



## Department of Energy

Washington, DC 20585

March 4, 2005

The Honorable John T. Conway  
Chairman  
Defense Nuclear Facilities Safety Board  
625 Indiana Avenue, NW, Suite 700  
Washington, DC 20004-2901

Dear Mr. Chairman:

The purpose of this letter is to complete the requests contained in your January 18, 2005, letter. The requested report is enclosed that describes the Tank Farm contractor activities implementing the U.S. Department of Energy, Office of River Protection (ORP), planned approach for the long-term management of double-shell tanks and tank waste retrieval. The report has been reviewed by my staff and the ORP and is acceptable in delineating the planned approach. An ORP implementation plan is being finalized and will be provided by ORP later this month to the Board.

The second requested deliverable was provided by the ORP in a briefing to the Board on February 28, 2005. The briefing provided a status of the implementation of the ORP Waste Chemistry Expert Panel's recommendations. The Expert Panel will continue to be used at ORP to provide ideas and periodic reviews.

If you have any questions, please call me at (202) 586-7709 or Mr. Roy Schepens, Manager, ORP, at (509) 376-6677, or your staff may contact Mr. James Poppiti, Licensing Office, at (301) 903-1733 or Mr. Dana Bryson, ORP Tank Farms Engineering Division, at (509) 372-0947.

Sincerely,

A handwritten signature in black ink, appearing to read "Paul M. Golan".

Paul M. Golan  
Principal Deputy Assistant Secretary for  
Environmental Management

Enclosure:  
Long Term Management of  
Tank Waste at Hanford

cc w/enclosure:  
M. Whitaker, DR-1  
R. J. Schepens, ORP



# **THE LONG-TERM MANAGEMENT OF TANK WASTE AT HANFORD**

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### Abbreviations and Acronyms

ASME	American Society for Mechanical Engineers
BDGRE	Buoyant Displacement Gas Release Event
CAAT	Compatibility Assessment Automated Tool
CH2M HILL	CH2M HILL Hanford Group, Inc.
CPP	Cyclic Potentiodynamic Polarization
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
DST	double-shell tank
EN	Electrochemical Noise
ER	Electrical Resistance
EPA	U.S. Environmental Protection Agency
FY	fiscal year
GRE	Gas Release Event
HIDS	HTWOS Integrated Database System
HLW	high-level waste
HTWOS	Hanford Tank Waste Operations Simulator
IMAP	Integrated Mission Acceleration Plan
JCO	Justification for Continued Operation
LAW	low-activity waste
LFL	lower flammability limit
LPR	Linear Polarization Resistance
NDE	nondestructive
OOS	out-of-specification
ORP	U.S. Department of Energy, Office of River Protection
PFS	process flowsheet
PNNL	Pacific Northwest National Laboratory
PWHT	Post –Weld Heat Treated

RPP	River Protection Project
SCC	stress corrosion cracking
SpG	specific gravity
SRS	Savannah River Site, Aiken, SC
SSR	Slow Strain Rate
SST	single-shell tank
TFC	Tank Farm Contractor
TSIP	Tank Structural Integrity Program
TSR	Technical Safety Requirement
TRU	transuranic
TTT	Tapered Tensile Test
TWINS	Tank Waste Information Network System
UT	ultrasonic test
WTP	Waste Treatment and Immobilization Plant

**Units**

Btu	British thermal units
°C	degrees Celsius
°F	degrees Farenheight
ft	foot/feet
<u>M</u>	molar
Mgal	million gallons
Mpy	mil per year
W	Watts

## **1.0 INTRODUCTION AND BACKGROUND**

Reference: U.S. Department of Energy (DOE) Response to Defense Nuclear Facilities Safety Board (DNFSB) Letter, J. Conway to P. Golan, dated January 18, 2005.

This report is in response to the reference's request for a report within 45 days on DOE's planned approach for the long-term management of waste retrieval and tank space while remaining within Technical Safety Requirements (TSR) limits. It details the Tank Farm Contractor (TFC) activities implementing the U.S. Department of Energy, Office of River Protection's (ORP) planned approach for the long term management of double-shell tanks (DST) and tank waste retrieval.

The report is written by CH2MHILL Hanford Group, Inc. referred to throughout the report as the Tank Farm Contractor (TFC).

### **1.1 PURPOSE**

The purpose of this report is to describe the TFC plan to protect the DST assets, while executing the mission of waste management and disposition. The plan is based on balancing the needs of the two main drivers of the mission:

- The need to ensure that tank integrity is maintained through the life of the mission, by strengthening the technical basis for structural and leak integrity.
- The need to safely retrieve and store waste in a way that supports efficient treatment and disposal while maintaining safety basis controls.

This report fulfills the DNFSB request to provide the planned approach for the long-term management of waste retrieval and tank space, while remaining within the limits of the TSR. In addition, it describes the initiatives taken to strengthen the technical baseline that underpins the tank integrity program.

### **1.2 MISSION REQUIREMENTS**

Since 1990, the tank waste management strategy has been dictated by the needs of a largely static inventory. With the exception of pumping free liquids from single-shell tanks (SST) to DSTs and the acceptance of small volumes of wastes from the cleanup of old facilities, the mission has been focused on safe storage. In addition, the composition of these wastes did not challenge the waste chemistry limits for the DST system. However, the Tank Farms are now in the next phase: SST waste retrieval, staging for treatment, and treatment itself. This phase called for a new dynamic strategy for managing wastes. New tools have been developed to enable this strategy. A new front-end engineering component has been added to provide the TFC with an ability to look forward and assess the risks posed by retrievals and waste mixing

especially in view of limited DST space. This new forward-looking approach is based on sound chemical engineering principles. Process flowsheets have been developed for waste retrievals and new sophisticated tools combined with proven existing systems to predict outcomes from multiple operations. The new approach recognizes the need to remain within existing TSR controls.

This report describes the activities and processes put in place to achieve mission objectives of safe retrieval, storage, and staging of waste within the constraints of available tank space.

## 2.0 TANK INTEGRITY ASSURANCE

Successful execution of the River Protection Project (RPP) requires that tank integrity is maintained through the life of the mission, by implementing a program for structural and leak integrity that is underpinned by a sound technical basis. Several actions are planned to improve the basis for protection of the DSTs, while exploring opportunities to optimize the protection strategy. These actions are discussed in this section.

### 2.1 DOUBLE-SHELL TANK INTEGRITY

To verify and predict the integrity of the DSTs, the TFC has an ongoing Double-Shell Tank Integrity Program (RPP-7574, *Double-Shell Integrity Program Plan*). This program consists of visual and ultrasonic inspections of the DSTs, corrosion monitoring probes installed in tanks of particular interest, well-defined waste chemistry limits, and structural analysis. This program has been developed using the guidance of a series of expert panel reviews.

#### 2.1.1 Inspections

Inspections of the DSTs date back to their original construction. During construction, welds on the tanks were radiographically tested, and visually examined. Further, the tanks were subjected to a hydrostatic test in accordance with the requirements of applicable standards (e.g., the Boiler Pressure Vessel Code of the American Society for Mechanical Engineers [ASME]).

The subject of further inspection was raised as DOE was evaluating an overall approach to ensuring the integrity of tanks used to store high-level nuclear waste (HLW). The results of this review became known as the Tank Structural Integrity Program (TSIP, documented in BNL-52527, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*). Section 5.0 of the guidelines for that program addressed Non-Destructive Examination (NDE) and Appendix A discussed the philosophy behind the NDE methodology outlined in the program.

The approach described in the TSIP emphasized assessment aimed at identifying: pitting, in the vapor, liquid and/or sludge regions; stress corrosion cracking (SCC), particularly important for tanks that (unlike the DSTs) were not stress relieved; and uniform corrosion. The inspection requirements and procedures outlined in the program provided a general discussion of sampling strategy; a detailed table that described examination requirements, methods, acceptance levels, extent, and frequency of examination; regions to be examined; and qualifications and standards for execution of inspections and required sample sizes. Potential alternative examination methods were also mentioned along with evaluation criteria for assessing inspection results.



