washington.	X		
H-2-1786, 1949, *75-Foot Tank Dome Reinforcing,* Rev. 1, Hanford Engineer Works, Richland, Washington.	X		
H-2-1789, 1949, *75 Foot Tank Nozzle & Piping Details,* Rev. 3, General Electric Co., Hanford Works, Richland, Washington.			X
H-2-2244, 1951, *75 Foot Composite Storage Tank Sections,* Rev. 2, Hanford Engineer Works, Richland, Washington.	X		
H-2-2246, 1962, *75-Foot Tank Base Footing & Wall Reinforcing,* Rev. 2, Hanford Works Engineers, Richland, Washington.	X		
H-2-2247, 1962, *75-Foot Tank Dome Reinforcing,* Rev. 2, Hanford Engineer Works, Richland, Washington.		X	
H-2-2250, 1962, *75 Foot Tank Nozzle & Piping Details,* Rev. 3, General Electric Co., Hanford Works, Richland, Washington.		X	

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
H-2-2310, 2008, *Monument Layout 200-E Area,* Rev. 9, U.S. Department of Energy, Office of River Protection, Richland, Washington.		X	
H-2-2500, 2011, *Monument Layout 200-W Area,* Rev. 10, U.S. Department of Energy, Office of River Protection, Richland, Washington.		X	
H-2-39501, 1975, *General Layout Waste Disposal Facility 241-SX,* Rev. 11, Atlantic Richfield Hanford Company, Richland, Washington.		X	
H-2-39511, 1954, *75 Ft. Storage Tanks Composite Section Waste Disposal Facility 241-SX,* Rev. 3, U.S. Atomic Energy Commission Hanford Works, General Electric, Richland, Washington.	X		
H-2-39512, 1964, *75 Ft. Tank Base Footing & Wall Reinforcing Waste Disposal Facility 241-SX Additional Waste Disposal REDOX,* Rev. 2, U.S. Atomic Energy Commission Hanford Works, General Electric, Richland, Washington.	X		
H-2-39513, 1954, *75 Ft. Tank Dome Reinforcing Waste Disposal Facility 241-SX Additional Waste Disposal REDOX,* Rev. 1, U.S. Atomic Energy Commission Hanford Works, General Electric, Richland, Washington.	X		
H-2-44552, 1963, *Plot Plan Finished Grading and Facilities,* Rev. 3, U.S. Atomic Energy Commission, Hanford Atomic Products Operations, General Electric, Richland, Washington.		X	
H-2-44562, 1975, *Structural Waste Storage Tanks Composite Section & Details,* Rev. 4, U.S. Atomic Energy Commission, Hanford Atomic Products Operation, General Electric, Richland, Washington.	X		
H-2-44635, 1965, *Process Waste Lines Sections & Details,* Rev. 3, Bovay Engineers, Inc., U.S. Atomic Energy Commission, Hanford Atomic Products, Operations, General Electric, Richland, Washington.			X

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
H-2-55901, 1973, *241-A General Layout,* Rev. 4, U.S. Atomic Energy Commission, Hanford Works, General Electric, Richland, Washington.		X	
H-2-55910, 1967, *Waste Storage Tanks Dome Plan and Fixture Layout PUREX Waste Disposal,* Rev. 4, General Electric, U.S. Atomic Energy Commission Hanford Works, Richland, Washington.		X	
H-2-55911, 1956, *Waste Storage Tanks Composite Section,* Rev. 1, U.S. Atomic Energy Commission Hanford Works, General Electric, Richland, Washington.	X		
H-2-55912, 1956, *Waste Storage Tanks Base Footing & Wall Reinforcing,* Rev. 1, U.S. Atomic Energy Commission Hanford Atomic Products Operation, General Electric, Richland, Washington.	X		
H-2-55913, 1956, *Waste Storage Tanks Dome Reinforcing PUREX Waste Disposal Facility,* Rev. 2, U.S. Atomic Energy Commission, Hanford Works, General Electric, Richland, Washington.	X		
H-2-602, 1947, *Composite Tank Typical Details Concrete 241-BX,* Rev. 8, Hanford Engineer Works, Richland, Washington.	X		
H-2-63099, 1968, *105-A Tk Arrgt As Built,* Rev. 2, Atlantic Richfield Hanford Company, Richland, Washington.			X
H-2-73051, 1978, *Drawing Index,* Rev. 4, U.S. Department of Energy, Richland Operations Office, Richland, Washington.			X
H-2-73630, 1978, *Waste Tank Isolation Typical Details Pit Weather Covers,* Rev. 5, U.S. Energy Research and Development Administration, Richland, Washington.			X
H-2-808, 1968, *75 Foot Tank Sections,* Rev. 7, Atlantic Richfield Hanford Company, Richland, Washington.		X	
H-2-809, 1947, *75 Foot Tank Steel Plate Details,* Rev. 0, General Electric Co., Hanford Works, Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
H-2-812, 1950, *75 Foot Tank Base Footing & Wall Reinforcing 241-TX,* Rev. 3, Hanford Engineer Works, Richland, Washington.	X		
H-2-818562, 2013, *Project W-320 P & ID Air and Water System,* Rev. 8, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
Hanford Site Air Operating Permit			
HNF-2944, 1998, *Single-Shell Tank Retrieval Program Mission Analysis Report,* Rev. 0, Lockheed Martin Hanford Corporation, Richland, Washington.			X
HNF-4712, 1999, *Load Requirements for Maintaining Structural Integrity of Hanford Single-Shell Tanks During Waste Feed Delivery and Retrieval Activities,* Rev. 0, Lockheed Martin Hanford Corporation, Richland, Washington.	X		
HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending June 30, 2018,* Rev. 366, Washington River Protection Solutions, LLC, Richland, Washington.	X		
HNF-EP-0182, 2018, *Waste Tank Summary Report for Month Ending May 31, 2018,* Rev. 365, Washington River Protection Solutions, LLC, Richland, Washington.	X		
HNF-SD-RE-TI-178, 2005, *Single-Shell Tank Interim Stabilization Record,* Rev. 9, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
HNF-SD-RE-TI-178, 2007, *Single-Shell Tank Interim Stabilization Record,* Rev. 9A, CH2M HILL Hanford Group, Inc., Richland, Washington.			X
HNF-SD-WM-ER-352, 1997, *Historical Tank Content Estimate for the Southwest Quadrant of the Hanford 200 West Area,* Rev. 1, Fluor Hanford, Richland, Washington.			X
HNF-SD-WM-TSR-006, 2016, *Tank Farms Technical Safety Requirements,* Rev. 7Z, Washington River Protection Solutions, LLC, Richland, Washington.			X
HW-04798-S, 1962, *Standard Specification for Placing Reinforced Concrete,* General Electric, Hanford Atomic Products Operation, Richland, Washington.			

