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Selection of Representative High Level Waste Tanks for Ultrasonic Examination (U)

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1 EXECUTIVE SUMMARY

In-service inspection of the SRS HLW tanks is an essential element in the demonstration of their structural integrity to maintain the function of waste confinement throughout the desired service life. The basis for selection of the SRS Type I, II, and III waste tanks for Ultrasonic Testing (UT) examination has been developed for the SRS HLW Tank In-service Inspection Program plan. The tanks to be examined were determined by an analysis of factors that impact the degradation of waste tank materials. The analysis reduced the tanks into categories that encompassed the spectrum of materials, service history, and projected future service of the tanks. Representative tanks from each of these categories were chosen. Table 1 shows the categories and tanks that were recommended. The tanks will be examined on a 3-10 years interval. The regions and extent of the examinations, based on known and potential service-induced degradation, were prescribed.

Table 1: Representative Tanks for UT Inspection

Category	***Level 2 Category***	***Tanks Selected***
Type I and II Tanks	*Leakage Observed*	Tank 15*
	No-Leakage Observed	None**
Type III Tanks	*Fresh Waste Receiver*	
	H-Area	Tank 32 or 35
	F-Area†	Tank 33 or 34
	Waste Processing	
	Extended Sludge Processing†	Tank 40 or 42
	In-Tank Precipitation	Tank 48 or 49
	Unconcentrated Salt Solution	Tank 47
	Evaporator System	
	Evaporator Bottoms Receipt (H-Area)	Tank 29 or 31
	Evaporator Feed (F-Area)	Tank 26

*Tank 15 will be inspected twice to validate flaw growth rate models.
**The results of the UT Inspection performed on Tank 15 will be applied to the family of Type I and II tanks.
† These tanks will be inspected one time to confirm that no degradation has occurred in an environment expected to be relatively non-aggressive in comparison with the other tank within the same family.

2 INTRODUCTION

The Savannah River Site (SRS) High Level Waste (HLW) storage tanks have been in service for 20 to 45 years. To maintain safe continued service of the tanks, it is of paramount importance to demonstrate tank structural integrity (SI) with full consideration of degradation and aging mechanisms. The structural integrity of these tanks is the demonstrated confinement of the waste by the structures under design basis conditions. Confinement of wastes, which are in the form of supernate, saltcake, or sludge, is achieved through structural soundness of the tank, leak-tightness and mitigation of detrimental conditions identified.

An important element in the demonstration of structural integrity is an In-Service Inspection (ISI) Program to provide in-situ material condition information on the existing tank. Inspection also provides early detection of degradation and possible responses to maintain structural integrity. The current ISI program for the HLW tanks is limited to visual inspection. An Ultrasonic Testing (UT) element will be used to augment the current ISI program. This document will detail the selection of HLW tanks for UT inspection as part of a comprehensive HLW tank inspection program. In addition, the extent, frequency, and schedule of UT inspection will be included.

The current inspection program consists of direct photography that involves making detailed visual records of tank walls and annular space. Visual examinations are done with borescopes and periscopes. In addition, closed circuit television (CCTV) is used for further investigations into specific conditions found during inspections and to troubleshoot process problems. However, the current inspection program does not include thickness measurements, which are done by an Ultrasonic Thickness (UT) inspection. A previous UT program, performed between 1971-1985, showed no detectable wall thickness loss and therefore was discontinued. No measurements for cracks or pits were made during this time.

The program enumerated here is limited to HLW storage tanks and will not include the peripheral systems and transfer lines. The elements of the tank inspection plan presented here is organized into the following:

1. Drivers for Inspection
2. Basis for Technical Approach
3. SRS UT Inspection Plan
4. Path Forward

The entire document will consequently be included in the revision of WSRC-TR-95-0076 as the Chapter 11 revision, "HLWE Structural Integrity Inspection and Monitoring Program".

3 BACKGROUND

Radioactive supernate, salt, and/or sludge wastes are presently confined in 48 underground storage tanks at the Savannah River Site (SRS). These high level wastes will be processed in several of the tanks and then transferred by piping to other site facilities for further processing before they are stabilized for ultimate disposal. Based on waste removal and processing schedules, many of the tanks, including those with acceptable defects, will be required to be in service for times exceeding the initial intended life. Until the waste is removed from storage, transferred, and processed, the materials and structures of the tanks must maintain a confinement function by providing a barrier to the environment and by maintaining acceptable structural stability during design basis events (DBEs) which include loadings from both normal service and abnormal (e.g., earthquake) conditions.

To maintain the confinement function throughout extended service, it is essential that the potential changes in physical properties or in the geometry of the structural materials due to exposure to the service environment be evaluated and that conditions that can cause significant (active) degradation be avoided or mitigated. Aging mechanisms are those which cause changes in the materials including degradation of the materials. Degradation is either a reduction of the mechanical properties (e.g., loss of strength, stiffness, or ductility), or a loss of net section of the materials (e.g., cracking, pitting, thinning), or both which reduces the level of confinement inherent in the original, installed condition and could lead to a loss of confinement. Degradation of the materials can occur through various mechanisms under specific service conditions.

Degradation evaluations of DOE HLW tanks have concluded that pitting and stress corrosion cracking are two primary degradation modes for the carbon steel tanks in extended service. The SRS HLW tank service experience has been that some of the tanks have suffered stress corrosion cracking that led to leakage failures. In comparison, Hanford Double-Shell Tank experience has seen instances of pitting. [1] The proposed UT examinations will include the tank regions most susceptible to these degradation modes.

3.1 HLW Tank Summary

The steel tanks and liners of the Savannah River waste tanks were designed and fabricated in accordance with several editions of Section VIII of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC), depending on the vintage and type of tank, as listed in Table 2. The service history of the tanks shows that despite design and construction to appropriate commercial codes, several of the steel primary tanks of the first generation SRS tanks are known to have developed cracks. These were the non-stress-relieved design of mostly high heat waste tanks of Type I (tanks 1, 5, and 6F and 9-12H) and of Type II (tanks 13-16H) design except for two cases of low heat waste tanks of Type IV (Tanks 19F and 20F) design. Only one of these tanks (Tank 16H) had waste escape the secondary steel pan confinement and leak to the soil. This tank was drained and permanently retired from service. Subsequent design changes and operating conditions incorporated improved materials, fabrication methods, and/or chemistry controls to eliminate the cause of cracking in all tanks. Table 2 shows a summary of the HLW tank design codes.

Table 2: Summary of HLW Tank Design Codes

Tank No.	Type	Year Built	Steel Design Code
1F - 8F	I	1952	ASME BPV – 1949
9H - 12H	I	1953	ASME BPV – 1949
13H - 16H	II	1956	ASME BPV – 1952
17F - 20F	IV	1958	ASME BPV – 1956
21H - 24H	IV	1962	ASME BPV – 1956
25H - 32H 33F - 34F 35H - 37H 38H - 43H 44F - 47F 48H - 51H	III	1967-1981	ASME BPV, Section VIII

3.2 Degradation Mechanisms

Stress-corrosion cracking in the liquid waste has been the principal degradation mechanism for the primary liner in waste storage tanks that have not been stress-relieved. Seven Type I waste tanks and all four Type II waste tanks have developed through-wall stress corrosion cracks. Small surface cracks were also observed on the interior of the primary tank. The cracks were perpendicular to the butt welds and extended through the heat-affected zone before stopping shortly after penetrating the base metal. Chemistry control is maintained in the liquid phase to prevent the initiation of new crack, or the re-initiation of the old cracks.

No significant pitting of the primary or secondary liner has been observed in the liquid waste during waste storage operations. Only broad, shallow pits up to 0.020 inches deep were observed on sections removed from the primary wall of Tank 16H, a tank which contained high heat waste and experienced severe stress-corrosion cracking. Carbon steel coupons were placed in Tank 15H during the transfer of the waste from Tank 16H to that tank. The coupons were exposed to the vapor space, supernate and sludge over a seven month period. Only slight pitting was observed on all the coupons. Corrosion specimens were also placed in the supernate and sludge of Tank 15H and 16H for 13 and 18 years, respectively. The deepest pit observed after the coupons were removed was 0.0011 inches. [2] Chemistry control is maintained in the liquid phase to prevent the initiation of pitting and /or general thinning.

Crack like indications in areas above the waste level, and leakage of waste from a tank that was filled after being empty for an extended period of time, have also been observed in the Type I and II waste tanks. These observations suggest that degradation may occur in the vapor space region of the tank as well. These mechanisms are expected to be the same as those that occur in the liquid (i.e., stress corrosion cracking, pitting, and general corrosion). A laboratory investigation is being conducted to evaluate the potential for each of these mechanisms in the vapor space of the tanks.

The Type III tanks were stress relieved and therefore the potential degradation modes are limited to pitting and general corrosion. These mechanisms could occur in either the liquid, liquid/vapor interface or vapor space region of the tank. Chemistry control is maintained in the liquid phase to prevent the initiation of pitting and /or general thinning.

The ultrasonic inspections of the waste tanks will cover all degradation mechanisms in all regions of the tank, including liquid, liquid/vapor interface, and vapor phases.

3.3 HLWE SI Inspection and Monitoring Program

The HLW SI Inspection program is an integral part of an overall SI program designed to ensure confinement of wastes throughout desired service life and to manage the aforementioned degradation mechanisms and material aging through monitoring and inspection. The purpose of the HLW SI Inspection program is to provide information to support justification for continued safe use of HLW tanks and supporting systems for an extended period.