## Visual Inspections

The TSIP required that “all accessible regions” of the external surface of the primary tank and the internal surface of the secondary tank be visually inspected. In addition, it required that the vapor space at the top of the primary tank be inspected by remote visual methods. It should also be noted that TSIP recommended that a 10% sample of tanks (i.e., 3 DSTs) be so inspected and that a larger sample could be inspected and the coverage reduced proportionally (BNL 52527, pages 5-5 and 5-6).

All 28 DSTs were visually inspected in accordance with commitments made to the Washington State Department of Ecology under the *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement* (Tri-Party Agreement, Ecology et al. 1989). In the early 1990’s, approximately 18% of the exterior wall of the primary tanks and about 30% of the interior of the secondary tanks were examined. Annulus corrosion in tank AY-101 was found in a subsequent follow-up visual examination (RPP-8737, *Evaluation of 241-AY-101 Corrosion Products Risers 78 and 85*), but generally these examinations showed no evidence of significant degradation. The visual inspection program continues with both annulus and interior primary video inspections performed on all DSTs with a five-year periodicity.

## Ultrasonic Inspections

Guidelines and requirements in the TSIP place emphasis on volumetric examination of areas of concern on the tanks. The volumetric examination method most prominently discussed is ultrasonic inspection (UT). In fact, UT is specified for four of the regions to be examined and, while the inspection method for other regions is listed as the more generic “volumetric,” the specified acceptance levels are those from the ASME Boiler and Pressure Vessel Code for UT. Thus, although other volumetric methods are mentioned briefly, the TSIP assumed that UT inspection would play the significant role in tank structural integrity programs. (BNL-52527, pages 5-1 through 5-8).

The inspection program recommended by BNL-52527 involves examination of six areas of the tank. In addition to four required areas of the tanks, two areas are recommended for examination if accessible. The requirements are found in Table 5.1 (BNL-52527, pages 5-5 and 5-6) and are briefly summarized below:

1. Liquid Vapor Interface – examine 5% of the interface length of each tank to be examined with UT; the focus is pits >50% of wall thickness.
2. Liquid-Sludge Interface (if such exists) - examine 5% of the interface length of each tank to be examined with UT, looking for pits, cracks (>50% of wall thickness), and general corrosion (>20% of wall thickness).
3. Lower Knuckle of the Primary Tank (upper weld) – volumetric examination of 5% of the length of each weld to be divided into two or more segments (if accessible); the focus is on cracks.

4. Lower Knuckle of the Secondary Tank – volumetric examination of 5% (divided between the knuckle base metal and lower weld, if accessible); the focus of the inspection being on cracks.
5. External Surface of Primary Tank (below nominal vapor-liquid interface) – UT focused on general wall thinning.
6. Plate making up the bottom of the Primary Tank (if accessible) – a best effort volumetric examination is called for to look for cracking pitting or general corrosion.

The above inspections were to be conducted on a minimum of 10% of the tanks (i.e., 3 of the 28 DSTs). The TFC has scheduled for all 28 of the tanks to be examined by UT. As with the percentage of inspection requirement, the inspection program at the Hanford Site meets or exceeds all TSIP guidelines. The minimum UT inspection requirements are as follows (as summarized in RPP-7574, pages 4-11):

1. Perform a 30 inch (0.76 meter) wide vertical scan of the primary tank wall, for every DST.
2. Perform 20 foot (6 meter) length of circumferential weld joining the primary tank wall to the lower knuckle and the adjacent heat affected zone, for every DST.
3. Perform a 20 foot (6 meter) length of vertical weld joining shell plate courses of the primary tank, extended as necessary to include at least one foot (0.3 meter) of vertical weld in the nominally thinnest wall plate and adjacent heat affected zone.
4. Perform a 20 foot (6 meter) long circumferential scan at a location in the vertical portion of the primary tank wall corresponding to a static liquid/vapor interface that existed for any five-year period, extending at least one foot (0.3 meter) above that liquid/vapor interface for six DSTs.
5. Perform a 20 foot (6 meter) long circumferential scan of the predicted maximum stress region of the primary tank lower knuckle for six DSTs.
6. Examine the primary tank bottoms in each accessible air slot over a length of 10 foot (3 meter) toward the center of the tank from the lower knuckle joint, for six DSTs
7. UT examination of the secondary tank lower knuckle and floor, in accordance with TSIP guidelines, on three Dusts

Following completion of the initial UT of each DST, repeat inspections are to be conducted on an interval not to exceed 10 years. The results of the UT work have not found significant wall thinning or pitting, by TSIP standards, in any of the DSTs. Quantifying the amount of thinning and pitting due to waste storage has been hindered by a lack of baseline data for the condition of

the tanks when waste was originally placed in the tanks. Of the 24 tanks examined to date, the only notable corrosion has occurred at the liquid air interface for five tanks that contained waste not within the waste chemistry limits, and the liquid level was static in those tanks for a number of years. The UT program has not found any indication of SCC. Hanford Site UT work is on schedule to complete the remaining tanks during fiscal year (FY) 2005.

### 2.1.2 Corrosion Probes

The TFC has deployed electrochemical noise (EN) corrosion probes in five DST tanks. Currently, three tanks have corrosion probes, AN-104, AN-105, and AN-107, although only the latter is still providing data. The probes from tanks AZ-101 and AN-102 were early proto-types of the current probes and were removed on failure for examination. From the monitoring to date, no indication of corrosion has been identified.

Between March 15, 2004 and August 15, 2004, EN corrosion monitoring systems installed in the 241-AN tank farm indicated that uniform corrosion is the primary form of corrosion. Typical corrosion rates recorded by these systems were less than 1 mil per year (mpy). Although most of the data analyzed were indicative of uniform corrosion, some sharp electrochemical transients were recorded, particularly on the AN-105 and AN-107 systems. In most cases, however, the shape and size of these EN transients did not correspond with the shape and size of EN transients historically associated with pitting, SCC, or other forms of localized corrosion. These transients may be the result of hydrogen gas release events, tank waste movement, or other in-tank disturbances, but no laboratory work has been performed to confirm this hypothesis.

However, "bullet" coupons and stressed C-rings removed from AN-107 when the EN probe was changed out after 4 years in the DST, were forensically examined and confirmed the low corrosion rates and lack of SCC.

### 2.1.3 Tank Corrosion Chemistry

Waste Chemistry limits for corrosion control in DST are summarized in Table 2-1. These limits reduce the potential for general corrosion, pit corrosion, and SCC.

**Table 2-1. Current Hanford DST Waste Chemistry Limits**

[NO <sub>3</sub> <sup>-</sup> ] Range	Parameter	Waste Temperature Range (°F)		
		T < 167	167 = T = 212	T > 212
[NO <sub>3</sub> <sup>-</sup> ] = 1.0M	[OH <sup>-</sup> ]	0.01M = [OH <sup>-</sup> ] = 8M	0.01M = [OH <sup>-</sup> ] = 5M	0.01M = [OH <sup>-</sup> ] < 4M
	[NO <sub>2</sub> <sup>-</sup> ]	0.011M = [NO <sub>2</sub> <sup>-</sup> ] = 5.5M		
	[NO <sub>3</sub> <sup>-</sup> ]/([NO <sub>2</sub> <sup>-</sup> ] + [OH <sup>-</sup> ])	< 2.5		
1.0M < [NO <sub>3</sub> <sup>-</sup> ] = 3.0M	[OH <sup>-</sup> ]	0.01([NO <sub>3</sub> <sup>-</sup> ] = [OH <sup>-</sup> ] < 10M		0.01([NO <sub>3</sub> <sup>-</sup> ] = [OH <sup>-</sup> ] < 4M
	[OH <sup>-</sup> ] + [NO <sub>2</sub> <sup>-</sup> ]	= 0.4([NO <sub>3</sub> <sup>-</sup> ])		
[NO <sub>3</sub> <sup>-</sup> ] = 3.0M	[OH <sup>-</sup> ]	0.3M = [OH <sup>-</sup> ] < 10M		0.3M = [OH <sup>-</sup> ] < 4M
	[OH <sup>-</sup> ] + [NO <sub>2</sub> <sup>-</sup> ]	= 1.2M		
	[NO <sub>3</sub> <sup>-</sup> ]	= 5.5M		

The majority of DST waste complies with these waste chemistry limits. Waste chemistry is outside of the limits in four of the tanks (AN-102, AN-107, AY-102, and AZ-102), and these tanks have specific TSR recovery plans in place to bring them into compliance. A fifth tank, SY-102, is operating under a Justification for Continued Operation (JCO) and will be returned to specification before the JCO expires in June 2005.