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
HW-14946, 1949, *A Survey of Corrosion Data and Construction Details, 200 Area Waste Storage Tanks,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X
HW-18595, 1950, *Corrosion of Redox Waste Storage Tank Construction Materials,* Rev. 0, General Electric Company, Hanford Words, Richland, Washington.			X
HW-19140, 1951, *Uranium Recovery Technical Manual,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X
HW-1946, 1944, *Specification for Construction of Composite Storage Tanks Bldg. No. 241,* Rev. 0, Hanford Engineer Works, Richland, Washington.			X
HW-21260-DEL, 1951, *Hanford Works Monthly Report for May 1951,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X
HW-21273-RD, 1951, *Physical Properties of Neutralized RAW as a Function of Concentration,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-23140-DEL, 1951, *Hanford Works Monthly Report for December 1951,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X
HW-23437-DEL, 1952, *Hanford Works Monthly Report January 1952,* Rev. 0, General Electric Company, Richland, Washington.			X
HW-23477, 1952, *Heat Generation in Stored REDOX Wastes,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X
HW-24800-35, 1953, *Design and Construction History 241-TX Tank Farm 200 West,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.		X	
HW-26201, 1952, *Corrosion Tests – SAE 1010 Mild Steel in Synthetic Neutralized REDOX Waste Solution,* Rev. 0, Applied Research Unit, Engineering Department, Richland, Washington.	X		

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HW-3061, 1947, *Paragraph D. "Steel Tank Linking" of Specifications for Construction of Composite Storage Tanks,* Rev. 0, Hanford Works, General Electric Company, Richland, Washington.			X
HW-32624-DEL, 1954, *Hanford Works Monthly Report for July 1954,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X
HW-32734, 1954, *A Laboratory Study of the Extent of Pitting and General Corrosion of SAE-1010 Steel in Simulated Neutralized PUREX Process Waste Solutions,* Rev. 0, General Electric Company, Richland, Washington.	X		
HW-34860, 1955, *A Study to Determine the Economical Tank Size for Radioactive Waste Disposal,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington			X
HW-35962, 1955, *Vapor Handling Facilities for Project CG-539 and Some Comments on Waste Tank Eruptions,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-37207, 1955, *Storage of High Activity Wastes,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-37519, 1955, *Structural Evaluation Underground Waste Storage Tanks,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-3783, 1948, *Specifications for Construction of Additional Waste Storage Facilities, 200 East Area, Bldg. 241-BY, Project C-271,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.		X	
HW-3937, *Specification Waste Disposal Facility 241-A and 207-S 200 West Area,* Rev. 0, General Electrical Company, Hanford Works, Richland, Washington.		X	
HW-45115-DEL, 1956, *Hanford Works Monthly Report for August 1956,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
HW-45707-DEL, 1956, *Hanford Works Monthly Report for September 1956,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.			X
HW-4696, 1951, *Specification for Waste Disposal Facilities 241-BZ and TY Tank Farms,* Rev. 0, General Electric Company, Hanford Works, Richland, Washington.		X	
HW-4798-S, 1962, *Standard Specification for Placing Reinforced Concrete,* Rev. 6, General Electric Company, Richland, Washington.		X	
HW-49574, 1957, *Examination of Corrosion Test Coupons in PUREX 101 Waste Storage Tanks-RM-147,* Rev. 0, General Electric Company, Richland, Washington.	X		
HW-50216, 1957, *Current Status of REDOX Waste Self-Concentration,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-53641, 1957, *Hazards Study Self-Boiling Radioactive Wastes Storage Facilities,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-57249, 1958, Barnes R.G. and G.L. Hanson, *Interim Report on Displacement of the REDOX 113-SX Waste Storage Tank Liner,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-57274, 1958, *Instability of Steel Bottoms in Waste Storage Tanks,* Rev. 0, General Electric Hanford Atomic Products Operations, Richland, Washington.			X
HW-59919, 1959, *Limitations for Existing Storage Tanks for Radioactive Wastes from Separations Plants,* Rev. 0, General Electric Hanford Atomic Products Operations, Richland, Washington.			X
HW-61736-DEL, 1959, *Hanford Works Monthly Report for August 1959,* Rev. 0, General Electric Company, Hanford Atomic Products Operation, Richland, Washington.			X
HW-70529, 1961, *Basis for Process Design Engineering PUREX Tank Farm 241-AX,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
HW-72780, 1962, *Process Design Engineering PUREX Essential Waste Routing System and 241-AX Tank Farm,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-73884-DEL, 1962, *Hanford Works Monthly Report for May 1962,* Rev. 0, General Electric Hanford Atomic Products Operations, Richland, Washington.			X
HW-74814, 1962, *Project Proposal, Revision 2 New Waste Storage Tanks – PUREX (PROJECT CAC-945),* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-74914, 1962, *PUREX Tank Farm Fill Program,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-7-5264, 1946, *Project Proposal Additional Underground Waste Tank Facilities 241-B-Tank Farm,* Rev. 0, Hanford Engineer Works, Richland, Washington.		X	
HW-75714, 1962, *Leak Testing of the 113-SX Tank,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HW-76848, 1963, *Chemical Processing Department Monthly Report February 1963,* Rev. 0, General Electric Hanford Atomic Products Operations, Richland, Washington.			X
HW-82089, 1964, *Chemical Processing Dept. Monthly Report for 04/1964,* Rev. 0, General Electric Hanford Atomic Products Operation, Richland, Washington.			X
HWS-5614, 1953, *Specifications for PUREX Waste Disposal Facility,* Rev. 0, General Electric, Hanford Atomic Products Operations, Richland, Washington.		X	
HWS-8237, 1963, *Specification for PUREX 241-AX Tank Farm,* Rev. 2, General Electric, Hanford Atomic Products Operation, Richland, Washington.		X	
IBC, 2009, *International Building Code*, International Code Council, Washington, D.C.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
ISO-714-DEL, 1967, *Chemical Processing Dept. Research and Engineering Operation Monthly Report 08/1967,* ISOCHEM Inc., Richland, Washington.			X
ISO-89-DEL, 1966, *Chemical Processing Dept. Research and Engineering Operation Monthly Report 01/1966,* ISOCHEM Inc., Richland, Washington.			X
LA-UR-96-3860, 1997, Agnew, S.F., *Hanford Tank Chemical and Radionuclide Inventories: HDW Model,* Rev. 4, Los Alamos National Laboratory for Lockheed Martin Hanford Company, Richland, Washington.		X	
LET-041068, 1968, *Comments on the Proposed Inspection of the Concrete Portion of Underground Storage Tanks* (memo from P. Hatch to H.P. Shaw, Richland, Washington), dated April 1968.	X		
M&D-01-0028-A, 2002, *Single-Shell Tank In-Service Inspection Recommendations,* Rev. Draft, M&D Professional Services, Incorporated, Richland, Washington.			X
M&D-2053-001-DC-01, 2009, *Structural Design Criteria and Loadings for MARS (Mobile Arm Retrieval System) Project*, Rev. 0, M&D Professional Services, Inc., Richland, Washington.			X
M&D-2054-002-CALC-001, 2009, *Seismic Analysis of Hanford Tank 241-C-107 for New 56-Inch-Diameter Dome Penetration,* Rev. 0, M&D Professional Services, Inc., Richland, Washington.		X	
NA-DOEC, 2011, *Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Change Package M-45-10-01*, U.S. Department of Energy, Office of River Protection, Richland, Washington.			X
ORP-11242, *River Protection Project System Plan*, Rev. 8, U.S. Department of Energy, Office of River Protection, Richland, Washington.		X	
OSD-RAP-58754, 2015, *241-T Dome Survey OSD Recovery Action Plan,* Rev. 02, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
OSD-RAP-58755, 2015, *241-TX Dome Survey OSD Recovery Action Plan,* Rev. 02, Washington River Protection Solutions, LLC, Richland, Washington.	X		
OSD-T-151-00007, 2017, *Operating Specifications for the Double-Shell Storage Tanks,* Rev. 20, Washington River Protection Solutions, LLC, Richland, Washington.	X		
OSD-T-151-00013, 2016, *Operating Specifications for Single-Shell Waste Storage Tanks,* Rev. 7, Washington River Protection Solutions, LLC, Richland, Washington.	X		
OSD-T-151-00031, 2017, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection,* Rev. 12, Washington River Protection Solutions, LLC, Richland, Washington.	X		
PCA, 1953, ST-55, *Design of Circular Domes,* Portland Cement Association, Skokie, Illinois.			X
PCA, 1954, ST-57-1, *Circular Concrete Tanks with Prestressing,* Portland Cement Association, Skokie, Illinois.			X
PCA, 1989, *Effects of Substances on Concrete and Guide to Protective Treatments,* Portland Cement Association, Skokie, Illinois.			X
PER-2004-4048, *Several Concerns Were Identified with SST Tank Dome Surveys,* Washington River Protection Solutions, LLC, Richland, Washington.	X		
PNL-7779, 1991, *Modeling of Time-Variant Concrete Properties at Elevated Temperatures,* Pacific Northwest Laboratory, Richland, Washington.			X
PNL-8722, 1986, *Evaluation of Concrete Property Data at Elevated Temperatures for Use in the Safe-Crack Computer Code,* Pacific Northwest Laboratory, Richland, Washington.			X
PNNL-23361, 2014, *Hanford Sitewide Probabilistic Seismic Hazard Analysis,* Pacific Northwest National Laboratory, Richland, Washington.	X		