Activities to maintain confinement of the waste by SRS-HLW tanks have been performed throughout their service. In 1995, SRS issued a comprehensive program plan based upon guidelines recommended by the Tank Structural Integrity Panel (TSIP), to integrate these collective activities to demonstrate the structural integrity of the high level waste tank and piping systems. TSIP was an expert panel commissioned by the DOE to evaluate the effect of aging and service-induced degradation of the structural materials used in waste storage tanks in the DOE complex. The efforts of the panel culminated in the development of the "Guidelines for Development of SI programs for DOE High-Level Waste Storage Tanks." The DOE consequently issued Order 435.1 directing compliance by the DOE complex with these guidelines.

In 1998, the SRS high-level waste structural integrity program activities were augmented with additional activities to form the Tank Life Management Program. The program was designed to address the degradation issues of HLW Type I and II tanks. The present activities of the Life Management Program include augmented inspections, degradation evaluation, material property testing, structural analyses, and flaw stability analysis. It is designed to maintain confinement by evaluating any observed degradation, including service-induced flaws, to determine if they are acceptable at the operating conditions of Type I and II HLW tanks.

3.3.1 Current In-Service Inspection

Routine direct visual surveys are made in the annular spaces, and non-routine direct visual surveys are made in primary tanks through opened access risers and/or inspection ports. In 1961-62, the first remote imaging inspections were made of some tanks using a periscope. Random inspections continued trough 1970. A program was initiated in November 1971 to periodically inspect all waste tanks, using remote visual imagery techniques to monitor for corrosion and other degradation. Steel thickness measurements have been made periodically of waste tanks using ultrasonic techniques to monitor for general corrosion. Measurements were made over 14 years (1971-1985) and the results showed that no detectable thinning of SRS tanks had occurred.

The current inspection program is part of the administrative control, "Liquid Radioactive Waste Handling Facilities TSR Administrative Control Compliance Requirements," designated G-TRT-G-00003. Section 2.9.1.4, entitled "Waste Tank Inspection Program", is included as part of Appendix 9, "Structural Integrity Program".[3] Table 3 summarizes the Process Surveillance Requirements.

Table 3: Summary of Process Surveillance Requirements

SURVEILLANCE REQUIREMENT		**FREQUENCY**
PSR 3.9.1.4.1	For Type I, II , III and IIIA waste tanks, perform a visual inspection for THROUGH-WALL degradation through every accessible annulus opening.	2 Years
PSR 3.9.1.4.2	For Type IV waste tanks perform a visual inspection through at least one access opening.	2 Years

3.3.2 DOE Order 435.1

The following is a summary of DOE Order 435.1, "Subject: Radioactive Waste Management". The summary includes the objectives and salient points of the Structural Integrity portion of Order 435.1.

The objective of Order 435.1 is to ensure that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety, and the environment. Section II. Q. (2) of DOE Order 435.1 addresses the development of a Structural Integrity Program. The SI program outlined is delineated into (1) Leak-Tight Tanks In-Service and (2) In-Service Tanks that Have Leaked or Suspect. Table 4 enumerates the required capabilities of an in-service inspection plan, as directed by Order 435.1.

Table 4: SI Program Capabilities as directed by DOE Order 435.1

Leak-Tight Tanks In-Service		In-Service Tanks that Have leaked or Are Suspect	
1.	Verify the current leak-tightness and structural strength of each tank in-service.	1.	Verify the structural strength of each tank in-service which has leaked or is suspect.
2.	Identify corrosion, fatigue and other critical degradation modes.	2.	Identify corrosion, fatigue and other critical degradation modes.
3.	Adjust the chemistry of tank waste, calibrating cathodic protection systems, wherever employed, and implementing other necessary corrosion protective measures.	3.	Adjust the chemistry of tank waste, calibrating cathodic protection systems, wherever employed, and implementing other necessary corrosion protective measures.
4.	Provide credible projections as to when structural integrity of each tank can no longer be assured.	4.	Determine which of the tanks that have leaked or are suspect may remain in service by identifying an acceptable safe operating envelope.
5.	Identify the additional controls necessary to maintain an acceptable operating envelope.	5.	Provide credible projections as to when structural integrity of each tank can no longer be assured.
		6.	Identify the additional controls necessary to maintain an acceptable operating envelope.

4 TSIP GUIDANCE FOR TECHNICAL APPROACH

The Tank Structural Integrity Panel (TSIP) was a panel of experts commissioned by the DOE to provide general guidelines for demonstration of the structural integrity of high-level waste storage tanks and transfer lines at the facilities of the DOE. These guidelines were expected to serve as the technical basis of a site-specific structural integrity program. The most important elements of the plan include a leak-detection system and a reliable non-destructive examination (NDE) plan that is extracted from applicable ASME Code Sections and commensurate with the physical conditions in the waste storage tanks. The final TSIP report, TSIP Report BNL-52527, "Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks, is referenced by DOE Order 435.1 as containing the procedures that provide an acceptable technical approach to maintain the structural integrity of existing tanks and to estimate the end of service life. The following will be a summary of the TSIP guidance.[4]

Chapter 5 of the TSIP Guidance document describes a NDE plan for the detection of degradation of double shell HLW tanks. Appendix A of the TSIP Guidance includes the philosophy and bases used for development of the NDE plan. The scope herein will be a summary of the guidance for the examination of the primary tank and secondary tank. The peripheral structures are not addressed here, but are included in the TSIP Guidance. The NDE plan for tanks provides for the detection of pitting, cracking, and wall thinning. Table 5 describes the TSIP guidance on examinations to be performed on carbon or low-alloy HLW tanks (reproduced from Reference 4).

The TSIP guidance specifies that the tank population to be examined is to be 10% of the tanks but not less than one. If the population of tanks is not homogeneous, selection of more than 10% may be required to include representation of all tanks. Degradation found to be greater than the acceptance levels quantified require further examination. The tanks to be examined should be selected on the basis of age, severity of operating conditions, and transients, so that the tanks with the greatest potential for degradation are examined. The SRS in-service inspection plan for conforms to the TSIP guidance. The SRS tanks and service conditions are not homogeneous. The approach to the selection of SRS tanks for volumetric examination using UT will be described in detail in Section 5.

Table 5: Examinations of Carbon or Low Alloy Tank Containing High Level Waste (Reproduced from Reference 4.)

Region Examined	***Examination Requirements***	***Examination Methods***	***Extent of Examination***	***Frequency of Examination***
Liquid-Vapor Interface	± one foot of interface	Volumetric (0º UT)	5% of interface length of each tank to be examined	Each inspection interval (divided into two periods)
Liquid-Sludge Interface	± one foot of interface	Volumetric (UT) from outside	5% of interface length of each tank to be examined	Each inspection interval
Lower Knuckle of Primary Tank	Upper Weld	Volumetric	5% of length divided into two or more segments if accessible	Each inspection interval
	Predicted σ_{max} region of base metal plus lower weld, if accessible	Volumetric	5% divided between knuckle base metal and lower weld if accessible otherwise 5% of knuckle divided into two or more segments	Each inspection interval
External Surface of Primary Tank, & Internal Surface of Secondary Tank	Overall scan of accessible regions	Remote Visual	All accessible regions	At least once, each inspection interval
	Below nominal vapor-liquid interface	Volumetric (0º UT)	Each inspection interval	Each inspection interval
Vapor Region	Confirm VT with PT or UT if attack is found	Remote Visual	Remote scan of vapor region	Each inspection interval
Bottom Plate of Tank, if accessible	"Best Effort" NDE Examination	Volumetric	Primarily designed for new tanks designed for accessibility: However limited scans should be conducted if feasible	Each inspection interval
Overall Scan of Internal Surface	Essentially empty tank	Remote Visual	General scan of inside of primary tank	Empty Tank

5 SRS TECHNICAL APPROACH

This section focuses on the selection of SRS tanks to be volumetrically examined using UT as part of the SRS HLW Tank ISI Program Plan. Categories for representative tanks are constructed to identify similar tanks. The features considered in the construction include materials, service history, tank function, and projected future service. Representative tanks from these categories will be inspected with UT. Any active degradation mechanisms will be trended by follow-up inspections in these representative tanks for their remaining service life. The following sections discuss the basis for: 1) the selection of representative tanks, 2) the extent of examination, and 3) the inspection intervals.

Selection of the waste tanks with the highest potential for degradation will involve evaluation of criteria in the following general areas: 1) Primary Tank Materials and Fabrication, 2) Service History, and 3) Current and Projected Usage of the Tanks. These general criteria can be further divided into more specific factors as shown in Table 6. These variables, their impact on degradation, and how they will be utilized to reduce the tanks into a system of categories will be discussed.

Table 6: Selection Criteria for Tanks with Highest Potential for Degradation

Primary Tank Materials and Construction	Service History	Current and Projected Tank Usage
• Tank steel	• Years of service	• Years of service at projected closure
• Post-weld stress relief	• Waste temperature	• Tank function
	• Constant waste level for an extended period of time	
	• Tank function	
	• Corrosion control during the service life of the tank	
	• Observed leak sites	

5.1 Selection Criteria

Figure 1 shows a summary of the multi-level categorization criteria including tank function for the Type III tanks that were utilized to develop a UT inspection plan. The HLW tanks are categorized by materials and fabrication into the following two families: (1) Type I and Type II Tanks, (2) Type III Tanks. Type I and The Type I and Type II tanks were categorized into leaking and non-leaking tanks. The number of leaksites and anomalous observations further distinguished tanks with a history of leakage. The Type III tanks were categorized by tank function and further categorized by years of service, constant waste level, and corrosion control.