The basis for waste chemistry limits in DSTs comes from data developed by Pacific Northwest National Laboratory (PNNL) and the Savannah River Site (SRS). The majority of the requirements come from work done by Ondrejcin (DP-1478) in the 1970's to prevent SCC. This work examined the waste chemistry requirements for newly generated and concentrated waste at the SRS. In setting these requirements, SRS established a single set of requirements for operational simplicity. As such they established requirements for their worst case, which were not Post -Weld Heat Treated (PWHT) A285 Carbon Steel exposed to temperatures up to 100 °C at pH > 11.

All of the Hanford Site DSTs have been constructed out of higher tensile strength carbon steel than A285 Carbon Steel (A515 [AZ and AY], 516 [SY], and A537 [AN, AP, AW]), and have been PWHT at 1050 °F ± 50 °F. No PWHT tank has shown evidence of SCC at SRS or the Hanford Site in the over 30 years since this method of construction was adopted. In addition, wall thickness was increased for later tanks, which allows the wall to better handle the stresses, lowering their susceptibility to SCC.

Recent work at SRS has shown that during saltcake retrieval processing at temperatures below 50 °C, 0.4 M hydroxide is adequate to protect the non-PWHT A106 Carbon Steel cooling coils in the tanks. This work and other studies provided the driver to re-examine the waste chemistry limits for the Hanford Site DSTs. The goal of this testing is to validate the margin present in current standards, and perhaps be able to tailor the corrosion control program to the new mission requirements. Such a program may provide the technical basis that at lower temperatures, and depending on waste type, significantly smaller amounts of hydroxide could provide an adequate level of protection, without affecting the capability of the DSTs to support the long term mission.

#### **2.1.4 Structural Analysis**

The TFC is conducting modern, finite element structural analyses (some completed and some on-going) of the Hanford Site DSTs in support of the DST Integrity Program. This work will provide a structural evaluation of a representative and bounding DST, including concrete and soil interactions, and will be used as part of the documentation to demonstrate that the DSTs are fit for continued service.

A parametric study has been conducted to evaluate the effects of various waste levels and specific gravities on the primary tank. This information was used to define safe, new liquid levels that would allow for additional waste storage in the DSTs, with the proper controls on specific gravity and temperature. In addition, another parametric study was done to address the potential effects of degraded insulating concrete on the reinforced concrete slab (under the primary tank) and the primary liner of the DST.

The bounding finite element tank model was run to simulate 60 years of thermal cycling and creep. The model accounts for the effects of temperature on the properties of the reinforced concrete, thermal cycles from 50 °F to 350 °F, as well as the traditional dead loads and live loads. Load combinations, with the exception of the seismic, have been evaluated as well. The model results were evaluated to the ACI-349 criteria for the structural concrete and the ASME standards for the primary liner, secondary liner, and j-bolts. The initial review of the results indicates that the tanks will pass the evaluation criteria for nearly all conditions.

Seismic analyses of the DSTs are underway. The seismic analysis methodology is using ‘explicit time history’ for the input loading instead of implicit methods based upon Soil-and-Structure Interaction analyses of the past. Explicit methods are more accurate with less uncertainty.

Several projects have investigated methods for determining remaining minimum wall thickness based on ultrasonic measurements. To estimate the minimum thickness for tank AY-101, modifications were made to an ‘extreme-value estimation’ approach initially proposed by SRS personnel. The modifications included using an alternative ‘extreme-value probability’ distribution that better fit the data. They also provide confidence bounds on the resulting extreme-value estimates.

The DST Integrity Plan UT inspection is being reviewed to consider the suitability of the present method of using a single riser for obtaining the ultrasonic wall thickness and pitting measurements in all tanks, for leak integrity determination (versus structural integrity). The AY-101 UT results were statistically extrapolated to predict the deepest pitting if the UT could cover the entire tank. This methodology was found meaningful in the AY-101 case because considerable data were available and because four different risers were used to obtain the data. Tank AY-101 UT measurement data, compared to other DSTs UT data is being analyzed to determine if the area UT’d from a single riser will provide adequate information to predict the deepest pitting.. Differences within and between risers, and other sources of measurement variability, will be characterized in this manner. This approach should lead to a methodology for establishing the minimum tank surface area to be UT’d to provide the ability to predict worst case pitting, with 95% confidence limits.

## **2.2 ACTIONS TO FURTHER IMPROVE THE DST INTEGRITY PROGRAM**

The RPP has involved three expert panels that have investigated aspects of corrosion of the DSTs. The panel member’s were selected to cover a broad range of technical and operational background. In addition, there has been an overlap of members among the three expert panels, which provided continuity of the information gained.

- The Expert Panel for Hanford Double-Shell Tank Life Extension, 2001, PNNL-13571, reviewed all aspects of tank operation, corrosion control, and monitoring. The scope of the workshop was limited to corrosion of the primary tank liner, and the main areas for review were waste chemistry control, headspace and annulus humidity control, tank inspection, and corrosion monitoring. The panel made recommendations that included each of the above areas.

- The Expert Panel for Hanford Site Double-Shell Tank Waste Level Increase, 2003, RPP-19438, reviewed all factors affecting determination of maximum allowable waste height. The scope of the panel was to perform a comprehensive, expert review and assessment of all pertinent technical and operational information associated with DST structural integrity, inspections, safety, and controls for waste level operations. As such, the panel had limited comments pertaining to the waste chemistry limits, but had extensive comments about testing and monitoring the tanks. Waste level increases are being evaluated and are currently being focused on the AP Tank Farm.
- The Expert Panel for Hanford Site Double-Shell Tank Chemistry Optimization, 2004, RPP-22126, reviewed initiatives on temporary and permanent DST waste chemistry changes and core sampling frequency for TSR recovery plans. Building on the knowledge developed from the previous reviews and their professional experience, the panel laid out specific requirements for maintaining the technical baseline and adopting changes to the baseline.

The Expert Panels made recommendations in the following four areas with respect to maintaining tank integrity:

- Testing by means of UT to verify continued tank integrity,
- Monitoring to provide continuous real-time feed back of tank corrosion condition,
- Undertaking laboratory programs to strengthen technical basis, and
- Establishing operational procedures to allow increasing waste level in DSTs.

All of the panels recommended the following:

- Increased testing and monitoring regardless of waste chemistry limits and
- Improve the basis for the current waste chemistry limits.

As a result of the Life Extension Expert Panel, UT inspections of all the DSTs was planned to establish a baseline. This work will be completed in FY 2005. The current planning is to continue the testing with a frequency of every eight to ten years. Each tank has four access points in the annulus large enough to provide access for the equipment (two 24-inch risers and two 12-inch risers).

The current testing examines a swath of approximately 2.5 ft by 40 ft during the UT inspection, and involves additional scans of welds and the knuckles. This testing is compliant with the recommendation of the TSIP and regulations. However, since large areas of the tank go without examination, expert panel members have recommended that larger areas be examined for leak integrity. In addition, methods have recently been developed to inspect the bottom knuckle and bottom plate.

Monitoring of the tanks involves the installation of corrosion probes. The benefit for in-tank corrosion probe monitoring, in addition to the UT program, is to provide real time assurance of

continued tank integrity. Corrosion coupons were installed in the tanks during construction, but discarded after initial review many years ago. Expert panels have recommended that probes be installed in all of the tanks for real time and periodic coupon examination. The Life Extension Expert Panel recommended EN corrosion probes be installed. The Chemistry Optimization Expert Panel recommended new multi-function, multi-level probes be scoped that include stressed C-rings, EN, Linear Polarization Resistance (LPR), and Electrical Resistance (ER).