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Publication No. 92-91, *Dangerous Waste Regulations, Chapter 173-303,* Department of Ecology, State of Washington, Olympia, Washington.			X
Publication No. 94-114, *Guidance for Assessing and Certifying Tank Systems,* Department of Ecology, State of Washington, Olympia, Washington.	X		
R84-1227, 1984, Letter from Lorenzini, P. G. Rockwell International to A. G. Fremling, Richland Operations Office, U.S. Department of Energy, *Waste Management Programmatic Change (Contract DE-AC06-77RL091030)*, dated June 1984.			X
Resource Conservation and Recovery Act of 1976, as amended, 42 USC 6901, et. seq.	X		
Revised Code of Washington, RCW Chapter 18.43, *Engineers and Land Surveyors.*	X		
RHO-C-21, 1978, *Expansion of Hanford Concrete,* Construction Technology Laboratories of the Portland Cement Association, Skokie, Illinois.			X
RHO-C-22, 1991, *Strength and Elastic Properties of Concrete From Waste Tank Farms,* Construction Technology Laboratories, A Division of the Portland Cement Association, Skokie, Illinois.	X		
RHO-C-27, 1979, *Creep and Cycling Tests – Thermal Properties of Hanford Concretes,* Construction Technology Laboratories A Division of the Portland Cement Association, Skokie, Illinois.			X
RHO-C-28, 1979, *Elastic and Strength Properties of Hanford Concrete Mixes at Room and Elevated Temperatures,* Construction Technology Laboratories A Division of the Portland Cement Association, Skokie, Illinois.	X		
RHO-C-39, 1980, *A Comparison of the Microstructure of Hanford Type II Concrete Structures and Test Specimens,* Rockwell International, Rockwell Hanford Operations, Richland, Washington.			X

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RHO-C-40, 1979, *Strength and Elastic Properties of 1580-Day Old Hanford Concrete Cylinders at Room Temperature and 350F,* Construction Technology Laboratories A Division of the Portland Cement Association, Skokie, Illinois.	X		
RHO-C-50, 1980, *Final Report on Long-Term Creep of Hanford Concrete at 250 °F and 350 °F*, Construction Technology Laboratories of the Portland Cement Association, Skokie, Illinois.			X
RHO-C-54, 1992, *Effects of Long-Term Exposure to Elevated Temperature on the Mechanical Properties of Hanford Concrete,* Construction Technology Laboratories, Portland Cement Association, Skokie, Illinois.	X		
RHO-CD-1273, 1981, *Criterion for Selection of 100 Series Tanks to be Jet Pumped,* Rockwell Hanford Operations, Richland, Washington.			X
RHO-CD-14, 1980, *Waste Status Summary,* Rockwell Hanford Operations, Richland, Washington.	X		
RHO-CD-1485, 1981, *Description of Potential Failure Modes for Single-Shell Waste Tanks,* Rockwell Hanford Group, Richland, Washington.	X		
RHO-CD-1538, 1981, *Waste Tank 241-SX-115 Core Drilling Results,* Rockwell Hanford Operations, Richland, Washington.	X		
RHO-CD-980, 1980, *Waste Tank Core Drilling Demonstration Results,* Rockwell Hanford Operations, Richland, Washington.			X
RHO-CD-981, 1980, *Waste Tank Evaluation Program (JV),* Rev. 00, Rockwell Hanford Company, Richland, Washington.			X
RHO-R-29, 1981, *Nondestructive and Laboratory Tests 202-A PUREX Canyon Building,* Construction Technology Laboratories A Division of the Portland Cement Association, Skokie, Illinois.			X

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RHO-RE-CR-2, 1982, *Strength and Elastic Properties Tests of Hanford Concrete Cores – 241-SX-115 Tank and 202-A PUREX Canyon Building,* Rockwell Hanford Operations, Richland, Washington.	X		
RHO-RE-CR-4, 1981, *Effects of Moisture Loss Due to Radiolysis on Concrete Strength,* Rockwell Hanford Operations, Richland, Washington.	X		
RHO-RE-CR-8 P, 1982, *Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel,* Construction Technology Laboratories of the Portland Cement Association, Skokie, Illinois.	X		
RHO-RE-SA-55, 1984, *Strength and Elastic Properties of Concrete Exposed to Long-Term Moderate Temperatures and High Radiation Fields,* Rockwell International, Rockwell Hanford Operations, Richland, Washington.			X
RHO-RE-ST-4 P, 1982, *Status of Tank Assessment Studies for Continued In-Tank Storage of Hanford Defense Waste,* Rockwell International, Rockwell Hanford Operations, Richland, Washington.			X
RL-SEP-018-DEL, 1965, *Chemical Processing Dept. Monthly Report for 06/1965,* General Electric Hanford Atomic Products Operation, Richland, Washington.			X
RL-SEP-269, 1965, *Specifications and Standards for Operational Control of the PUREX Self-Boiling Tank Farms,* General Electric Hanford Atomic Products Operation, Richland, Washington.			X
RL-SEP-282, 1965, *Chemical Processing Dept. Monthly Report for 01/1965,* General Electric Hanford Atomic Products Operation, Richland, Washington.			X
RL-SEP-282, 1965, *Chemical Processing Dept. Monthly Report for 03/1965,* General Electric Hanford Atomic Products Operation, Richland, Washington.			X
RL-SEP-509-DEL, 1965, *Chemical Processing Dept. Monthly Report for 05/1965,* General Electric Hanford Atomic Products Operations, Richland, Washington.			X

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RPP-5926, 2018, *Steady-State Flammable Gas Release Rate Calculation and Lower Flammability Level Evaluation for Hanford Tank Waste*, Rev. 20, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-10435, 2002, *Single-Shell Tank System Integrity Assessment Report,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-11802, 2015, *Analysis of Record Summary for Single-Shell Tanks,* Rev. 03B, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-11803, 2006, *Analysis of Record Summary for DCRTs, Catch Tanks, and IMUSTs,* Rev. 1, AREVA NC Inc., Richland, Washington.			X
RPP-13033, 2017, *Tank Farm Documented Safety Analysis,* Rev. 07B, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-15286, 2003, *Integrity Assessments for Hose-In-Hose Transfer Lines for 241-S Farm Retrieval Program,* Rev. 0, COGEMA Engineering Corporation, Richland, Washington.	X		
RPP-16363, 2007, *Tank-Specific Allowable Dome Load for Hanford-Site 100-Series Single-Shell Tanks,* CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-16364, 2003, *Tank-Specific Allowable Dome Load for Hanford-Site Double-Shell Tanks,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.			X
RPP-16660, 2004, *200 Series Single-Shell Tank Dome Load Capacity (200, B, C, T and U),* CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-16666, 2004, *Integrity Assessment for 200 Series Tank Retrieval,* Rev. 0A, COGEMA Engineering, Richland, Washington.	X		
RPP-16666, 2004, *Integrity Assessment for Hose-in-Hose Transfer Lines for 200 Series Tank Retrieval,* Rev. 0, COGEMA Engineering, Richland, Washington.	X		