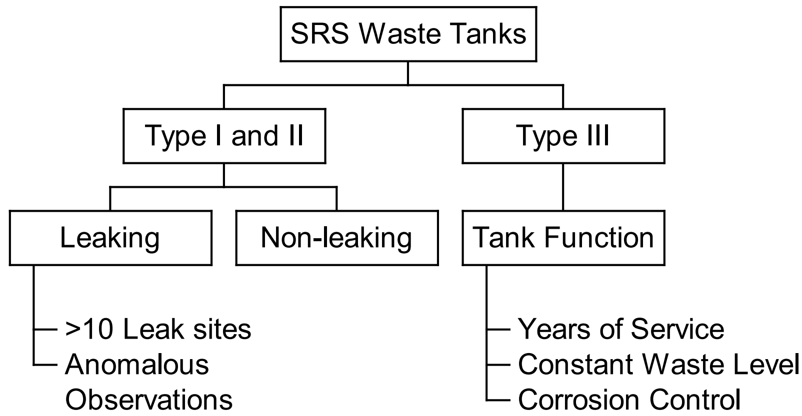

Figure 1: Summary of Tank Categorization

5.1.1 Primary Tank Materials and Construction

The degree of degradation is dependent upon the type of steel utilized and heat treatments that the steel has received. Welding of the structure induces microstructural changes in the steel and tensile residual stresses adjacent to the weld. These residual stresses, in conjunction with the waste tank environment, contribute to degradation in the primary tanks. Previous structural integrity evaluations have demonstrated that the primary degradation mechanisms of concern for low carbon steels exposed to waste tank environments are stress corrosion cracking (SCC) and pitting.

The composition of the steel impacts the degradation mechanisms. The introduction of carbon into bulk pure iron results in a material that is susceptible to SCC. Parkins observed that bulk carbon free iron is not susceptible to SCC, the introduction of relatively small amounts of carbon promotes SCC, and the propensity for stress corrosion cracking becomes less severe as carbon content increases.[5] Parkins suggested that the relationship between carbon concentration and SCC propensity must pass through a maximum at a carbon concentration between 0% and about 0.2% and then decreases significantly as carbon content increases. The association of intergranular cracking with the presence of cementite (Fe_3C) at the grain boundaries was proposed to explain the appearance of this maximum. Sulfur is another impurity that appears to increase the susceptibility of a material to SCC.[6] The high concentration of sulfur at the grain boundaries relative to the bulk metal result is proposed to increase the SCC susceptibility of iron. Engineers at Hanford have suggested that sulfur concentrations greater than 0.02% increase a material's susceptibility to SCC.[7] The most important structural factor appears to be grain size. Coarse grain materials appear to be more susceptible to SCC than finer grain materials . Either the heat treatment temperature or the cooling rate of the melt controls ferritic grain size.

Pitting in low carbon steels is frequently associated with the presence of sulfide inclusions (FeS and MnS).[8] In oxidizing media, and particularly in neutral solutions that cannot dissolve the sulfide, the sulfides act as local cathodes and promote the initiation of pitting. At low pH, the inclusions are easily dissolved and leave crevices from which pitting initiates. As with SCC, higher concentrations of sulfur tend to make the material more susceptible to pit initiation. However, it is recognized that pitting may also initiate in the absence of sulfides.

The most significant fabrication variable is the post-weld heat treatment or stress relief of the structure. Laboratory testing demonstrated that as-welded specimens readily crack in simulated waste environments, while stress-relieved specimens were not susceptible to cracking.[9] The stress-relief is desirable since it reduces the residual stresses near the weld, and also reduces the inherent SCC susceptibility of the material. Therefore, tanks that have not been stress-relieved are more susceptible to SCC.

The materials and fabrication characteristics of the tanks provide the first level of categorical reduction. The Type I and II tanks were constructed from ASTM A285 Grade B carbon steel and were not stress-relieved. On the other hand the Type III tanks were constructed from superior materials (ASTM A516 or ASTM A537 carbon steel) and received post-weld stress-relief treatment. Therefore, as has been observed, the Type I and Type II tanks are more susceptible to nitrate stress corrosion cracking than the Type III tanks.

5.2 Service History

A review of the service history considers evidence of degradation as well as factors that may have induced significant degradation in the past. The following sections discuss the relevant elements of the service history, and the consequent evaluation of each of the elements.

5.2.1 Observed Leaksites in Type I/II HLW Tanks

Routine visual inspections of the tanks have been performed on waste tanks since 1977. Non-routine visual inspections were performed prior to this date, whenever conductivity probes were in alarm. Leakage is detected by the presence of salt deposits on the primary wall. Leakage in the past has been primarily associated with SCC at the welds or weld attachments in non-stress relieved tanks.[10]

Leakage from tanks also separates the Type I and II tanks from the Type III tanks. Leakage has been observed in eleven of the Type I and II waste tanks, while no leakage has been observed in the Type III tanks. Additionally, there are some Type I tanks that have no observable leakage. Therefore a category level beneath the Type I and II tanks can be created.

There are several reasons for performing UT examination of tanks with cracks. The examination will characterize the length and depth of flaws present in the tank. Currently the database of flaws is limited to thirteen cracks that were observed during a liquid penetrant (PT) examination on a single vertical weld in one tank, and a trepanned section of material from the same tank. In order to increase this database it is recommended that the tank examined have a minimum of 10 known leak sites. Once the tank is selected, the flaws should be characterized to establish degradation and/or any initiation rates. Tanks that demonstrate visual anomalies (i.e., different crack shape, location, or size) should also be given preference.

Volumetric examination of Tank 13 has been performed utilizing the same scan plan as intended for other tanks. The tank contained approximately 254 inches of waste (maximum fill level is 272 inches). Although the tank has two recorded leak sites, these are above the waste level, and consequently the tank may be considered as representative of non-leaking tanks. (Note: The two leak sites mentioned were not inspected because program validation was in progress and needed to be performed without contaminating the equipment). The data showed that no reportable conditions were detected in the areas examined.

However, more recent visual inspections of Tank 5 prior to the transfer of waste to the tank revealed no indications of leak sites.[11] At that time there was no supernate present in the tank. Following the transfer, fifteen leak sites were discovered. This occurrence demonstrates that even though a visual inspection indicates a non-leaking condition, leak sites may actually be present in the Type I and II tanks. Therefore, it is expected that all Type I and Type II tanks have flaws similar to those observed and due to stress corrosion cracking. The results of the UT inspection performed on a leaking Type I or Type II tank will thus be used to predict the behavior of all other tanks within this family.

Since Type III tanks have exhibited no leakage to date, this criterion will not be utilized to create a sub-category for these tanks.

5.2.2 HLW Type III Tank Function

This criterion examines the type of waste chemistry a tank may have experienced or will experience during service. A review of the service history of the tanks indicates that there are essentially five general categories: (1) Fresh Waste Receivers (FWR), (2) Waste Processing (WP), (3) Unconcentrated Supernate Storage (USS), and (4) Evaporator System (ES). The WP tanks are further characterized by their use as the Extended Sludge Processing (ESP) and the In-Tank Precipitation (ITP) process tanks. The ES tanks are further categorized into the Evaporator Bottoms Receiver (EBR) and the Evaporator Feed (EF) tanks. The characteristics of each category are summarized in Table 7. Figure 2 summarizes the multi-level categorization criteria used to distinguish the Type III HLW tanks.

Table 7: Categorization of Type III HlW Tanks by Tank Function

	FWR	**WP**	**USS**	**ES**
Waste Received	*F-Area* F-Purex SRL Waste *H-Area* HM Waste DWPF RBOF	Sludge & Salt Processing Tanks	Aged Fresh Waste Evaporator Vent Flushes Uninhibited Water Flushes Redissolved salt Solutions Sludge Slurry	*EBR* Concentrated Supernate *EF* Unconcentrated Supernate Low heat waste from canyon
Waste Chemistry	Low R-value ratios (described in detail in the following section)	Relatively dilute supernate Washing stages induce concentration transients	Concentration gradients Waste removal operations induce concentration transients	High hydroxide concentrations
Contents	Supernate Sludge	Supernate	Supernate Salt Sludge	*EBR* Supernate Sludge *EF* Salt Concentrated Supernate
Service	Higher temperatures Observed Leaksites in Type I/II FWR Tanks	Among last closed	Cooling coils failures occurred during waste removal	Numerous waste level changes due to frequent transfers

<u>Laboratory Experience</u>	Higher susceptibility to stress corrosion cracking	Susceptible to pitting at liquid/vapor interface w/o sufficiently inhibited bulk waste		

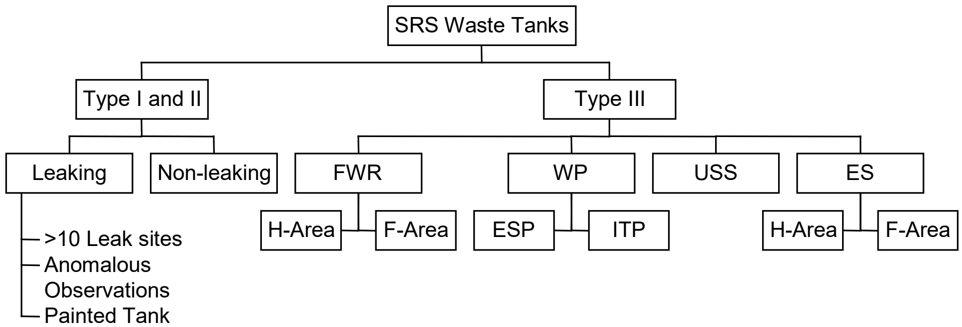

Figure 2: HLW Tank Categorization Criteria

5.2.2.1 Type III Tank Statistical Bases for Categorization

The ratio of the concentration of inhibitor species (nitrite and hydroxide) to aggressive species (nitrate), referred to as the R-value, was utilized to assess the potential for corrosion attack by a given waste solution. Low R-values represent waste solutions that are inhibited to a lesser degree, and higher R-values represent waste solutions that may be more aggressive to the tank. A statistical analysis of R-value was done to demonstrate differences in tank function that have a significant impact on the corrosivity of a solution.