The DST Waste Level Increase Panel focused on the propriety of safely increasing tank design fill height from 422 to 460 inches. As a result of the panel's review, a list consisting of pre-operational and operational conditions was established to allow the increased fill height in certain tank farms.

The Chemistry Optimization Panel made recommendations for testing and analysis to underpin any potential changes to chemistry limits. These recommendations were made against three initiatives. The recommendations against the first two initiatives have been completed or the RPP has decided not to pursue them. As a result of the Expert Panel recommendation for Initiative II, the core sampling for TSR recovery plans is based on a dynamic mixing model instead of previously specified arbitrary dates. The recommendations being pursued at this time are the Initiative III recommendations and the general recommendations from the panel. The following tables summarize these recommendations and give implementation status:

**Table 2-2. Implementation of Expert Panel Recommendations for Initiative III (4 pages)**

Initiative 3 Recommendation	Category	Implementation
"Finite-element stress analysis of the lower knuckle region. The analysis would take into account the maximum likely residual stresses based on the available PWHT data and the service stresses and compare the result with the revised $S_y$ threshold."	Analysis	Being accomplished for tank AN-107, to be completed at PNNL, by the end of May 2005. General DST bounding analysis (conservative for all DSTs) will follow by end of FY 2005.
"The costs of the retention of different levels of hydroxide between 0.1 <u>M</u> and 0.001 <u>M</u> be analyzed and compared with the benefits of potentially greater corrosion resistance."	Analysis	Completed. Very large cost savings potential, if lower hydroxide concentration is justified, when both tank farm and vitrification plant operations are considered.
"Successful completion of the complete supernate simulant-testing program (and any follow-on testing identified during the currently defined testing program). A prerequisite for implementing the initiative is that no SCC is found in the tests under the anticipated service conditions."	Testing	Accepted. Testing for the required chemistry standards to avoid SCC, is being phased on a waste-type-by-waste-type basis, and may even require a tank-by-tank basis to appropriately define controls.

**Table 2-2. Implementation of Expert Panel Recommendations for Initiative III (4 pages)**

Initiative 3 Recommendation	Category	Implementation
<p>“Prepare a cold sample of the expected chemical composition after the OOS [out-of-specification] addition and immerse matched to those in the tank, stressed C-ring coupons as soon as possible before the chemical composition modification. Remove and examine the specimens on a monthly basis prior to chemical composition modification. A prerequisite for implementing the initiative is that no excessive corrosion or SCC is found in the C-rings removed prior to the chemical composition modification.”</p>	Testing	<p>Not considered appropriate or cost effective for the benefit. Waste simulant behavior already will have been exhaustively tested by Cyclic Potentiodynamic Polarization (CPP) measurements, Slow Strain Rate (SSR) testing and Tapered Tensile Test (TTT) studies for SCC, over a wide variation in chemistry.</p> <p>Actual DST waste will have real-time monitoring plus frequent initial coupon and stressed C-ring examination.</p> <p>The Expert Panel is reviewing this response, considering the installed multi-probes.</p>
<p>“Withdraw a grab sample of the tank contents shortly after the tank contents are expected to be mixed and compare the results to the range of chemical compositions evaluated in Task 2 of the SCC testing program and adjust the tank contents, as necessary.”</p>	Testing	<p>Accepted. This protocol for testing will be used to confirm tank contents before new Documented Safety Analysis (DSA, RPP-13033) limits are invoked.</p>
<p>“Perform a slow strain rate test using the simulated anticipated OOS chemical composition before chemical composition modification in the tank. A prerequisite for implementing the initiative is that no SCC is found in these SSR tests.”</p>	Testing	<p>Accepted. This will be accomplished by the use of a statistically designed SSR chemistry test matrix, for each of the seven waste types, which will explore the limits of critical waste compounds (e.g., hydroxide, nitrite, organics, etc.).</p>
<p>“For the first three months after chemical composition has been taken OOS, remove and examine coupons from the cold stimulant on a monthly basis. Thereafter, at twice the previous interval up to a maximum time between samples of two years. The chemical composition of the tanks should be returned to the specifications if excessive corrosion or SCC is found in the C-ring specimens.”</p>	Testing	<p>Not considered appropriate or cost effective for the benefit. Waste simulant behavior already will have been exhaustively tested by CPP measurements, SSR testing, and TTT studies for SCC, waste type by waste type.</p> <p>Actual DST waste will have real-time, multi-probe monitoring plus frequent initial coupon and stressed C-ring examination per the Expert Panel protocol, for each waste type.</p> <p>The Expert Panel is reviewing this response to their recommendation.</p>



**Table 2-2. Implementation of Expert Panel Recommendations for Initiative III (4 pages)**

Initiative 3 Recommendation	Category	Implementation
<p>“Management support for, and phased incorporation of, the complete Panel defined monitoring program into the DST integrity program with the goal of complete implementation in DSTs subject to the proposed corrosion chemistry modifications within five years.”</p>	Monitoring	<p>Conditionally Accepted. Multi-functional corrosion probes with ER, EN, and LPR sensors, stressed C-rings, and corrosion coupons will be installed at vapor, liquid, and solids levels for DSTs under potential new standards. The prototype probe for tank AN-107 is in the procurement phase.</p> <p>Implementation schedule is 11 DSTs by 2010 and the remainder by 2014.</p>
<p>“As a minimum, each tank targeted for permanent chemical composition modifications should be monitored for corrosion and SCC with stressed C-rings and any proven monitoring techniques available at the time the tank is permitted outside the current limits and into the new chemistry.”</p>	Monitoring	<p>Accepted. Multi-functional corrosion probes with ER, EN and LPR sensors, stressed C-rings and corrosion coupons will be installed at vapor, liquid, and solids levels for DSTs under potential new standards. The prototype probe for tank AN-107 is in the procurement phase</p>
<p>“Installation of numerous stressed C-ring coupons in the supernatant as early as possible after a tank is identified as a candidate to be taken OOS and as long before the chemical composition modification as possible.”</p>	Monitoring	<p>DST AN-107 has had EN probe for several years. Case-by-case decision on other DSTs, based on degree of SCC margin from laboratory testing results. As a minimum, the new multi-function probe will be installed prior to chemistry changes.</p>
<p>“Remove and examine coupons from the tank just before chemical composition modification to ensure that the tank is performing as expected. A prerequisite for implementing the initiative is that no excessive corrosion or SCC is found in the C-rings removed prior to the chemical composition modification.”</p>	Monitoring	<p>Not considered effective or practical. DSTs will have had UT and visual inspections. Coupons and stressed C-rings would need to be in place for extensive time frames to show any effect of the present in-specification chemistry. As a minimum, the new multi-function probe will be installed prior to chemistry changes.</p>
<p>After three months of immersion in the OOS supernate, remove and examine coupons and sample thereafter at twice the previous interval up to a maximum frequency of two years, unless results indicate otherwise. The chemical composition of the tanks should be returned to the specifications if any cracking is found in the C-ring specimens.”</p>	Monitoring	<p>Conditionally Accepted. Comparison of real-time monitoring results relative to condition of stressed C-rings and corrosion coupons will allow adjustment of sampling frequency. The recommended frequency protocol will be followed for each new waste type under potentially new chemistry requirements. Forensic sampling will not start until a DST is out-of-specification with reference to the present requirements.</p> <p>The Expert Panel is reviewing this response.</p>

**Table 2-2. Implementation of Expert Panel Recommendations for Initiative III (4 pages)**

<b>Initiative 3 Recommendation</b>	<b>Category</b>	<b>Implementation</b>
“Tanks with less-than-complete monitoring, as recommended by this Panel, should, if appropriate, be upgraded to the most currently available systems as soon as feasible. The chemical composition of the tanks should be returned to the specifications if excessive corrosion or SCC is indicated by these monitoring techniques.”	Monitoring	All instrumented DSTs will have the full multi-element probe design derived from the AN-107 prototype. Any subsequent upgrades will occur at the expected six-year replacement cycle.  Procedures for response to probe results are being developed and will be issued prior to any potential DSA changes.
Demonstrate the integrity of the tank prior to taking the tank OOS and increase the frequency of UT inspection of both the tank and the annulus after taking the tank out of specification. The chemistry of the tanks should be returned to the specifications if any evidence of excessive corrosion or cracking is found in the inspections.”	Inspecting	Present UT inspections look at about 1% of the tank surface, which is considered adequate for structural integrity determination. Analysis is underway, using extreme value statistics, and expected to be completed by the end of March 2005. It is expected that this work will define the minimum area to UT, to ensure DST leak integrity.  Depending on results, additional follow-on tasks may be required. UT frequency not yet resolved.