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RPP-16746, 2003, *Evaluation of Load in Single-Shell and Double-Shell Tank Exclusion Zones,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.		X	
RPP-16903, 2004, *Dome Load Capacity for 301 Catch Tanks 241-301-B, C, T and U,* Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-16922, 2017, *Environmental Specification Requirements,* Rev. 34, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-19747, 2004, *Engineering Management Assessment Dome Load Control Program,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-20444, 2017, *241-A Tank Farm Historic Dome Load Record Data,* Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20445, 2017, *241-AX Tank Farm Historic Dome Load Record Data,* Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20446, 2015, *241-B Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20447, 2016, *241-BX Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20448, 2016, *241-BY Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20449, 2015, *241-C Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20450, 2016, *241-S Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20451, 2015, *241-SX Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		

Table H-1: Documents Reviewed by Subject Matter Experts (52 sheets)

Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-20452, 2016, *241-T Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20453, 2016, *241-TX Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20454, 2017, *241-TY Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20455, 2016, *241-U Tank Farm Historic Dome Load Record Data,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-20473, 2004, *Design and Dome Loads Criteria for Hanford Waste Storage Tanks,* Rev. 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-20473, 2007, *Design and Dome Load Criteria for Hanford Waste Storage Tanks,* Rev. 1A, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-21916, *Engineering Management Assessment of the Tank Farms Dome Load Controls Program (FY2004-ENG-M-0163),* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-25782, 2007, *DST Dome Survey Program,* Rev. 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.			X
RPP-26516, 2013, *SST Dome Survey Program,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-33431, 2007, *Design Analysis for T-Farm Interim Surface Barrier (TISB),* Rev. 0, CH2M HILL Hanford Group, Richland, Washington.		X	
RPP-33431, 2007, *Design Analysis for T-Farm Interim Surface Barrier (TISB),* Rev. 0A, CH2M HILL Hanford Group, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-37248, 2008, *Inspection and Maintenance Guidance Manual for the T Farm Interim Surface Barrier Demonstration Project,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.			X
RPP-46305, 2010, *Single-Shell Tank Inspection Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-46442, 2010, *Single-Shell Tank Structural Evaluation Criteria,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-46644, 2010, *Single-Shell Tank Integrity Project Analysis of Record-Preliminary Modeling Plan for Thermal and Operating Loads,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-49003-VA, 2011, *241-C-107 Large Riser Install for Mobile Arm Retrieval System,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-49300, 2011, *Data Quality Objectives for Single-Shell Tank Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-49674, 2011, *Single-Shell Tanks Corrosion Chemistry Data Quality Objectives,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-56892, 2014, *Independent Qualified Registered Professional Engineer Installation Integrity Assessment Report for C-107 MARS-S Slurry Pump Replacement – IQRPE Installation Integrity Assessment Report No. IA-259835-01,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-57176, 2014, *Fit For Use Letter – C-107 MARS-S Slurry Pump Replacement – IQRPE Installation Integrity Assessment, Per the Requirements of WAC 173-303-640,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-58044, 2015, *IQRPE Fabrication Installation Integrity Assessment Report MARS-V Spares C-105,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-9937, 2014, *Single-Shell Tank System Leak Detection and Monitoring Functions and Requirements Document,* Rev. 3E, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-ASMT-27757, 2005, *Engineering Management Assessment of the Dome Load Program,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-ASMT-59981, 2015, *Fifth Single-Shell Tank Integrity Project Expert Panel Meeting August 28-29, 2014,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-CALC-35333, 2007, *Impact of Increasing Tank Radius by One Foot on Dome Load Calculation in RPP-33431,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-CALC-36699, 2009, *Calculation Package for the Installation of a Large Riser on Tank 241-C-107,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-CALC-41539, 2010, *Calculation Package for the 241-TY Tank Farm Interim Surface Barrier,* Rev. 0D, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-CALC-43416, 2011, *An Evaluation of Single-Shell Tank 241-C-107 for the Addition of a Large Penetration in the Tank Dome,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-CALC-48447, 2018, *Calculation Package for the SX Tank Farm Interim Surface Barrier,* Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.		X	