Waste chemistry data collected since 1977 was reviewed for each tank and the average R-value for each of the tanks was calculated using available data as shown in Table 8. A statistical analysis was performed on the R-value for the waste solutions in each category, in order to determine the degree of variability between the categories. The result of this analysis is shown in Tables 10 through 14. The wide range in the average R-value between the categories (1.19 to 4.60) suggests that tank function has a significant impact on waste chemistry and therefore the waste chemistry cannot be considered to be homogeneous for all tanks. Yet, as shown in Table 8, other factors suggest these tanks may be grouped together in categories. These factors include the frequency of transfers into a tank, waste processing versus waste storage functions, the waste forms (salt, sludge, and/or supernate), and waste temperatures.

Table 8: Type III Tanks R-Value Figure of Merit and their Categorization

Tank	R-Value	Tank Function	Location
25	4.99	ES – EBR	F
27	3.92	ES – EBR	F
28	4.47	ES – EBR	F
29	3.58	ES – EBR	H
31	2.99	ES – EBR	H
36	6.01	ES – EBR	H
37	3.83	ES – EBR	H
41	2.33	ES – EBR	H
44	6.15	ES – EBR	F
45	7.70	ES – EBR	F

46	4.63	ES – EBR	F
26	3.81	ES - EF	F
43	3.37	ES - EF	H
32	1.10	FWR	H
33	1.59	FWR	F
34	2.96	FWR	F
35	0.88	FWR	H
39	1.12	FWR	H
30	1.91	USS	H
38	4.36	USS	H
47	3.34	USS	F
40	2.41	WP	H
42	4.37	WP	H
48	9.43	WP	H
49	1.94	WP	H
50	0.64	WP	H
51	3.35	WP	H

The statistical analysis also demonstrated the degree of variability within a category. The results in Table 9 suggest that there is a significant difference between the mean R-value for the EBR tanks in F-area versus similar tanks in H-area. However, it is expected that the EBR in H-Area will receive the more aggressive species. In addition, the F-Area EBR and EF tanks are expected to be similar in waste chemistry due to numerous recycles. Therefore, an EF tank from F-Area, and an EBR tank from H-Area are recommended for inspection. The results in Table 10 show that there is no significant difference in the R-value for the wastes in FWR. However, H-area tanks have received waste from the HM process in H-canyon, while F-area tanks have received waste from the F-Purex process in F-canyon. The HM waste has tended to result in higher waste temperatures and therefore a more corrosive situation. To verify this difference, one tank from each area should be selected. Table 13 shows that the waste processing tanks had the greatest degree of variability. The differences in processing operations likely resulted in this variability (i.e. ESP vs. ITP vs. ETF). Two tanks from this category are recommended for inspection. One tank that is utilized for the ESP process and another tank that will be utilized for the alternate salt processing option. The tanks within the USS category have a reasonably low degree of variability and a relatively few number of tanks within their respective categories. Therefore, one tank within this category will be sufficient for inspection.

Table 9: R-Value Statistical Analysis Results within the Evaporator Bottoms Receipt Sub-Category

ES - EBR		*ES – EBR - F Tank Farm*		*ES - EBR – H Tank Farm*	
Mean	4.60	Mean	5.31	Mean	3.75
Standard Error	0.47	Standard Error	0.57	Standard Error	0.62
Median	4.47	Median	4.81	Median	3.58
Standard Deviation	1.55	Standard Deviation	1.39	Standard Deviation	1.39
Sample Variance	2.40	Sample Variance	1.92	Sample Variance	1.93
Range	5.37	Range	3.78	Range	3.68
Minimum	2.33	Minimum	3.92	Minimum	2.33
Maximum	7.70	Maximum	7.70	Maximum	6.01
Sum	50.59	Sum	31.86	Sum	18.74
Count	11.00	Count	6.00	Count	5.00

Table 10: R-Value Statistical Analysis Results within the Fresh Waste Receiver Category

FWR	
Mean	1.19
Standard Error	0.13
Median	1.12
Standard Deviation	0.28
Sample Variance	0.08
Range	0.77
Minimum	0.88
Maximum	1.65
Sum	5.95
Count	5

Table 11: R-Value Statistical Analysis Results within the Unconcentrated Salt Solution Category.

USS	
Mean	3.20
Standard Error	0.71
Median	3.34
Standard Deviation	1.23
Sample Variance	1.51
Range	2.44
Minimum	1.91
Maximum	4.36
Sum	9.61
Count	3.00

Table 12: R-Value Statistical Analysis Results within the Evaporator Feed Category.

ES - EF	
Mean	3.59
Standard Error	0.22
Median	3.59
Standard Deviation	0.31
Sample Variance	0.10
Range	0.44
Minimum	3.37
Maximum	3.81
Sum	7.18
Count	2.00

Table 13: R-Value Statistical Analysis Results within the Waste Processing Category.

	WP
Mean	3.69
Standard Error	1.26
Median	2.88
Standard Deviation	3.08
Sample Variance	9.49
Range	8.78
Minimum	0.64
Maximum	9.43
Sum	22.13
Count	6.00

5.2.3 Years of Service

The extent of corrosion degradation experienced by a structure is dependent upon the time of exposure to a corrosive medium. Years of service is defined as the time interval since the first fluid, water or waste, was added to a tank. This time is considered more significant than the date of construction age because in several cases the first fluid entry occurred years after initial construction (e.g., Tank 6 and Tank 46).

The years of service at the anticipated closure date for a tank will be utilized as the screening variable. The High Level Waste System Plan will be utilized to make the determination of total service years.[12] The years of service will be compared by normalizing the years of service with respect to the tank with the longest years of service within a given category. For example, if the worst case tank experienced 60 years of service, a tank that experienced only 30 years at these temperatures would be at a risk level approximately 2 times less than the worst case tank. Since both non-leaking Type I tanks and Type III tanks are impacted, this variable will be utilized to screen these tanks at the category 3 level.

5.2.4 Temperature

The severity of corrosion due to localized modes almost always increases with temperature. Nitrate stress corrosion cracking has strong temperature dependence. Corrosion testing at SRS indicated that for carbon steels in fresh high heat waste environments, maintaining the supernate temperature below 70 C would mitigate SCC.[13] For concentrated salt supernates, the probability of SCC is less and therefore temperatures up to the boiling point of the waste were acceptable.[14] In dilute waste supernates (e.g, waste removal or waste processing), the minimum inhibitor concentration has an exponential dependence upon the temperature.[15] The Corrosion Control Program requires that tanks that service this type of waste have a minimum inhibitor concentration that will be sufficient at temperature of 40 C or less.[16]

Exposure time is also a factor in the temperature variable. In other words, longer exposure times above a given temperature are expected to increase the likelihood of corrosion degradation. A high temperature limit of 66 C (150 F) will be utilized to distinguish between the environments in the tanks. This temperature is approximately the limit for the supernate temperature in a fresh waste receiver. Temperature history documents will be utilized to determine the length of time the tanks were above this temperature. The tank temperature will be compared by normalizing the length of time the waste temperature was greater 66 C with respect to the longest time a tank experienced these temperatures. For example, if the worst case tank experienced 20 years at these temperatures, a tank that experienced only 5 years at these temperatures would be at a risk level approximately 4 times less than the worst case tank.

This variable primarily applies to the Type I tanks with no leak sites. Most of the Type III tanks have operated under a corrosion control program that monitors and control the waste temperature. Thus, the tanks in most cases have not seen these high temperatures for extended periods of time. Therefore, this variable will be utilized as a level 3 category for Type I tanks with no leak sites.

5.2.5 Constant Waste Level

Stationary waste levels can result in the formation of galvanic cells or the depletion of inhibitor at the liquid-vapor interface. [17,18] Both mechanisms can result in pitting of the tank wall if the bulk waste is not properly inhibited.

Tanks that have a virtually constant waste level for a period of 5 years are potentially vulnerable to attack and therefore received a score of 10. The level history for each tank will be evaluated to determine which tanks have had an essentially constant level for 5 years or more.

All Type I and II tanks have been at a constant level for longer than 5 years. Therefore, this is not a discriminating variable for these tanks. However, for Type III tanks there are several tanks that have not had a constant level for a significant time. Constant waste level will be utilized as a level 3 category for Type III tanks.

5.2.6 Corrosion Control During Service Life of Tank

In-tank sampling of the waste was initiated in 1977 on a routine basis.[19] The waste chemistry from the sample was then compared with inhibitor concentration limits determined from laboratory studies. The inhibitor concentrations were developed to prevent the initiation of new cracks or pits and to prevent the re-initiation of growth in the old cracks. If the chemistry was outside the limits, remedial actions were taken to re-establish chemistry control. Prior to this time, the waste was neutralized at the source of generation. Although this likely accomplished initial inhibition of the waste it did not take into account changes that could occur to the waste chemistry during storage. Therefore tanks that were not part of this routine sampling program during their entire service life are more susceptible to corrosion than those that were sampled on a regular basis.

Since the corrosion control program was not active during the majority of the service life for Type I and II tanks, it is not a discriminating variable for the non-leaking tanks. However, there were several Type III tanks that experienced extended service without the corrosion control program. Therefore, this variable will be utilized as a level 3 category for Type III tanks. Tanks that were not part of the corrosion control program for their entire service life will receive a score of 10. Tanks that were part of the corrosion control program for their entire service life will receive a score of 3. This score reflects the uncertainties in sampling and analysis of the waste.