**Table 2-3. Expert Panel’s General Recommendations (2 pages)**

<b>Expert Panel General Recommendations</b>	<b>Category</b>	<b>Implementation</b>
“Perform the recommended, two task, supernatant simulant testing to establish the chemistry control limits for the DSTs to: -Determine the potential range for cracking. -Determine the effect of pH on SCC susceptibility. -Establish chemistry limits to prevent SCC. -Evaluate effect of chemistry on long-term corrosion potential by confirming SSR results. -Define threshold stress for SCC initiation in potent cracking chemistries.	Testing	CPP measurements, and SSR testing for SCC were initiated in October 2004, to establish test protocols. The expanded test program for DST AN-107 includes SSR tests, CPP measurements, plus TTT determinations. All AN-107 waste testing (and probe) is funded in FY 2005.  Testing will be on a waste-type-by-waste-type basis (i.e., only AN-107 waste limits and SCC threshold will be validated from present testing). Testing for all DSTs is expected to take five years.

**Table 2-3. Expert Panel's General Recommendations (2 pages)**

<b>Expert Panel General Recommendations</b>	<b>Category</b>	<b>Implementation</b>
<p>The Panel strongly recommends that corrosion monitoring be instituted in conjunction with these initiatives.”</p> <p>Linear Polarization Resistance (LPR) Electrical Resistance (ER) Electrochemical Noise (EN) Weight loss coupons Stressed notched coupons (C-rings).”</p>	Monitoring	Accepted. Multi-functional corrosion probes with ER, EN, and LPR sensors, stressed C-rings, and corrosion coupons will be installed at vapor, liquid, and solids levels for DSTs under new standards. The probe prototype for AN-107 is in the procurement phase.
<p>“In addition to the recommendation for a more in-depth statistical analysis of the UT data to support predictive general corrosion and pitting rates and impacts, the Panel recommends that the adequacy of the leak integrity program, as a function of area covered by the inspection program, be addressed in more detail. Further, the Panel noted that the statistical analysis discussions did not address the confidence level associated with SCC inspection and recommends that this issue be investigated and evaluated.”</p>	Inspecting	<p>Analysis is underway, using extreme value statistics, and expected to be completed by the end of March 2005.</p> <p>UT frequency issue is not yet resolved. Statistical analysis and IQRPE assessment will allow decision. Preliminary work indicates a 5 – 7 year UT cycle vs. 8 – 10 now.</p> <p>DSTs with installed multi-probes may warrant a longer UT inspection frequency, when confidence is established in multi-probe and corrosion coupon monitoring. This may also resolve the SCC inspection confidence issue.</p>
<p>The DST panel unanimously recommends that work on the combined chemical consumption and chemical mixing model be continued to provide a robust model that can be applied to determine inhibitor concentrations in the critical regions of the sludge.”</p>	Analysis	Accepted. Work funded for FY 2005 to enhance the combined chemical consumption and waste mixing model.

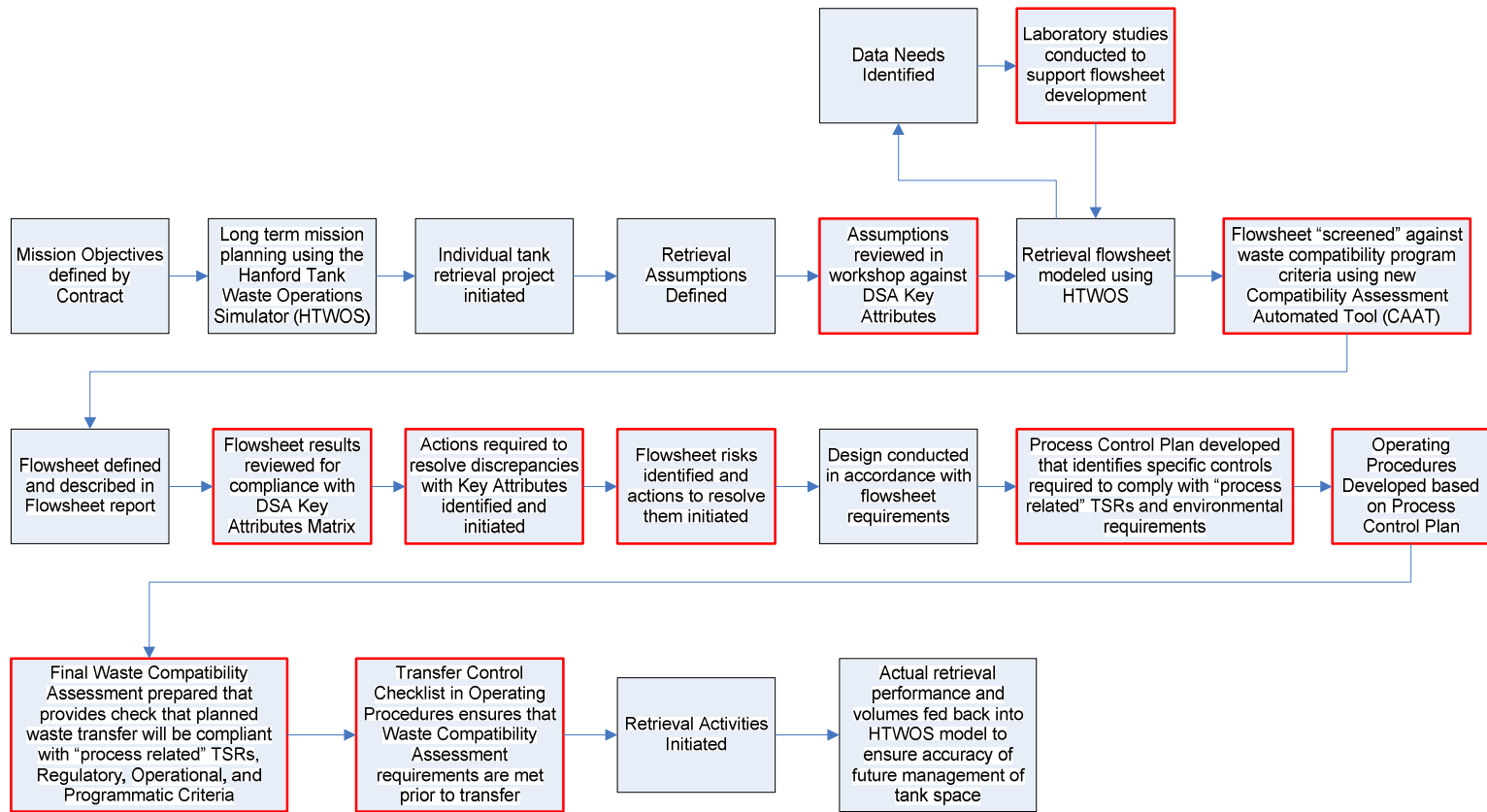
### 3.0 TECHNICAL BASIS ASSURANCE

The approach taken to tank space management and retrieval engineering and planning follows a systematic process. The key elements of this strategy are summarized below and illustrated in Figure 3-1:

- Mission objectives are defined by TFC contract which incorporates commitments to regulators as defined by *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement).
- Tank retrieval and treatment planning is developed through an integrated model, Hanford Tank Waste Operations Simulator (HTWOS), that incorporates ORP objectives associated with tank retrieval, tank space management, supplemental treatment, and waste feed delivery to the Waste Treatment and Immobilization Plant (WTP).
- As individual retrieval projects are initiated, it is necessary to manage the design and operation of those projects in such a manner that they meet project schedule objectives, while remaining consistent with overall mission objectives, and compliant with technical safety requirements. In order to meet these requirements, greater emphasis on front-end engineering is required than has been necessary during static storage. The key elements of this approach are:
  - Develop process flowsheet early in project life.
  - Review process flowsheet against safety basis key attributes and waste compatibility program criteria (that include “process related” technical safety requirements).
  - Identify risks and issues with flowsheet and initiate actions to resolve them.
  - Undertake detailed design and operational planning consistent with flowsheet requirements.
  - Develop process control plans based on process flowsheet that define the specific controls to ensure compliance with “process related” technical safety requirements.
  - Incorporate process control plan requirements into operating procedures.
  - Conduct final waste compatibility assessment and ensure that requirements are met before initiating retrieval or transfer.
- Conduct retrieval activities consistent with plans.
- Review and revise flowsheet if retrieval assumptions/activities change.
- Incorporate actual retrieval performance in HTWOS and review lessons learned for future planning.

Further details of these steps are provided in the following sections.

**Figure 3-1. Front-End Engineering of Tank Space Management and Tank Retrieval Planning**



Steps in process providing controls that ensure compliance with Technical Safety Requirements

### 3.1 MISSION PLANNING AND MODELING

#### 3.1.1 Mission Objectives

Objectives for the Tank Farm Contractor (TFC) in support of the mission are:

- Safely store Hanford Site tank waste and maintain the infrastructure to accomplish the RPP mission.
- Retrieve wastes remaining in SSTs (beginning with mobile wastes in tanks S-102 and S-112) to DSTs for staging to the WTP or directly to transuranic (TRU) waste packaging or supplemental treatment.
- Manage DST space so that retrieval and closure of SSTs can complete within mission objectives.
- Protect DST through chemistry control limits.
- Assess DST condition through Non-destructive Testing Program.

#### 3.1.2 Optimization Studies

With new technologies emerging as candidates for final waste immobilization, the TFC is exploring new ideas for optimum waste management. The potential for some fractions of the waste to be immobilized or treated by technologies other than the WTP has caused the TFC to review its waste management strategy. If technology development is successful, it is probable that considerable fractions of low-curie waste could be immobilized with little or no impact to the DST space. In addition, the TFC is conducting optimization studies to evaluate tank farm processing scenarios that may enhance the performance of the WTP and support early completion of the RPP mission. The scope of each study includes preparing process flowsheets, preliminary cost estimates, and HTWOS modeling to evaluate total RPP system impacts. A brief description of each optimization study follows:

- **Sludge Washing / Leaching in the Tank Farms:** Tank waste sludges contain components such as aluminum, chromium, phosphate, sodium, and sulfate that if not removed would increase the volume of HLW glass produced during vitrification. These components are removed from the HLW sludges by water washing and leaching with sodium hydroxide solution.
- **Sr/TRU Separation in Double-Shell Tank System:** The supernatant stored in tanks AN-102 and AN-107 contain soluble strontium-90 and TRU that if incorporated into the low-activity waste (LAW) glass would exceed the WTP contract limits for these radionuclides. This study evaluates conducting a Sr/TRU precipitation process in the DST system to avoid HLW processing interruption in the WTP.

- **Processing Leachate from HLW Pretreatment in Supplemental Treatment:** This study evaluates processing in the Supplemental LAW Treatment system the caustic leachate, oxidative leachate, and post leachate wash solutions derived from HLW sludge pretreatment.
- **Determine Equipment for Storing Wastes Temporarily in SSTs or Grout Vaults:** The DST system has a finite capacity to store wastes and is quickly being filled with wastes retrieved from the SSTs. This study evaluates temporarily storing waste in the SSTs or the existing four grout vaults.
- **Blending AZ-101 Sludge:** The WTP contractor has identified the need to blend the HLW sludge in tank AZ-101 with other compatible HLW sludges to reduce the flammable gas generation potential for this sludge when processing in the WTP. This study evaluates blending the tank AZ-101 sludge with sludges that are being retrieved from C-Farm.
- **HLW Sludge Blending:** The HLW sludges contain many different components (e.g., aluminum iron, nickel, chromium, zirconium, phosphate, and sulfate) that can limit their incorporation into borosilicate glass. This study evaluates blending HLW sludges together in the tank farm system to produce sludge blends that result in a reduction in the production of HLW glass.

As part of each of these studies, the TFC will evaluate the impact of the planned activities on the tank integrity and its waste components. All of the elements of the waste compatibility program will be taken into account during the study.

### 3.1.3 Long Range Mission Modeling using HTWOS

DST Space at the Hanford Site has been a key issue for the last 20 years. There are twenty-eight DSTs of which twenty-five are in the 200 East Area and three are in 200 West Area. Figure 3-2 shows a recent status of DST contents along with the projected inventory at the end of 2006. The importance of tank space is immediately clear from the figure.

A dynamic computerized flowsheet model, HTWOS, is used to manage tank space. HTWOS is used to predict and evaluate the movements of tank waste mass and activity over the full life of the RPP mission. It is used to determine DST space in support of near-term planned activities, to plan operations necessary to manage transfers, and also provides life-cycle analysis of the mission. Current estimates indicate that approximately 6.7 Mgal of DST storage capacity is needed for the waste retrieved from SSTs designated in the Retrieval Pool through FY 2006 (RPP-21216, *Single-Shell Tank Retrieval Selection and Sequence*). The DST space-saving efforts required to accomplish the planned SST retrievals are identified in the Hanford Site's regulatory commitment as Tri-Party Agreement milestone M-46-21.