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-CALC-49671, 2011, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-CALC-49671, 2011, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0A, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-CALC-49671, 2012, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0B, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-CALC-49671, 2012, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0C, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-CALC-49671, 2012, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0D, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-CALC-49671, 2012, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0E, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-CALC-49671, 2012, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0F, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-CALC-49671, 2012, *Calculation Package for the Installation of a Large Riser on Tank 241-C-105,* Rev. 0G, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-CALC-51195, 2011, *An Evaluation of Single-Shell Tank 241-C-105 for the Addition of a Large Penetration in the Tank Dome,* Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.	X		
RPP-CALC-51994, 2012, *A Maximum Dome Load Evaluation for Single-Shell Tank 241-C-105,* Rev. 0, Pacific Northwest Laboratory, Richland, Washington.	X		
RPP-CALC-51995, 2012, *A Soil Excavation and Loading Evaluation for Single-Shell Tank 241-C-105,* Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.	X		
RPP-CALC-53887, 2013, *SST 241-A-106 Sidewall Coring Structural Analysis Dome Loading and 4-in. Plug Removal from Tank Sidewall,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-ENV-33418, 2016, *Hanford C-Farm Leak Inventory Assessments Report,* Rev. 4, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-ENV-37956, 2014, *Hanford 241-A and 241-AX Tank Farms Leak Inventory Assessment Report,* Rev. 02, Washington River Protection Services, LLC, Richland, Washington.			X
RPP-ENV-39658, 2010, *Hanford SX-Farm Leak Assessments Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-ENV-41309, 2009, *Criteria for Prioritizing Hanford Site Tank Farm Interim Surface Barriers and for Evaluating Their Performance,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-PLAN-36705, 2009, *241-TY Tank Farm Interim Surface Barrier Monitoring Plan,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-PLAN-45082, 2010, *Implementation Plan for the Single-Shell Tank Integrity Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-PLAN-46847, 2015, *Visual Inspection Plan for Single-Shell Tanks and Double-Shell Tanks,* Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-PLAN-47369, 2011, *Core Drilling Demonstration Plan for a Single-Shell Tank Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-PLAN-47370, 2010, *Sidewall Core Drilling Plan for the Single-Shell Tank 241-A-106 Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-PLAN-48439, 2011, *241-SX Tank Farm South Interim Surface Barrier Monitoring Plan,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-PLAN-48753, 2011, *Analytical Test Plan for the Removed 241-C-107 Dome Concrete and Rebar,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-PLAN-49187, 2011, *241-SX Tank Farm North Interim Surface Barrier Monitoring Plan,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-PLAN-49651, 2012, *Maintenance Guidance Manual for Tank Farm Interim Barrier Evapotranspiration Basins,* Rev. 0, Washington River Protection Solutions, LLC., Richland, Washington.		X	
RPP-PLAN-50077, 2011, *Test Plan to Evaluate the Propensity for Corrosion in Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-PLAN-50182, 2011, *Sampling and Analysis Plan for the Single-Shell Tank Sidewall Coring Project,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-PLAN-50376, 2011, *Single-Shell Tank Sidewall Coring Project Sampling and Analysis Work Plan,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-PLAN-55112, 2013, *September 2012 Single-Shell Tank Waste Level Increase Evaluation Plan,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-PLAN-55113, 2013, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-PLAN-55726, 2014, *Single-Shell Tank Intrusion Investigation Plans,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-PLAN-57173, 2014, *Independent Qualified Registered Professional Engineer Inspection Plan for C-107 MARS-S Slurry Pump Replacement – IQRPE Inspection Plan Report No. IP-259835-01,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-PLAN-57554, 2014, *Portable Exhauster Usage Plan for Evaporation of Supernatant Liquid in Selected Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-PLAN-60765, 2016, *Single-Shell Tank Integrity Program Plan,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-PLAN-61510, 2017, *Single-Shell Tank Structural Integrity Assessment Plan,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-25608, 2005, *Hanford Double-Shell Tank Thermal and Seismic Project – Increased Concentrated Load Analysis,* Rev. 0, CH2M HILL Hanford Group, Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-RPT-26475, 2008, *Retrieval Data Report for Single-Shell Tank 241-C-203,* Rev. 1A, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-RPT-26718, 2006, *Dome Load Collapse Assessment for Hanford Double- and Single-Shell Tanks,* Rev. 0, CH2M HILL Hanford Group, Richland, Washington.		X	
RPP-RPT-27406, 2005, *Demonstration Retrieval Data Report for Single-Shell Tank 241-S-112,* Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.	X		
RPP-RPT-28004, 2005, *Integrity Assessments for 241-C-103 Waste Retrieval Project,* Rev. 0, CH2M HILL Hanford Group, Richland, Washington.	X		
RPP-RPT-31599, 2017, *Double-Shell Tank Integrity Inspection Report for 241-AN Tank Farm*, Rev. 8, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-32094, 2006, *Integrity Assessment for 241-C-108 Waste Retrieval Project,* Rev. 0, CH2M HILL Hanford Group, Richland, Washington.			X
RPP-RPT-34052, 2008, *Integrity Assessments for 241-C-109 Waste Retrieval Project,* Rev. 1, CH2M HILL Hanford Group, Richland, Washington.			X
RPP-RPT-38323, 2009, *Tank Farm Interim Surface Barrier Materials and Runoff Alternatives Study,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-40516, 2009, *C-104 Heel Pit (C-04B) Pumping System Independent Design and Construction Integrity Assessment Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-42296, 2010, *Hanford TY-Farm Leak Assessments Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-43116, 2009, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project,* Rev. 0, Perot Systems Government Services, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-RPT-43704, 2011, *Hanford BY-Farm Leak Assessments Report,* Rev. 0A, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-45921, 2010, *Single-Shell Tank Integrity Expert Panel Report,* Rev. 0, Dell Perot Systems, Richland, Washington.	X		
RPP-RPT-46168, 2010, *C-107 Centering Tool Data Evaluation,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-46804, 2010, *Project W-566 Waste Feed Delivery – Transfer Line Upgrades 241-SY Transfer Line Replacement Process Hazards Analysis Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-47123, 2010, *Interim Surface Barrier Evaluation Report,* Rev. 0A, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-47488, 2011, *241-sx Tank Farm Interim Surface Barrier Material Alternatives Study,* Rev. 0, Washington River Protection Solutions, LLC., Richland, Washington.		X	
RPP-RPT-47562, 2011, *Hanford BX-Farm Leak Assessments Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-47645, 2010, *Integrity Assessment for AN-101 Pump Replacement in the C-104 Waste Retrieval System,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-47646, 2010, *Integrity Assessment for C-111 Waste Retrieval System,* Rev. 0, Washington River Protection Solution, Richland, Washington.	X		
RPP-RPT-48168, 2010, *C-107 Centering Tool Data Evaluation,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-48194, 2010, *Fiscal Year 2010 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-RPT-48326, 2011, *Mobile Arm Retrieval System Corrosion Review,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-48499, 2010, *Integrity Assessment for Articulating Mast System (AMS) in the C-104 Modified Sluicing Waste Retrieval System,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-48589, 2011, *Hanford 241-S Farm Leak Assessment Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-49272, 2011, *Fourth Single-Shell Tank Integrity Project Expert Panel Meeting,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-49457, 2011, *Mobile Arm Retrieval System Project Bulk Retrieval Option independent Design and Fabrication Integrity Assessment Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-49824, 2012, *Vacuum Mobile Arm Retrieval System Corrosion Review,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-49989, 2011, *Hanford B-Farm Leak Inventory Assessments Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-49990, 2011, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type III Single-Shell Tank Thermal and Operating Loads and Seismic Analysis,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-49991, 2014, *Single-Shell Tank Integrity Project Analysis of Record Tank to Tank Interaction Study of the Hanford Single-Shell Tanks,* Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.	X		
RPP-RPT-49992, 2014, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type IV Single-Shell Tank Thermal and Operating Loads and Seismic Analysis,* Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.	X		

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RPP-RPT-49993, 2014, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type I Single-Shell Tank Thermal and Operating Loads and Seismic Analysis,* Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.	X		
RPP-RPT-49994, 2015, *Summary Report for the Hanford Single-Shell Tank Structural Analyses of Record – Single-Shell Tank Integrity Project Analysis of Record,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-50097, 2011, *Hanford 241-U Farm Leak Inventory Assessment Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-50145, 2011, *Integrity Assessment for the C-107 Large Riser,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-50204, 2011, *Independent Integrity Assessment Report for Tank 241-C-107 Waste Retrieval System Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-50714, 2011, *Demonstration Report for the Single-Shell Tank Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-50799, 2015, *Suspect Water Intrusion in Hanford Single-Shell Tanks,* Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-50870, 2013, *Hanford 241-TX Farm Leak Inventory Assessment Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-50934, 2011, *Inspection and Test Report for the Removed 241-C-107 Dome Concrete,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-51111, 2011, *Integrity Assessment for C-108 Hard Heel Removal Waste Retrieval Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-51396, 2011, *Integrity Assessment for C-112 Waste Retrieval Project,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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RPP-RPT-51404, 2012, *Fiscal Year 2011 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-52721, 2012, *Integrity Assessment for C-104 Hard Heel Removal Waste Retrieval Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington	X		
RPP-RPT-53494, 2012, *An Evaluation of the 241-C-105 Maximum Dome Loads for Application to the Other C-Farm 100 Series Tanks*	X		
RPP-RPT-53591, 2013, *IQRPE Integrity Assessment Reports for C-109 Hard Heel Removal Waste Retrieval Project,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-54173, 2013, *IQRPE Integrity Assessment Reports for C-101 Waste Retrieval Project,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-54268, 2013, *IQRPE Integrity Assessment Reports for C-102 Waste Retrieval Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-54564, 2013, *Inspection and Test Report for the Removed 241-C-107 Dome Rebar,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-54764, 2013, *Independent Qualified Registered Professional Engineer (IQRPE) Reports for Single-Shell Tank 241-A-106 Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-54813, 2013, *Mobile Arm Retrieval System Project Vacuum Retrieval Option – Independent Assessment Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-54909, 2014, *Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-RPT-54964, 2014, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection,* Rev. 2, Richland, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-54981, 2013, *Evaluation of Fourteen Tanks with Decreasing Level Baselines Selected for Review in RPP-PLAN-55113, Revision 1,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-55202, 2015, *Dome Survey Report for Hanford Single-Shell Tanks,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-55202, 2017, *Dome Survey Report for Hanford Single-Shell Tanks,* Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington	X		
RPP-RPT-55263, 2013, *Evaluation of Tank 241-TY-105 Level Data and In-Tank Video Inspection,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-55264, 2013, *Evaluation of Tanks 241-T-203 and 241-T-204 Level Data and In-Tank Video Inspections,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-55265, 2013, *Evaluation of Tanks 241-B-203 and 241-B-204 Level Data and In-Tank Video Inspections,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-RPT-55291, 2013, *IQRPE Integrity Assessment Reports for C-110 Hard Heel Removal Waste Retrieval Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-55666, 2016, *Double-Shell Tank Tertiary Leak Detection System Evaluation,* Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.			X