5.2.7 Scoring Approach for Prioritization of HLW Tanks for Inspection

A scoring system was developed for the level 3 category factors in order to make recommendations for tank selection within a given level 2 category. The scoring system and the weighting of the variables is shown in Table 14. The score from the level 3 category factor was multiplied by the weighting factor and then added together with the other weighted level 3 category factors to calculate a total weighted score for a given level 2 category.

Table 14: Scoring System for Prioritization within Level 3 Category

Level 2 Category	Level 3 Category Factor	Scoring within Level 3 Category Factor	Weight of Level 3 Category
Leaking Type I and II Waste Tanks	Greater than 10 known leaksites	10 points if greater than 10 leak sites; 0 points if less than 10 leak sites.	0.6
	Anomalous visual observation	10 points if anomaly observed; 0 points if no anomaly observed.	0.3
	Painted	10 points if painted; 0 points if no paint	0.1
Non-Leaking Type I and II Tanks	Years of service at closure	10 points for the tank with most expected years of service; remaining tanks will be normalized with respect to this tank and receive a score from 1 to 10.	0.7
	Years at temperature greater than 66 C.	10 points to the tank with maximum number of years; remaining tanks will be normalized with respect to this tank and receive a score from 1 to 10.	0.3
Type III Tank: Fresh Waste Receiver, Waste Processing Tank, Unconcentrated Salt Solution, Evaporator Feed Tank, Evaporator Bottoms Receipt Tank	Years of service at closure	10 points to the tank with maximum expected years of service; remaining tanks will be normalized with respect to this tank and receive a score from 1 to 10.	0.7
	Corrosion control program for the service life of the tank	10 points if tank did not have corrosion control program for entire service life; 3 points if tank had corrosion control.	0.2
	Constant Waste Level	10 points if the waste level was constant for longet than 5 years; 0 points if the waste level was constant for less than 5 years.	0.1

6 SRS UT INSPECTION PLAN

Table 9 shows the number of tanks that should be examined from each level 1 and 2 category to provide a sound technical basis for understanding degradation of the tanks using the aforementioned criteria. The technical bases for the number of tanks is discussed in detail in the following sections.

The selection criteria data for each tank is tabulated in Appendix A, Table A.1. Sources of data for the table include the waste temperature history, waste tank service history, waste level history, tank chemistry history, tank inspection history, materials and construction reports, the Structural Integrity Database and the High Level Waste System Plan.[20,21,22,23,24,25]

Table 15 summarizes the recommended tanks for UT inspection.

Table 15: Representative Tanks for UT Inspection

Category	***Level 2 Category***	***Tanks Selected***
Type I and II Tanks	*Leakage Observed*	Tank 15*
	No-Leakage Observed	None
Type III Tanks	*Fresh Waste Receiver*	
	H-Area	Tank 32 or 35
	F-Area†	Tank 33 or 34
	Waste Processing	
	Extended Sludge Processing†	Tank 40 or 42
	In-Tank Precipitation	Tank 48 or 49
	Unconcentrated Salt Solution	Tank 47
	Evaporator System	
	Evaporator Bottoms Receipt (H-Area)	Tank 29 or 31,
	Evaporator Feed (F-Area)	Tank 26

*Tank 15 will be inspected twice to validate flaw growth rate models.
† These tanks will be inspected one time to confirm that no degradation has occurred in an environment expected to be relatively non-aggressive in comparison with the other tanks within the same family.

6.1 Tank Selection

6.1.1 Type I and II Tanks: Leakage Observed

Tank 15 had the highest score in this category primarily due to the large number of observed leak sites and the anomalous crack that has been observed and is recommended for inspection. The results of the UT Inspection performed on Tank 15 will be applied to the family of Type I and II tanks.

6.1.2 Type III Tanks: Fresh Waste Receivers

Tanks 32, 33, 34, and 35 received the highest scores within this category. The F-Area tank chosen is to be inspected one time to confirm that no degradation has occurred in an environment expected to be relatively non-aggressive in comparison with the H-Area tank within the same family. The H-Area Tank is part of the routine inspection program.

6.1.3 Type III Tanks: Waste Processing Tanks

Tanks 40, 42, 48, 49, and 51 received the highest scores in this category. It is recommended that one of Tanks 40 or 42 and on of tank 48 or 49 be chosen for UT inspection. Tanks 40 and 42 have been used as ESP tanks and are distinguished on this basis from the other WP tanks. The ESP tank will be inspected once to validate expected models.

6.1.4 Type III Tanks: Unconcentrated Supernate

F-Area Tank 47 will be the tank inspected within this category to ensure that we have a balanced inspection program. However, Tank 30 received the highest score because it was not operated with corrosion control for the entire service life.

6.1.5 Type III Tanks: Evaporator System

The evaporator system tanks were further categorized as EBR and EF tanks. Tanks 26 and 43 serve as evaporator feed tanks and receive fresh low heat waste from various generators (e.g., canyons, DWPF, and RBOF). However, it is recognized that Tank 32 will be utilized in this function during future operations. Therefore, in actuality there are at least three tanks with this function. The scores in Table A6 indicate that there is not a significant difference between these two tanks. Tank 43 is recommended for inspection on the basis of the R-value calculations.

Tanks 29 and 31 received the highest scores in EBR category primarily due to the number of service years and the lack of corrosion control for the entire service life, therefore one of these tanks is recommended for inspection.

6.2 Extent of UT Inspection

Selection of a representative sample of the tank wall is a critical step in determining the condition of a tank. Factors to consider when selecting an area and sample size for UT inspection include: 1) determination of significant degradation mechanisms, 2) determination of regions of the tank where these mechanisms may be active, and 3) determination of accessibility of region that will be inspected.

The guidance provided by the TSIP document will be utilized to recommend the area and sample size that will be inspected by UT. Any reasons for deviation from these guidelines will be noted in this document or in the field inspection plan. It is intended that on subsequent examinations that the same area of the tank will be inspected in order to trend any indications of degradation. However, it is recognized that results of UT and VT inspections may suggest other regions of the tanks that need to be inspected by UT. These changes would be noted in the field inspection plan.

Table 16 summarizes the extent of the UT examinations. In most cases the regions and sample size will meet or exceed the TSIP guidance. SRS intends to examine vertical strips from different regions of the tank, from above the top weld to below the bottom weld. Although a smaller percentage of the tank circumference will be examined, there is assurance that if the waste levels remained at more than one constant level for an extended period of time, a sample of that area will be examined. This implies that the current interface TSIP requirements will not be strictly met, but such an approach will ensure that all historical interfaces are sampled.

The extent of examination will be the same in all level 2 categories except for Type I and II tanks. In the latter case, known leak sites will be characterized in addition to the normal extent of examination. Finally, the feasibility and benefit of inspecting the secondary pan and the bottom plate will need to be examined. The results of these studies will be included in the final ISI program documentation.

Table 16: Extent of UT Inspection

Inspection Region	***Examination Requirements***	***Extent of Examination***	***Deviations from TSIP Guidance***
1. Liquid-Vapor Interface	± one foot of interface	See Item 4	See Item 4
2. Liquid-Sludge Interface	± one foot of interface	See Item 4	See Item 4
3. Lower Knuckle of Primary Tank	Horizontal Girth Weld	5% divided into two segments	There is no deviation from the TSIP guidance.
	Highest Stress Region	See Item 4	See Item 4
4. External surface of primary tank	Below nominal vapor-liquid interface	Type I tanks: Four 7 inches vertical strips. Two strips in each half of the tank. Type II and III tanks: Four 8.5 inches vertical strips. Two strips in each half of the tank.	Exceeds the TSIP requirement of 10 sq. feet of area. Note that this examination will cover approximately 1% of the liquid-vapor and liquid sludge regions. Although this is less than the TSIP guidance, all historical fill heights will be inspected. Additionally the inspection will cover approximately 10 inches above the weld between the bottom knuckle and side wall, which is. the region of highest stress.
5. Vertical and horizontal welds other than the lower knuckle weld	Vertical weld and middle horizontal weld.	~10 feet of vertical weld and ~ 13 feet of the middle horizontal weld	Not required by TSIP guidance, however, flaws have been observed in these regions of Type I/II tanks. The 10 foot section of vertical weld represents the width of a plate in the tank. The 13 foot section of horizontal weld represents approximately 5% of the circumference of the tank.
6. Bottom Plate of the Tank if accessible	"Best Effort" NDE	No access for UT of the bottom plate of Type I and II tanks. SRS will investigate the feasibility inspecting via the cooling slots beneath Type III tanks.	Feasibility study will be performed.
7. Secondary pan or wall	Knuckle region welds or the weld wall intersection and wall and floor.	Ventilation duct is located at the bottom of the annulus. Need to investigate accessibility issues.	Secondary pan UT inspection will be conducted on areas to be determined.

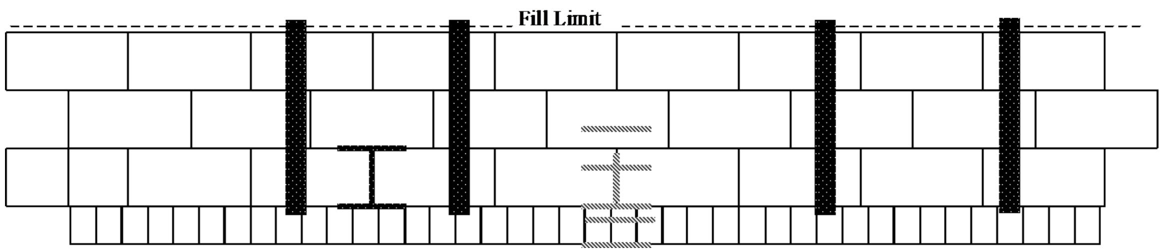

Figure 3: Unwrapped Surface of a Typical Type III Waste Tank, Illustrating TSIP Inspection Requirements (- - - -) and Planned Inspection Extent (▬▬▬).