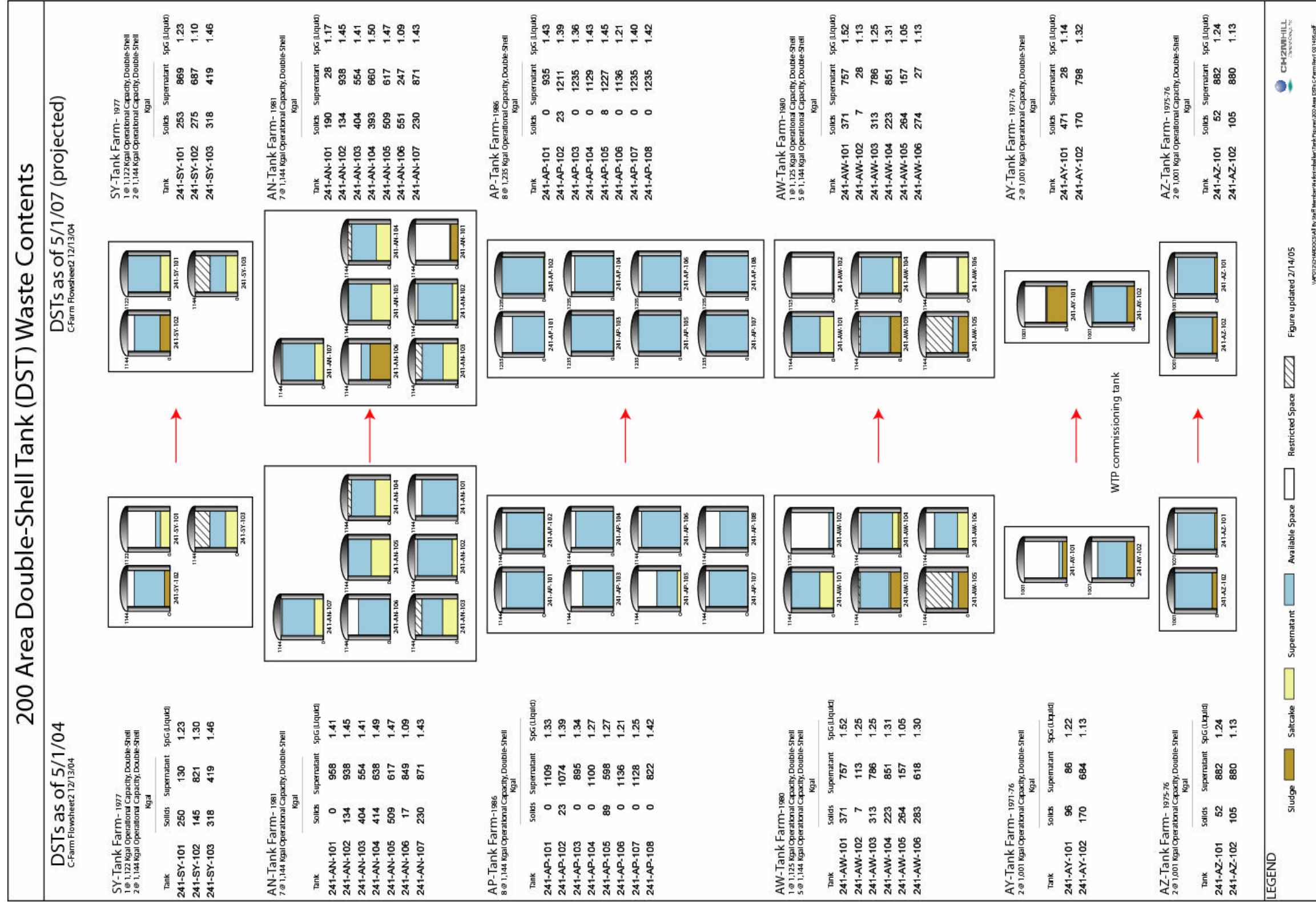
In 2001, the RPP-7702, *Tank Space Options Report* presented options that were reviewed for the purpose of alleviating a DST waste storage capacity shortfall. Eight options were identified that had the potential for increasing DST waste storage capacity an additional 5 to 10 Mgal. The study reflected a qualitative analysis conducted to identify promising options. The study pointed out that implementing the options would require more study to establish feasibility, enhance cost estimates, and understand the operational impacts. The options identified in RPP-7702, *Tank Space Options Report* were revisited in the RPP-13678, *Integrated Mission Acceleration Plan (IMAP)*. During the two years between preparation of the *Tank Space Options Report* and the IMAP, several significant changes have occurred: SST retrieval plans had accelerated, the WTP schedule and capacity were modified, and supplemental treatment of SST waste was being considered. It was clear that DST space limitations represented a significant risk to accelerating the RPP mission, and several DST space-savings options were targeted for action to support SST waste retrieval and closure. The recommended space-saving options were:

1. Increase DST fill height,
2. Maintain reserve emergency space compliant with DOE Order 435.1,
3. Concentrate supernatant waste to 1.41 specific gravity (SpG),
4. Bypass DSTs for retrieval of selected SST waste to supplemental processing,
5. Concentrate supernatant waste to maximum SpG,
6. Use restricted DST space, and
7. Retrieve and package DST TRU waste.

Options 2, 3, 5, and 6 have been implemented. Option 1 is planned for the AP tank farm and a demonstration of option 4 is planned as part of the Demonstration Bulk Vitrification Project. Option 7 is under consideration as a post-2010 activity



Figure 3-2. 200 Area Double-Shell Tank Waste Contents



WTP commissioning tank

**LEGEND**

- Sludge
- Saltcake
- Supernatant
- Available Space
- Restricted Space

Figure updated 2/14/05

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### 3.2 PROCESS FLOWSHEET DEVELOPMENT

The process flowsheet (PFS) is the key document in the new front-end engineering approach. It is a schematic block diagram representation of the process together with a tabular presentation of the material balance for the process. It shows the arrangement of equipment or stages in a process, the stream connections, stream flow-rates (or batch sizes) and compositions and provides the data necessary for the process engineer to evaluate the process performance against project goals and to compare stream and waste tank compositions to specified limits and controls. The flowsheet forms the basis for the development of the process flow diagram and process control plan and lays the foundation for subsequent engineering deliverables and activities. The requirements for the process flowsheet have been defined in a newly developed procedure, TFC-ENG-CHEM-C-01, *Process Flowsheets*, which requires the development of process flowsheets for all tank retrieval projects and for other complex processes such as supplemental treatment.

Once prepared, the flowsheet is documented in a process flowsheet report that provides the material balance and block diagram; defines the basis for the flowsheet including the initial conditions, governing requirements, scope, and assumptions; provides a description of the process; and discusses the results of the flowsheet including any necessary control parameters, results of waste compatibility screening, and any risks to the flowsheet that require resolution. A recent flowsheet report for C-Farm retrieval resulted in the early prediction of issues to the receiving tanks in AN-Farm. Early identification of these risks has instigated mitigating actions such as additional sampling and laboratory work to be done to reduce risk to retrieval.

To ensure that risks are fully understood, the scope of the PFS is defined such that it encompasses all affected downstream areas. For example, in defining the PFS for retrieval of waste from SSTs in 200 West Area, it was important that the flowsheet included all downstream systems. By doing this, it was possible to predict the impact to, not only, tank SY-102 in 200 West, but also the cross-site transfer of solids, impacts on tank space and waste compatibility in 200 East Area DSTs; any planned evaporation of the retrieved waste in the 242-A Evaporator; and any applicable impacts on waste feed delivery to the WTP.

The previously described HTWOS model is used to develop the PFS. In this way, tank space management is fully integrated with process requirements for the waste. The block diagram that represents the full material balance is created by a new tool called the HTWOS Integrated Database System (HIDS). Using specified technical and programmatic assumptions, the HTWOS model calculates the flow of events occurring during the retrieval, storage, pretreatment, vitrification, and supplemental treatments of Hanford Site tank waste. Retrieval system and new facility capacities, project requirements and schedules, and treatment contractor integration can all be linked and evaluated in the model. The model is used to predict the impact of waste transfers on available tank space, waste compositions throughout the modeled flowsheet, and the impact of waste mixing activities on the predicted volumes of LAW and HLW glass. Use of HTWOS enables the impact of a proposed process on the full RPP mission to be assessed and enables rapid screening of the flowsheet results against waste compatibility criteria and limits through the use of new software designed to directly interface with HTWOS.

### 3.2.1 Sampling, Analysis, and Testing

Tank sampling and analysis have been important in providing a sound technical basis for the resolution of tank safety issues, providing assurance of waste compatibility during supernatant waste transfers, and ensuring compliance with corrosion chemistry limits during static storage. However, for the new dynamic mission, in which solids dissolution and transfer are key processes, it becomes even more important to ensure that adequate data are available to support the development of process flowsheets and that waste behavior and interaction are sufficiently understood to enable robust controls to be developed for retrieval operations. As a result of these changing mission requirements, new procedures and standards have been developed that emphasize the importance of ensuring the adequacy of available data and provide requirements for data needs, sampling, analysis, and testing.

A new procedure that establishes the process for determining data needs and sampling requirements has been produced, TFC-ENG-CHEM-P-46, *Process Monitoring Requirements*. It covers the following TFC activities:

- Retrieval and closure (modified sluicing, sludge retrieval, saltcake dissolution, mobile retrieval system/vacuum);
- Evaporator campaigns;
- Tank farm waste transfers (compatibility);
- Corrosion mitigation (chemistry control);
- Bulk vitrification; and
- TRU packaging.

This procedure specifies the data needs before, during, and after conducting the activities shown above or other tank farm activity requiring tank data.

Another new standard that has been developed is TFC-ENG-STD-26, *Dilution and Flushing Requirements*, which specifies requirements and emphasizes the data needed to avoid problems with precipitation, solids deposition, and gelling during transfer of concentrated supernatant or slurry wastes, such as will be encountered during retrieval operations.

Examples of recent laboratory testing undertaken to support flowsheet development are the S-112 saltcake dissolution study (RPP-10984), the S-102 phosphate precipitation/gelling study (letter 7S110-DLH-04-025), and the planned C-Farm phosphate solubility study (letter 7S110-DLH-05-001).