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RPP-RPT-55804, 2015, *Common Factors Relating to Liner Failures in Single-Shell Tanks,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-55951, 2015, *Fiscal Year 2013 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-56120, 2013, *Mobile Arm Retrieval System Project Vacuum Retrieval option, Independent Assessment Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-56141, 2014, *FY2013 DNV DST and SST Corrosion and Stress Corrosion Cracking Testing Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-56389, 2013, *IQRPE Integrity Assessment Report for C-105 Waste Retrieval Project Phase 1,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-56390, 2014, *IQRPE Integrity Assessment Report for C-105 Waste Retrieval Project Phase 2,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-56391, 2015, *IQRPE Integrity Assessment Report for C-105 Waste Retrieval Project Phase 3,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-56506, 2013, *IQRPE Integrity Assessment Reports for C-112 Hard Heel Removal Waste Retrieval Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-57096, 2014, *Examination of Simulated Non-Compliant Waste from Hanford Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
RPP-RPT-58116, 2014, *Sidewall Core Drilling Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-58239, 2015, *Fiscal Year 2014 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-58254, 2014, *Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-58300, 2015, *Fiscal Year 2014 DST and SST Chemistry Testing Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-58441, 2016, *Double-Shell Tank System Integrity Assessment Report (DSTAR),* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-58849, 2015, *Fiscal Year 2015 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-58931, 2016, *Single-Shell Tank Leak Detection, Intrusion and Monitoring Description,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-58931, 2017, Single-Shell Tank Leak Detection, Intrusion and Monitoring Description, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-59272, 2017, *Fiscal Year 2016 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-59273, 2017, *Evaporation of Water from Single-Shell Tank 241-T-111 with 500 CFM Portable Exhauster POR06,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X

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RPP-RPT-59684, 2017, *FY2015 DST and SST Chemistry Testing Report,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-59843, 2017, *Solid Phase Characterization of Tank 241-C-111 Solids,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-RPT-60093, 2018, *Fiscal Year 2017 Visual Inspection Report for Single-Shell Tanks,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-60176, 2017, *AN-AW Level Rise Analysis of Record Structural Evaluation Criteria,* Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.	X		
RPP-RPT-60192, 2018, *System Plan, Revision 8, Lifecycle Cost Analysis*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-60565, 2018, *Fiscal Year 2018 Visual Inspection Report for Single-Shell Tanks,* DRAFT, Washington River Protection Solutions, LLC, Richland, Washington.	X		
RPP-RPT-60722, 2018, *241-TX Tank Farm Interim Surface Barrier Recommendations,* DRAFT, Washington River Protection Solutions, LLC, Richland, Washington.			X
RPP-SPEC-32483, 2007, *T Farm Interim Surface Barrier Subsystem Specification,* Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.		X	
RPP-SPEC-38937, 2009, *TY Farm Interim Surface Barrier Subsystem Specification,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
RPP-SPEC-47469, 2011, *241-SX Tank Farm Interim Surface Barrier Subsystem Specification,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.		X	
SD-RE-TI-012, 1983, *Single-Shell Waste Tank Load Sensitivity Study,* Rev. A-0, Rockwell Hanford Operations, Richland, Washington.	X		

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
SD-WM-TI-097, 1984, *Criteria for Interim Isolation of Radioactively Contaminated Tank Farm Facilities at Hanford,* Rev. 0, Rockwell Hanford Operations, Richland, Washington.			X
SD-WM-TI-097, 1984, *Criteria for Interim Isolation of Radioactively Contaminated Tank Farm Facilities at Hanford,* Rev. 1, Rockwell Hanford Operations, Richland, Washington.			X
Statement of Work, 2017, *Requisition 302716 Evaluation A-Farm Tanks for Addition of Multiple Penetration,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.			X
TFC-ENG-DESIGN-C-10, 2016, *Engineering Calculations,* Rev. B-10, Washington River Protection Solutions, LLC, Richland, Washington.			X
TFC-ENG-DESIGN-C-30, 2017, *Post-Natural Phenomena Hazard Assessment,* Rev. A-9, Washington River Protection Solutions, LLC, Richland, Washington.	X		
TFC-ENG-FACSUP-C-10, 2016, *Control of Dome Loading and SSC Load Control,* Rev. C-24, Washington River Protection Solutions, LLC, Richland, Washington.	X		
TFC-ENG-STD-39, 2017, *Civil Survey for Tank Farm Facilities,* Rev. A-3, Washington River Protection Solutions, LLC, Richland, Washington.	X		
TFC-OPS-OPER-C-10, 2016, *Vehicle and Dome Load Control in Tank Farm Facilities,* Rev. B-28, Washington River Protection Solutions, LLC, Richland, Washington.	X		
TFC-OPS-OPER-C-60, 2018, *Surveillance Records,* Rev. B-13, Washington River Protection Solutions, LLC, Richland, Washington.			X
TFC-PLN-142, 2014, *Dome Loading Management Plan,* Rev A-1, Washington River Protection Solutions, LLC, Richland, Washington.	X		
TFC-WO-12-5505, 2015, *241-A-106 Excavation and Caisson Installation/Removal,* Washington River Protection Solutions, LLC, Richland, Washington.			X