<u>TSIP Requirements are:</u>

5% (13 feet) of liquid-vapor interface, plus

5% (13 feet) of liquid-sludge interface, plus

5% (13 feet) of lower weld on lower plate (upper weld of bottom knuckle), plus

5% (13 feet) divided between knuckle base metal and knuckle lower weld, if accessible.

Otherwise 5% of knuckle divided into two or more segments. (Note: Knuckle lower weld is not accessible.)

<u>Extent of planned weld inspection will be:</u>

Four 8.5 inch wide vertical strips (two in each half) extending from the top of the bottom knuckle to the bottom of the top knuckle, plus

5% (13 feet) of lower weld on middle plate, plus

5% (13 feet) of lower weld on lower plate (upper weld of knuckle), plus

9 feet of vertical weld on lower plate.

The weld areas will be scanned ultrasonically for parallel and perpendicular cracking with 45 degree and 60 degree shear waves. The vertical strips will be scanned ultrasonically over the entire accessible height of the tank, covering all past and present interface areas. These scans will be conducted at 0 degrees for thickness/pitting, and 45 degrees for cracking.

6.3 Frequency of Inspections

The TSIP guidance will be utilized to develop the frequency of inspections. TSIP recommends a maximum 10-year inspection interval. However, the inspection interval will be determined for specific degradation mechanisms using historical and laboratory evidence as the bases for the frequency.

The mechanical properties of the carbon steels of the waste tanks and transfer piping are not expected to degrade in the waste tank service environment up to a nominal 100 years of service. Corrosion mechanisms, however, can lead to changes in the physical condition (i.e. thinning, pitting, cracking) of the low carbon steel under certain material and chemistry conditions. Regions susceptible to general corrosion that cause thinning include steel surfaces in contact with certain waste forms. However, some of the stored waste has been neutralized specifically to protect the steel contacted. Liquid/vapor interfaces are potentially susceptible to pitting attack. Crevices are potentially susceptible to extended pitting attack. Regions of material extending approximately 6 inches away from welds in non-stress relieved systems are susceptible to SCC in non-inhibited, high nitrate chemistries.

Degradation rates for general corrosion, pitting corrosion, and stress corrosion cracking have been determined from laboratory tests in aggressive conditions in simulated or actual waste. No significant thinning, pitting, or cracking is expected at the benign conditions presently maintained in the Type I and II waste tanks, and maintained over the fabrication and service history of the Type III tanks. Nevertheless, for the purpose of establishing the basis for the successive examination interval, bounding rates from laboratory testing are applied.

The upper bound rate of general thinning of waste tank steel due to corrosion under caustic conditions was determined to be 0.001 inches/year.[26,27] Pitting corrosion testing of low carbon steel within an aggressive simulate waste condition have been determined to be bounded by approximately 0.050 inches/year. The tests were done within the liquid, and do not include liquid/vapor interface or vapor space pitting at aggressive chemistry conditions.[28] The upper bound stress corrosion cracking rate at aggressive chemistry conditions has been determined to be 1.25 inches/year from Wedge-Opening Loaded (WOL) tests of ASTM A285 steel.[29] Thus the rate for crack growth for a double-ended crack is twice this rate or 2.5 inches/year.

These degradation rates have been used to determine the following frequency of inspections.

1. The FWR tanks have been subject to the harshest environments and the interval will be reduced to seven years. Other Type III tanks that will be part of the routine inspection program will be inspected at an interval of 10 years.

2. In order to validate previous observations of no crack growth outside the residual stress field, Tank 15 will be inspected two times at an interval of five years. In addition, expected growth rates will be validated. The results of the UT inspection will be applied to the family of Type I and II tanks.

3. The results of the inspections shall be disposed of in accordance with the set of standards, or acceptance criteria, detailed in WSRC-TR-2002-00063, “Acceptance Criteria for Disposition of Inspection Results of SRS Type III High Level Waste Tanks”.[30]

6.4 Schedule for UT Inspections

Figure 4 and Figure 5 show an example of how the UT inspection schedule may be planned for the remaining service life of the tanks. This schedule assumes that the recommended tanks will be selected. The schedule presented may be revised as the acceptance criteria are developed.

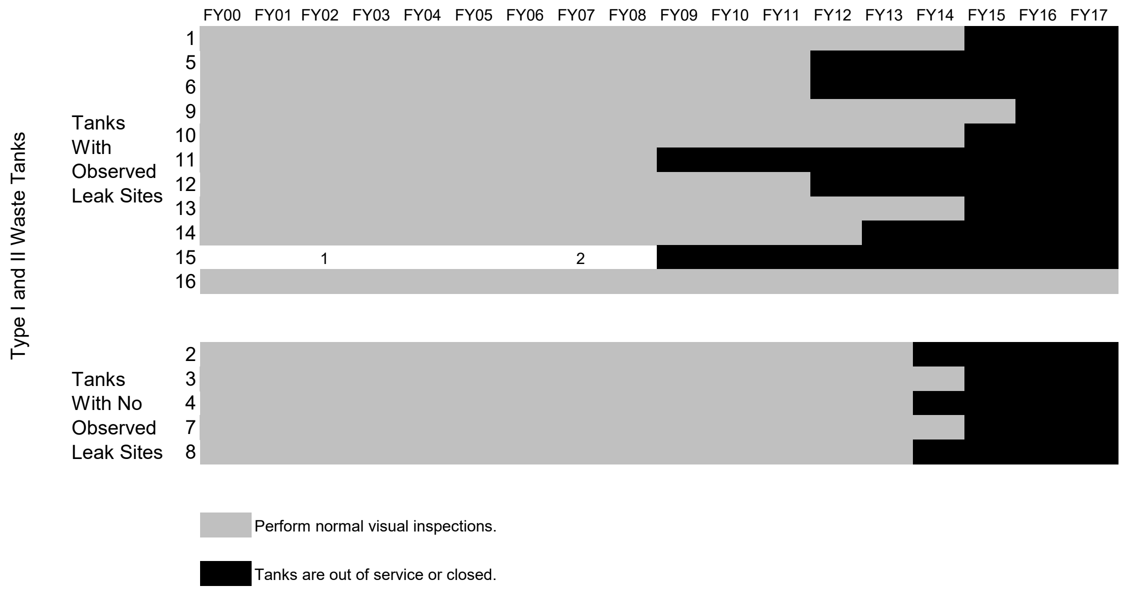

Figure 4: UT Inspection Schedule for Type I/II Tanks.

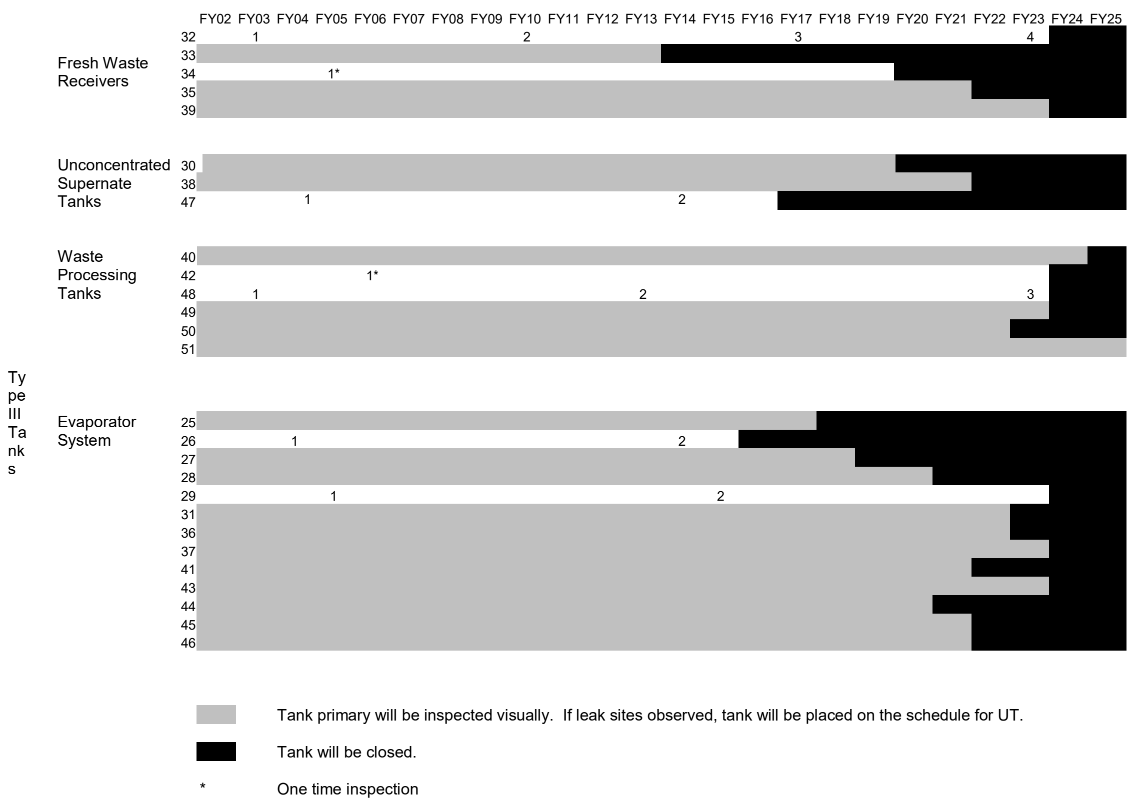

Figure 5: UT Inspection Schedule for Type III Tanks

7 SUMMARY OF HANFORD UT INSPECTION

Hanford has 28 double shell tanks (DST) that are similar in design and age to the SRS Type III tanks. The

Hanford in-service inspection program is detailed within the Double Shell Tank Integrity Program Plan.[31] Guidance from TSIP was utilized to develop their plan. They have been performing a routine surveillance program since FY97. Criteria for selection of Hanford DST for UT inspection were essentially equivalent to SRS criteria. However, rather than for selection of representative tanks, the data was utilized to prioritize UT inspection of selected regions of all DSTs at Hanford. Certain regions of the tank will be inspected in representative tanks. These requirements met regulatory agreements, and far exceeded the TSIP guideline minimum requirements.

The SRS inspection program inspects a representative sample of tanks and applies the results of inspection in accordance with the acceptance criteria outlined in WSRC-TR-2002-00063.[32] The database of historical UT inspections and extensive visual inspection program provide a basis for inspection of a representative sample of tanks. In addition, effective chemistry control and an active corrosion sampling program provide additional validation to ensure that the proposed UT inspection program is effective. The SRS inspection program addresses the potential vapor space phenomena through inspection of a tank that has had a low level of waste for an extended period of time.

The extent of examination requirements for the Hanford tanks, as with SRS tanks generally exceeded the TSIP guidelines. The only portion that they are unable to examine is the high stress region in the lower knuckle. UT technology is being developed for this purpose.

8 CONCLUSIONS

The strategy for implementation of UT examinations of the Type I, II and III waste tanks was outlined. The methodology utilized for selecting representative tanks that will be placed on a routine UT surveillance program was described. The methodology involved an evaluation of the potential for degradation of the tank materials based upon the materials of construction, service history, and projected future service of the tanks. A scoring system was utilized to select the most susceptible tanks over the full spectrum of tank service environments. Five Type III tanks were selected for a routine surveillance program. Three other tanks were selected for unique UT examinations. Tank 15 was chosen for two inspections to validate degradation models and rates for the family of Type I/II tanks. An F-Area FWR was selected to validate the hypothesis that F-Area wastes are less aggressive than H-Area wastes. Likewise, an additional ESP tank was selected to compare the relative aggressiveness of the ESP and ITP processs. Both the FWR and ESP tanks will be inspected once. The ultrasonic inspections of the waste tanks will cover all degradation mechanisms in all regions of the tank, including liquid, liquid/vapor interface, and vapor phases.

The extent of the examination was also recommended. In most cases the extent met or exceeded the TSIP guidance. Deviations from the TSIP guidance were explained. There were also areas where accessibility will be an issue (e.g., secondary pan and bottom plate). Feasibility studies on these issues will be performed prior to issuing the revision to the structural integrity document.

A schedule for performing UT inspections was also presented. Inspections will begin in FY02 with Tank 15. The routine surveillance program will be initiated in FY03. The FWR tank will be inspected on a more frequent basis than the other tanks. The inspection intervals may be adjusted as acceptance levels for the UT examinations are developed.

9 FUTURE STRUCTURAL INTEGRITY WORK

This memo will provide input into the in-service inspection (ISI) document that is being developed for the High Level Waste organization. Currently the ISI program is documented in chapter 11 structural integrity program.[2] Chapter 11 will be revised to include UT examinations. A team that includes personnel from CSTE, SRTC, TSD/NDE, and PE&CD has been formed to make these revisions. The sections that this team will analyze include:

- Personnel Qualifications
- Equipment Requirements
- Selection Criteria for Representative Tanks
- Extent of Examination

- Frequency of Examination
- Acceptance Levels
- Schedule of Inspections

This revision will be completed by April, 2002. Results from these analyses may slightly alter the extent and frequency of examination. Since only Tank 15 will be inspected during FY02, this would only alter the routine surveillance program.

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APPENDIX A

Table A1: Summary of Tank Selection Criteria

	Material and Construction		Service History							Projected Usage		
Tank	*Steel*	*Stress Relief*	*Corrosion Control Program for entire life of the tank*	*Years of Service*	*Years Temp. >66 C*	*Constant Waste Level for a period of 5 years*	*Observed Anomalous Behavior*	*Tank Function*	*Leaksites*	Closure Year	Years of service @ Closure	Tank Function
1	A285	No	No	47	5.5	Yes	Leakage appears to be from tank bottom.	HHW Receiver (F-Purex) for 12 years; Evaporator Bottoms for 4 years;Inactive for 28 years	> 1	2015	61	Will store primarily dry salt; No free liquid until waste removal operations
2	A285	No	No	46	1	Yes	None	HHW Receiver (F-Purex) for 12 years; Evaporator Bottoms for 6 years;Inactive for 28 years	No	2014	59	Will store primarily dry salt; No free liquid until waste removal operations
3	A285	No	No	45	2.5	Yes	None	HHW Receiver (F-Purex) for 12 years; Evaporator Bottoms for 5 years;Inactive for 28 years	No	2015	59	Will store primarily dry salt; No free liquid until waste removal operations
4	A285	No	No	40	10.5	Yes	Pre-service inspection indicates several weld attachments on interior of tank.	HHW Receiver (F-Purex) for 9 years; Evaporator Bottoms for 2 years;HHW Receiver (F-Purex) for 6 years; Inactive for 21 years	No	2014	53	Will store unconcentrated supernate and sludge for 6 years prior to waste removal operations.
5	A285	No	No	42	11.5	Yes	None	Blend of HHW Receiver (F-Purex) and SRL Waste for 12 years; Concentrated Supernate for 2 years; Inactive for 28 years.	15	2012	51	Will store dry sludge with unconcentrated supernate (DWPF recycle) prior to waste removal operations.
6	A285	No	No	37	7.5	Yes	Pre-service inspection indicates several weld attachments on interior of tank.	Blend of HHW Receiver (F-Purex) and SRL Waste for 7 years; Concentrated Supernate for 2 years; Inactive for 28 years.	6	2012	48	Will store dry sludge with unconcentrated supernate (Tk 17+DWPF recycle) prior to waste removal operations.
7	A285	No	No	47	8	Yes	None	Blend of LHW Receiver (F-Purex) and Evaporator Feed Tank for 29 years; Inactive for 18 years	No	2015	61	Sludge removal operations will begin in FY02; Tank will be utilized during the removal of salt from Tanks 1, 2, and 3 starting in FY2008.
8	A285	No	No	45	8.5	Yes	None	LHW Receiver (F-Purex) for 4 years;Blend of HHW Receiver (F-Purex) and SRL Waste for 14 years; LHW Receiver (F-Purex) for 6 years; Inactive for 21 years.	No	2014	58	Will store unconcentrated supernate (DWPF recycle from Tank 6) prior to waste removal.
9	A285	No	No	46	2.5	Yes	Amount leaked on to the annulus floor does not coincide with leakage observed from the sidewall of primary	HHW Receiver (H-Purex) for 12 years; Evaporator Bottoms for 5 years; Inactive for 27 years	>4	2016	61	Will store primarily dry salt; No free liquid until waste removal operations
10	A285	No	No	45	7.5	Yes	No leakage observed from the sidewall of primary.	HHW Receiver (H-Purex + HM) for 12 years; Evaporator Bottoms for 5 years; Inactive for 27 years	>1	2015	59	Will store primarily dry salt; No free liquid until waste removal operations
11	A285	No	No	46	19.5	Yes	None	LHW Receiver (H-Purex) for 7 years;Blend of HHW Receiver (HM + Thorex) and Concentrated Supernate for 20 years; Inactive for 19 years.	2	2008	53	Will store unconcentrated supernate (60s sludge removal) and sludge prior to waste removal operations.
12	A285	No	No	45	18	Yes	None	HHW Receiver (H-Purex + HM) for 17 years; Inactive for 28 years	2	2012	56	Will store primarily dry sludge; No free liquid until waste removal operations
13	A285	No	No	45	13	Yes	None	Blend of LHW Receiver (H-Purex+HM +Thorex) and Evaporator Feed for 17 years;Evaporator Feed Tank for 21 years;	2	2015	59	Will store unconcentrated supernate (evap feed tank) and sludge prior to waste removal