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TFC-WO-13-1060, 2015, *241-A-106 Side-Wall Coring,* Washington River Protection Solutions, LLC, Richland, Washington.			X
TF-ERP-008, 2017, *Emergency Response Procedure 008 Seismic Event Response,* Rev. O-4, Washington River Protection Solutions, LLC, Richland, Washington.	X		
TF-OR-QR-AN, 2017, *AN Farm Quarterly Rounds,* Rev. A-42, Washington River Protection Solutions, LLC, Richland, Washington.			X
TF-OR-QR-AZ, 2018, *AZ Quarterly Rounds,* Rev. A-22, Washington River Protection Solutions, LLC, Richland, Washington.			X
TF-OR-QR-ST, 2017, *ST Quarterly Rounds,* Rev. A-31, Washington River Protection Solutions, LLC, Richland, Washington.			X
TF-OR-WR-AN, 2018, *AN Weekly Rounds,* Rev. A-55, Washington River Protection Solutions, LLC, Richland, Washington.			X
TF-OR-WR-AZ, 2018, *AZ Weekly Rounds,* Rev. A-25, Washington River Protection Solutions, LLC, Richland, Washington.			X
TF-OR-WR-ST, 2017, *ST Weekly Rounds,* Rev. A-44, Washington River Protection Solutions, LLC, Richland, Washington			X
TID-26431, *Report on the Investigation of the 106-T Tank Leak at The Hanford Reservation,* Richland, Washington.	X		
TO-320-370, 2017, *Operate POR357-RW-RWDD-001 Raw Hot Water Distribution Skid,* Rev. B-10, Washington River Protection Solutions, LLC, Richland, Washington.			X
Tomlinson, R.E., 1961, *Waste Management Program Chemical Processing Department,* Electric Hanford Atomic Products Operations, Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
U.S. Department of Energy, Washington State Department of Ecology, United States Environmental Protection Agency, *Hanford Federal Facility Agreement and Consent Order,* as amended.			X
VID # 17989, 2017, *Visual Inspection A-105 Riser 2 Primary Inspection,* Richland, Washington.	X		
VID # 18030, 2018, *Visual Inspection U-103 Riser 2 In Tank Inspection,* Richland, Washington	X		
VID# 12700, 2010, *Visual Inspection B-102 Riser 7 In Tank Video,* Richland, Washington.			X
VID# 12701, 2010, *Visual Inspection A-106 Riser 17 In Tank Video,* Richland, Washington.			X
VID# 12702, 2010, *Visual Inspection C-110 ORSS Riser 3 In Tank Video,* Richland, Washington.			X
VID# 12703, 2010, *Video Inspection SX-101 Riser 19 In Tank Video,* Richland, Washington.			X
VID# 12704, 2010, *Video Inspection S-103 Riser 08 In Tank Video,* Richland, Washington.			X
VID# 12705, 2010, *Video Inspection S-108 Riser 7 In Tank Video,* Richland, Washington.			X
VID# 12706, 2010, *Video Inspection U-104 Riser 2 In Tank Video,* Richland, Washington.			X
VID# 12707, 2010, *Video Inspection S-101 Riser 7 In Tank Video,* Richland, Washington.			X
VID# 12708, 2010, *Video Inspection BY-110 Riser 12B In Tank Video,* Richland, Washington.			X
VID# 12709, 2010, *Video Inspection A-105 Riser 2 In Tank Video,* Richland, Washington.			X
VID# 12710, 2010, *Video Inspection B-102 Riser 7 In Tank Video,* Richland, Washington.			X
VID# 12712, 2010, *Video Inspection AX-102 Riser 9G In Tank Video,* Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
VID# 12818, 2011, *Visual Inspection T-102 Riser 2,* Richland, Washington.			X
VID# 12834, 2011, *Visual Inspection C-101 Riser 7,* Richland, Washington.			X
VID# 12836, 2011, *Video Inspection TX-101 Riser 12B In Tank Video,* Richland, Washington			X
VID# 12837, 2011, *Video Inspection AX-104 Riser 3A Primary Video,* Richland, Washington.			X
VID# 12838, 2011, *Video Inspection TX-104 Riser 13A,* Richland, Washington.			X
VID# 12883, 2011, *Video Inspection C-112 Riser 2,* Richland, Washington.			X
VID# 12884, 2011, *Video Inspection T-112 Riser 2 In Tank Video,* Richland, Washington.			X
VID# 12887, 2011, *Visual Inspection SX-107 Riser 16 Tank Integrity Assessment,* Richland, Washington.			X
VID# 12888, 2011, *Visual Inspection B-106 Riser 2 Obstruction Video,* Richland, Washington.			X
VID# 12889, 2011, *Visual Inspection AX-101 Riser 3A,* Richland, Washington.			X
VID# 12890, 2011, *Visual Inspection AX-103 Riser 3A In Tank Video,* Richland, Washington.			X
VID# 13059, 2011, *Visual Inspection BY-101 Primary Tank Inspection,* Richland, Washington.			X
VID# 13060, 2013, *Visual Inspection BY-111 Primary Inspection,* Richland, Washington.			X
VID# 13249, 2013, *Visual Inspection BX-110 Riser 6 Tank Inspection,* Richland, Washington.			X
VID# 13312, 2013, *Visual Inspection BX-101 Riser 7 Primary Tank Inspection 27 Ft,* Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
VID# 13315, 2013, *Visual Inspection SX-106 Riser 6 Primary Tank Inspection,* Richland, Washington.	X		
VID# 13316, 2013, *Visual Inspection S-111 Riser 8 Primary Tank Inspection,* Richland, Washington.			X
VID# 13317, 2013, *Visual Inspection TY-105 Riser 7 Primary Tank Inspection,* Richland, Washington.			X
VID# 13347, 2013, *Visual Inspection T-111 Riser 6 Video Inspection,* Richland, Washington.			X
VID# 13355, 2013, *Visual Inspection BY-102 Primary Inspection,* Richland, Washington.			X
VID# 13357, 2013, *Visual Inspection B-203 Riser 2 Tank Inspection,* Richland, Washington.	X		
VID# 13358, 2013, *Visual Inspection T-203 Riser 7 Primary Video,* Richland, Washington.	X		
VID# 13359, 2013, *Visual Inspection T-204 Riser 7 Tank Inspection,* Richland, Washington.			X
VID# 13360, 2013, *Visual Inspection B-204 Riser Primary Video,* Richland, Washington.			X
VID# 13373, 2013, *Visual Inspection BX-103 Riser 7 Primary Inspection,* Richland, Washington.			X
VID# 13403, 2013, *Visual Inspection TX-112 Riser 5 Primary Inspection,* Richland, Washington.			X
VID# 13404, 2013, *Visual Inspection S-109 Primary Video Inspection,* Richland, Washington.	X		
VID# 13893, 2013, *Visual Inspection SX-102 Riser 8 In Tank Inspection,* Richland, Washington.			X
VID# 13894, 2013, *Visual Inspection T-111 Riser 2 Primary Inspection,* Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
VID# 13896, 2014, *Visual Inspection A-103 Riser 12 Primary Inspection,* Richland, Washington.			X
VID# 13898, 2014, *Visual Inspection B-202 Riser 2 In Tank Inspection,* Richland, Washington.			X
VID# 13899, 2014, *Visual Inspection B-109 Riser 2 In Tank Inspection,* Richland, Washington.			X
VID# 13900, 2014, *Visual Inspection U-111 Riser 3 Primary Video,* Richland, Washington.			X
VID# 14013, 2014, *Visual Inspection T-201 Riser 7 In Tank Video,* Richland, Washington.			X
VID# 14014, 2013, *Visual Inspection BY-106 Riser In Tank Video,* Richland, Washington.	X		
VID# 14015, 2014, *Visual Inspection T-101 Riser 2B Primary Inspection,* Richland, Washington.			X
VID# 14016, 2014, *Visual Inspection TY-102 Riser 5 Primary Inspection,* Richland, Washington.			X
VID# 14017, 2014, *Visual Inspection S-106 Riser 8 Primary Video,* Richland, Washington.	X		
VID# 14020, 2013, *Visual Inspection A-103 Riser 12 Primary Inspection,* Richland, Washington.			X
VID# 14021, 2013, *Visual Inspection U-111 Riser 7 Primary Inspection,* Richland, Washington.			X
VID# 14065, 2014, *Visual Inspection BX-111 Riser 3 Inspection,* Richland, Washington.			X
VID# 14108, 2014, *Visual Inspection C-102 Riser Water Addition,* Richland, Washington.			X
VID# 14517, 2015, *Visual Inspection T-111 Riser 6 In Tank Baseline,* Richland, Washington.			X
VID# 14517, 2016, *Visual Inspection S-105 Riser 8 Primary Tank Inspection,* Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
VID# 14537, 2015, *Visual Inspection TX-115 Riser 12B In Tank Inspection,* Richland, Washington.			X
VID# 14538, 2015, *Visual Inspection TY-103 Riser In Tank Video,* Richland, Washington.			X
VID# 14539, 2015, *Visual Inspection TX-117 Riser 10B Tank Inspection,* Richland, Washington.			X
VID# 14540, 2015, *Visual Inspection TX-115 Riser 12B In Tank Inspection,* Richland, Washington.			X
VID# 14547, 2015, *Visual Inspection TX-108 Riser 11B Primary Inspection,* Richland, Washington.			X
VID# 14640, 2015, *Visual Inspection BX-106 Riser 2 Primary Inspection,* Richland, Washington.			X
VID# 14641, 2015, *Visual Inspection BY-110 Riser 7 (part shows Riser 12B but video from Riser 7),* Richland, Washington.			X
VID# 14642, 2015, *Visual Inspection SX-104 Riser 3 Primary Inspection,* Richland, Washington.			X
VID# 14691, 2015, *Visual Inspection S-108 Riser 7 Tank Inspection,* Richland, Washington.			X
VID# 14694, 2015, *Visual Inspection A-101 Riser 16 Primary Video Inspection,* Richland, Washington.	X		
VID# 15113, 2016, *Visual Inspection T-111 Riser 6 Primary Inspection,* Richland, Washington.			X
VID# 15567, 2016, *Visual Inspection T-110 Riser 6 Primary Tank Inspection,* Richland, Washington.			X
VID# 15568, 2016, *Visual Inspection T-107 Riser 2 Primary Tank Inspection,* Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
VID# 15714, 2016, *Visual Inspection B-102 Riser 2 In Tank Video Inspection,* Richland, Washington.			X
VID# 15715, 2016, *Visual Inspection B-101 Riser 7 In Tank Video Inspection,* Richland, Washington.			X
VID# 17070, 2016, *Visual Inspection T-112 Riser 2 Primary Inspection,* Richland, Washington.			X
VID# 17750, 2016, *Visual Inspection TX-111 Riser 7 Primary Inspection,* Richland, Washington.			X
VID# 17751, 2016, *Visual Inspection TX-103 Riser 13A Primary Inspection,* Richland, Washington.			X
VID# 17762, 2016, *Visual Inspection TX-116 Riser 1 Primary Inspection,* Richland, Washington.			X
VID# 17811, 2016, *Visual Inspection U-102 Riser 7 In Tank Inspection,* Richland, Washington.			X
VID# 17812, 2016, *Visual Inspection U-105 Riser 17,* Richland, Washington.			X
VID# 17835, 2016, *Visual Inspection BY-105 Riser 5 In Tank Inspection,* Richland, Washington.			X
VID# 17836, 2016, *Visual Inspection TX-113 Riser 5 Primary Inspection,* Richland, Washington.			X
VID# 17897, 2014, *Visual Inspection A-102 Riser 19 Primary Inspection,* Richland, Washington.			X
WA7890008967, *Dangerous Waste Permit Application Part A Form, Part V, Closure Unit Group 4,* Washington State Department of Ecology.	X		
WAC 173-303-040, "Definitions", *Washington Administrative Code,* as amended.	X		