								Inactive for 7 years.				operations.
14	A285	No	No	44	3	Yes	None	Blend of HHW Receiver (H-Purex + HM + Thorex) and LHW Receiver (HM + Thorex) for 12 years; Evaporator Bottoms for 2 years; Inactive for 31 years	50	2013	56	Will store primarily dry salt; No free liquid until waste removal operations
15	A285	No	No	41	10	Yes	Long crack that has a curved shape located near the middle girth weld.	Blend of HHW Receiver (HM + Thorex) and LHW Receiver (HM) for 20 years; Inactive for 21 years.	16	2009	49	Will store primarily dry sludge; No free liquid until waste removal operations
16	A285	No	No	42	5	Yes	None	HHW Receiver (HM) for 8 years; Blend of LHW Receiver and Concentrated Supernate Receiver for 10 years; Out of service for 22 years	>300	2010	51*	* Tank is clean; Annulus contains waste.
25	A516	Yes	Yes	21	0	Yes	None	Evaporator Concentrate Receiver for 8 years; Inactive for 13 years	No	2018	38	Will be a 2F Evaporator receipt tank.
26	A516	Yes	Yes	21	3	Yes	None	Blend of LHW Receiver (F-Purex) and Evaporator Feed Tank for 20 years	No	2016	36	Will be the 2F Evaporator feed tank. Will receive high heat waste from 221-F
27	A516	Yes	Yes	22	0	Yes	None	Blend of Salt Dissolution Water and Evaporator Concentrate for 9 years; Inactive for 13 years	No	2019	40	Will store concentrated supernate above saltcake until waste removal.
28	A516	Yes	Yes	21	0	Yes	None	Evaporator Concentrate for 5 years; Inactive for 16 years	No	2021	41	Will store concentrated supernate above saltcake until waste removal.
29	A516	Yes	No	30	6	Yes	None	Evaporator Concentrate for 17 years; Inactive for 13 years.	No	2024	53	Will be the 3H evaporator vent tank.
30	A516	Yes	No	27	0	No	None	Blend of HHW and LLW Concentrated Supernates for 26 years; Evaporator Concentrate Receiver for 1 year	No	2020	46	Will store concentrated supernate above saltcake until waste removal.
31	A516	Yes	No	29	11	No	None	Evaporator Concentrate Receiver for 11 years; Inactive for 17 years	No	2023	51	Will store concentrated supernate above saltcake until waste removal.
32	A516	Yes	No	30	19	No	None	HHW Receiver (HM) for 17 years; Inactive for 12 years; Evaporator Feed Tank for 1 year	No	2024	53	Will be the 3H evaporator feed tank.
33	A516	Yes	No	27	0	No	None	Evaporator Concentrate Receiver for 9 years; HHW Receiver (F-Purex) for 18 years	No	2014	40	Will receive low heat waste from 221-F.
34	A516	Yes	No	28	4	No	None	Evaporator Concentrate Receiver for 7 years; Blend of HHW Receiver and Evaporator Concentrate Receiver for 14 year; Inactive for 7years	No	2020	47	Will receive low heat waste from 221-F.
35	A516	Yes	Yes	24	9	Yes	None	Blend of HHW Receiver (HM) and Concentrated Supernate Receiver for 13 years; Inactive for 11 years	No	2022	45	Will store unconcentrated supernate above sludge until waste removal.
36	A516	Yes	Yes	23	0	Yes	None	Blend of Concentrated Supernate and Evaporator Concentrate Receiver for 10 years; Inactive for 13 years	No	2023	45	Will store concentrated supernate above saltcake until waste removal.
37	A516	Yes	Yes	23	0	Yes	None	Blend of Concentrated Supernate and Evaporator Concentrate Receiver for 10 years; Inactive for 13 years	No	2024	46	Will be the 3H evaporator receipt tank.
38	A537	Yes	Yes	20	0	No	Minor pitting of tank bottom during construction	Blend of Concentrated Supernate and Evaporator Concentrate Receiver for 20 years	No	2021	40	Will be a 2H evaporator receipt tank.
39	A537	Yes	Yes	19	7	No	Minor pitting of tank bottom during construction	Blend of HHW Receiver (HM) and Evaporator Concentrate Receiver	No	2024	42	Will receive low heat waste from 221-H.

								for 19 years.				
40	A537	Yes	Yes	15	0	Yes	Minor pitting of tank bottom during construction	Sludge Slurry Tank for 15 years	No	2025	39	Will be involved in sludge processing.
41	A537	Yes	Yes	20	0	Yes	Minor pitting of tank bottom during construction	Blend of LHW Receiver (HM) and Evaporator Concentrate Receiver for 6 years; Inactive for 13 years	No	2020	39	Will store concentrated supernate above saltcake until waste removal.
42	A537	Yes	Yes	19	0	Yes	Minor pitting of tank bottom during construction	Sludge Slurry Tank for 19 years	No	2024	42	Will be a 2H evaporator receipt tank.
43	A537	Yes	Yes	19	2	No	Minor pitting of tank bottom during construction	Blend of LHW Receiver and Evaporator Feed Tank for 19 years	No	2024	42	Will be the 2H evaporator feed tank. Will receive low heat waste from 221-H
44	A537	Yes	Yes	19	2	Yes	Minor pitting of tank bottom during construction	Evaporator Concentrate Receiver for 10 years; Inactive for 9 years	No	2021	39	Will store concentrated supernate above saltcake until waste removal.
45	A537	Yes	Yes	19	1	Yes	Minor pitting of tank bottom during construction	Evaporator Concentrate Receiver for 11 years; Inactive for 8 years	No	2022	40	Will store concentrated supernate above saltcake until waste removal.
46	A537	Yes	Yes	8	0	No	Minor pitting of tank bottom during construction	Evaporator Concentrate Receiver for 8 years	No	2022	29	Will be a 2F Evaporator receipt tank.
47	A537	Yes	Yes	20	1	Yes	Minor pitting of tank bottom during construction	Blend of LHW Receiver (F-Purex) and Evaporator Concentrate Receiver for 14 years; Inactive for 6 years	No	2017	36	Will be the 2F Evaporator vent tank.
48	A537	Yes	Yes	18	0	Yes	Minor pitting of tank bottom during construction	ITP Tank	No	2024	41	Will store unconcentrated supernate until salt processing begins.
49	A537	Yes	Yes	18	0	Yes	Minor pitting of tank bottom during construction	ITP Tank	No	2023	40	Will store unconcentrated supernate until salt processing begins.
50	A537	Yes	Yes	13	0	No	Minor pitting of tank bottom during construction	ETF Stream for 13 years	No	2024	36	Will store ETF concentrate until salt processing begins. Mods needed before waste storage use.
51	A537	Yes	Yes	15	0	Yes	Minor pitting of tank bottom during construction	Sludge Slurry for 9 years; DWPF Feed Tank for 6 years	No	2023	37	Will be involved in sludge processing. DWPF Feed tank.

Table A2. Raw Scores for Leaking Type I and II Waste Tanks

Tank	> 10 Leak Sites	Weighted Leak Site Score	Observed Anomalous Behavior	Weighted Observed Behavior Score	Painted Tank	Weighted Painted Tank Score	Total Score
1	0	0	10	3	10	1	4
5	10	6	0	0	10	1	7
6	0	0	0	0	10	1	1
9	0	0	10	3	10	1	4
10	0	0	10	3	10	1	4
11	0	0	0	0	10	1	1
12	0	0	0	0	10	1	1
13	0	0	0	0	0	0	0
14	10	6	0	0	0	0	6
15	10	6	10	3	0	0	9

Table A3. Raw Scores for Non-leaking Type I and II Waste Tanks

Tank	Normalized years of service @ closure	Weighted Years of Service	Normalized years at temperature > 66 °C	Weighted Temperature	Total Score
2	9.6	6.72	1	0.3	7.02
3	9.6	6.72	2	0.6	7.32
4	8.7	6.09	10	3	9.09
7	10	7	8	2.4	9.4
8	9.5	6.65	8	2.4	9.05

Table A4. Raw Scores for Type III Waste Tanks: Fresh Waste Receiver

Tank	Normalized years of service @ closure	Weighted normalized years of service @ closure	Corrosion control for entire service life	Weighted corrosion control for entire service life score	Constant level for > 5 years	Weighted constant level for > 5 years	Total Score
32	10	7	10	2	0	0	9
33	7.54	5.28	10	2	0	0	7.28
34	8.87	6.21	10	2	0	0	8.21
35	8.49	5.94	3	0.6	10	1	7.54
39	7.92	5.54	3	0.6	0	0	6.14

Table A5. Raw Scores for Type III Tanks: Waste Processing Tanks

Tank	Normalized years of service @ closure	Weighted normalized years of service @ closure	Corrosion control for entire service life	Weighted corrosion control for entire service life score	Constant level for > 5 years	Weighted constant level for > 5 years	Total Score
40	9.28	6.50	3	0.6	10	1	8.1
42	10	7.00	3	0.6	10	1	8.6
48	9.76	6.83	3	0.6	10	1	8.43
49	9.52	6.66	3	0.6	10	1	8.26
50	8.57	6.00	3	0.6	0	0	6.6
51	8.8	6.16	3	0.6	10	1	7.76

Table A6. Raw Scores for Type III Tanks: Evaporator Feed Tanks

Tank	Normalized years of service @ closure	Weighted normalized years of service @ closure	Corrosion control for entire service life	Weighted corrosion control for entire service life score	Constant level for > 5 years	Weighted constant level for > 5 years	Total Score
26	8.57	6.00	3	0.6	0	0	6.6
43	10	7.00	3	0.6	0	0	7.6

Table A7. Raw Scores for Type III Tanks: Unconcentrated Supernate

Tank	Normalized years of service @ closure	Weighted normalized years of service @ closure	Corrosion control for entire service life	Weighted corrosion control for entire service life score	Constant level for > 5 years	Weighted constant level for > 5 years	Total Score
30	10	7.00	10	2	0	0	9
38	8.69	6.08	3	0.6	0	0	6.68
47	7.5	5.25	3	0.6	10	1	6.85

Table A8. Raw Scores for Type III Tanks: Evaporator Bottoms Receivers

Tank	Normalized years of service @ closure	Weighted normalized years of service @ closure	Corrosion control for entire service life	Weighted corrosion control for entire service life score	Constant level for > 5 years	Weighted constant level for > 5 years	Total Score
25	7.17	5.02	3	0.6	10	1	6.62
27	7.55	5.29	3	0.6	10	1	6.89
28	7.75	5.43	3	0.6	10	1	7.03
29	10	7	10	2	10	1	10
31	9.62	6.73	10	2	0	0	8.73
36	8.49	5.94	3	0.6	10	1	7.54
37	8.68	6.08	3	0.6	10	1	7.68
41	7.35	5.15	3	0.6	10	1	6.75
44	7.35	5.15	3	0.6	10	1	6.75
45	7.55	5.29	3	0.6	10	1	6.62
46	5.47	3.83	3	0.6	0	0	4.43