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WAC 173-303-640, "Tank Systems," *Washington Administrative Code,* as amended.	X		
WAC 173-303-810(13)(a), "Certification," Washington Administrative Code, as amended.	X		
WAC 173-303-810, "General Permit Conditions," *Washington Administrative Code,* as amended.	X		
WAC 196-27A, "Rules of Professional Conduct and Practice," *Washington Administrative Code,* as amended.	X		
WHC-MR-0132, 1990, *A History of the 200 Area Tank Farms, Section 1 of 2,* Westinghouse Hanford Company, Richland, Washington.			X
WHC-MR-0132, 1990, *A History of the 200 Area Tank Farms, Section 2 of 2,* Westinghouse Hanford Company, Richland, Washington.			X
WHC-MR-0132, 1990, *A History of the 200 Area Tank Farms,* Westinghouse Hanford Company, Richland, Washington.			X
WHC-MR-0250, 1979, *Excerpt Letter 65260-79-0730, Tanks Which Present a Potential for Reduced Structural Integrity,* Westinghouse Hanford Company, Richland, Washington.		X	
WHC-MR-0300/UC-721, 1992, *Tank 241-SX-108 Leak Assessment,* Westinghouse Hanford Company, Richland, Washington.			X
WHC-SD-ER-310, 1997, *Supporting Document for the Historical Tank Content Estimate for B-Tank Farm,* Rev. 1B, Lockheed Hanford Corporation, Richland, Washington.			X
WHC-SD-ER-313, 1996, *Supporting Document for the Historical Tank Content Estimate for C-Tank Farm,* Rev. 1, Westinghouse Hanford Company, Richland, Washington.			X
WHC-SD-ER-320, 1997, *Supporting Document for the Historical Tank Content Estimate for T-Tank Farm,* Rev. 1, Lockheed Hanford Corporation, Richland, Washington.			X
WHC-SD-ER-321, 1997, *Supporting Document for the Historical Tank Content Estimate for TX-Tank Farm,* Rev. 1, Lockheed Hanford Corporation, Richland, Washington.			X

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Document	This document was reviewed in its entirety.	This document was partially reviewed.	This document was not referenced in the IAR.
WHC-SD-ER-325, 1997, *Supporting Document for the Historical Tank Content Estimate for U-Tank Farm,* Rev. 1, Lockheed Hanford Corporation, Richland, Washington.			X
WHC-SD-TWR-RPT-002, 1998, *Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste Tanks,* Rev. 0-A, Lockheed Martin Hanford Company, Richland, Washington.	X		
WHC-SD-W236A-TI-002, 1996, *Probabilistic Seismic Hazard Analysis, DOE Hanford Site, Washington,* Rev. 1A, Fluor Daniel Hanford, Richland, Washington		X	
WHC-SD-W320-ANAL-001, 1994, *Structural Integrity Evaluation for In-Situ Conditions,* 2 Volumes, Rev. 0A, Westinghouse Hanford Company, Richland, Washington.		X	
WHC-SD-W320-ANAL-001, 1994, *Tank 241-C-106 Structural Integrity Evaluation for In Situ Conditions Volumes 1 and 2,* Rev. 0, Westinghouse Hanford Company, Richland, Washington		X	
WHC-SD-WM-ER-349, 1995, *Historical Tank Content Estimate for the Northeast Quadrant of the Hanford Company,* Westinghouse Hanford Company, Richland, Washington.			X
WHC-SD-WM-TA-019, 1990, *Sludge in Aging Waste Tank and Maximum Overserved Temperature,* Westinghouse Hanford Company, Richland, Washington.			X
WHC-SD-WM-TI-097, 1990, *Criteria for Interim Isolation of Radioactively Contaminated Tank Farm Facilities at Hanford,* Rev. 2, Westinghouse Hanford Company, Richland, Washington.			X
WHC-SD-WM-TI-591, 1994, *Maximum Surface Level and Temperature Histories for Hanford Waste Tanks,* Rev. 0, Westinghouse Hanford Company, Richland, Washington.			X

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Woodward, Clyde, 1978, *An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford Washington,* WCC Project 13974A-0300, Letter Report dated March 30, by Woodward Clyde Consultants, San Francisco, California for Rockwell Hanford Operations, Richland, Washington.			X
WRPS-1100725, April 2011, Interoffice Memo, *Ammonium Nitrate in Tank 241-A-105,* Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.			X
WRPS-40656, 2009, *Summary of First Single-Shell Tank Integrity Expert Panel Workshop – January 2009,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
WRPS-42005, 2009, *Summary of Second Single-Shell Tank Integrity Expert Panel Workshop – April 2009,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.	X		
WRPS-PER-2012-0931, *During an EAPC Walkdown in TX/TY Farms, it was Noticed that the Pit Foam of TX-102 is Deteriorating*, Washington River Protection Solutions, LLC, Richland, Washington.			X