### 3.3 FLOWSHEET REVIEW AND SCREENING

Creation of the process flowsheet provides the ability to review and screen the key waste properties and compositions within the proposed retrieval process against known safety basis assumptions and limits. New tools have been developed and proceduralized as part of the implementation of the strengthened front-end engineering process to facilitate this screening. These tools are discussed below.

#### 3.3.1 Documented Safety Analysis Key Attributes

During readiness review for C-200 retrieval, it was acknowledged that the potential solids content of vacuum retrieval may be outside the assumptions used in the DSA. As a result of this discovery, key assumptions used in the DSA were gathered in a published document, RPP-23624, *Tank Farms Documented Safety Analysis (DSA) Key Attributes Matrix*. Processes were proceduralized in TFC-ENG-SB-C-01, *Safety Basis Issuance and Maintenance*, to ensure that this matrix is maintained current as the safety basis is updated and amended. Review of the flowsheet assumptions and results against this matrix is a new requirement incorporated in the process flowsheet procedure allowing early identification and communication of conflict or inconsistency between the safety basis and planned activities.

#### 3.3.2 Waste Compatibility Screening Tools

The *Tank Farms Waste Transfer Compatibility Program*, HNF-SD-WM-OCD-015, is one of the safety management programs required by the *Tank Farms Documented Safety Analysis* (RPP-13033). The *Waste Transfer Compatibility Program* requires assessments of all planned transfers of waste and chemicals into the DST System and more recently of planned waste recycle to SSTs. These assessments evaluate the composition and properties of the source waste to be transferred and the receiver tank(s) for each planned transfer against established limits from technical safety requirements, safety management programs, environmental requirements, programmatic requirements, and good engineering practices established to prevent operational problems. The specific criteria evaluated and the limits are documented in HNF-SD-WM-OCD-015. In the past, these assessments have been performed independently for each transfer, as a pre-requisite for the transfer, and scheduled relatively shortly before the actual time of transfer. While this approach ensures that transfers are not performed that would violate technical safety requirements or cause operational difficulties, it has not typically been performed sufficiently in advance of the scheduled transfer to enable any encountered difficulties to be resolved without causing last minute rework.

With the increased number of transfers required to meet the goals of SST retrieval and closure, it was recognized that the historic approach of performing waste compatibility assessments individually for each transfer, close to the scheduled transfer date was time consuming and constraining and did not provide an efficient mechanism for evaluating the large numbers of planned transfers sufficiently in advance of the anticipated transfer date to allow time to address identified problems. In order to address these concerns, a new CAAT was developed during 2004 within the Tank Waste Information Network System (TWINS) that can be used for both the preparation of single waste compatibility assessments but more importantly for the “screening”

of multiple planned transfers in a retrieval flowsheet. CAAT was utilized for the evaluation and screening of the C-Farm flowsheet.

CAAT incorporates several major enhancements to the historic approach of preparing waste compatibility assessments. These enhancements largely involve the integration of existing calculation methodologies and data sources into a single, flexible web-based tool that is able to rapidly perform calculations and present the results in a manner that enables the reviewer to quickly and easily see potential problem areas. CAAT is able to directly access and utilize input data from a range of existing sources including the Best-Basis Inventory and from HTWOS via the newly created HIDS. The ability to directly access flowsheet data from HTWOS enables the tool to perform early screening of the flowsheet results to look for potential difficulties.

The *Waste Transfer Compatibility Program* includes a total of 21 primary criteria that are evaluated for each individual transfer and are addressed in the waste compatibility assessment that is prepared close to the time of actual transfer. Although these criteria are all important, it was recognized that only a few of the criteria are likely to be challenged during tank transfers and, in particular, during tank retrievals. These criteria have been selected as “screening” criteria and include:

- DST Waste Chemistry,
- Flammable Gas Waste Group,
- Time to lower flammability limit (LFL),
- Tank Bump,
- Waste Feed Delivery Feed Control List, and
- High Phosphate Waste.

Although CAAT assesses all 21 waste compatibility criteria for all transfers evaluated, it was recognized that a simpler presentation of the results than that normally provided in a waste compatibility assessment was required for screening large numbers of transfers, such as generated from an HTWOS flowsheet. CAAT, therefore, includes a “screening report” that includes a simple list of all transfers included in a flowsheet. Each transfer is contained on a single line, together with key information about the volumes of waste transferred, information about the predicted receiver tank final waste composition, and a “Yes/No,” color-coded, “Red/Green” determination as to whether the transfer meets each of the six screening criteria. This format enables a user to quickly scan an entire flowsheet looking for criteria that are “red-flagged” as being a potential problem. Examination of the detailed calculation results generated by CAAT for that transfer enables further investigation of identified problems.

The newly developed flowsheet procedure, TFC-ENG-CHEM-C-01, *Process Flowsheets*, includes the requirement to “screen” all flowsheets that involve transfer into the DST system against the waste compatibility screening criteria at an early stage. This new screening capability enables initial flowsheets to be developed in HTWOS, screened using CAAT, problems to be identified (such as high phosphate concentration in a waste being transferred or a receiver tank that would be outside of the chemistry control limits), the flowsheet to be modified to resolve the problems where possible, and re-screened quickly to determine whether the changes have resolved the identified issues. In instances where the flowsheet cannot be readily

modified to resolve conflicts with limits, this early screening also provides the ability to identify when a safety basis amendment may need to be pursued.

Prior to initial operations, a formal waste compatibility assessment will still be prepared as a pre-requisite to each transfer that will ensure that the planned transfer has remained compliant with the Waste Transfer Compatibility Program limits. Any specific requirements necessary to ensure that the transfer remains compliant are specified in this waste compatibility assessment.

### **3.4 IDENTIFYING THE TECHNICAL CONSTRAINTS AND RISKS**

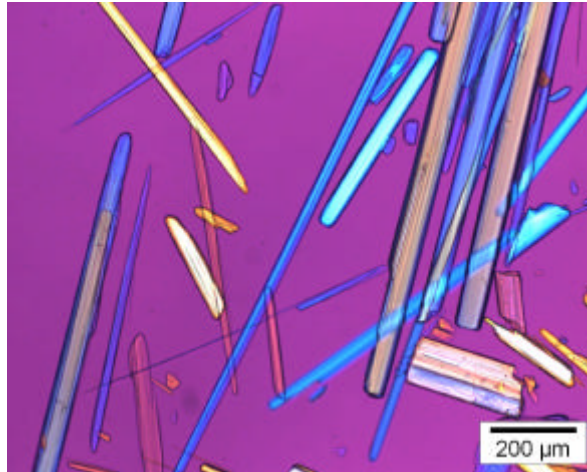
Review of the process flowsheet using the techniques and tools discussed above enables key technical and programmatic risks with a proposed process to be identified and actions taken to mitigate those risks. The key technical risks identified in the planned retrievals are briefly described in this section. The list is not intended to be exhaustive. The topics are selected because they have a significant influence on the long-term strategy. With each issue, the TFC is reviewing the technical basis to ensure consistency with the mission.

#### **3.4.1 Phosphates**

Wastes containing phosphates pose a high risk of solids precipitation and/or gelling during transfer, after evaporation and cooling, or during mixing with the waste in the receiver tank. Historically, lines have become plugged and have had to be abandoned due to phosphate plugs, and significant difficulties have been encountered during evaporation of phosphate wastes due to gel formation. Because of these known issues, controls for the transfer of phosphate wastes have been in place in HNF-SD-WM-OCD-015, *Tank Farms Waste Transfer Compatibility Program*, since its earliest revision dating back to 1991. Most recently, concerns have been identified with the formation of gels in the tank system that are able to retain flammable gas and then release that gas rapidly due to collapse of the gel associated with shear-thinning, thixotropic behavior. It has been postulated that this behavior could result in a Gas Release Event (GRE) not covered by the DSA, which addresses Buoyant Displacement – Gas Release Events (BDGREs). These concerns have led to the introduction of a new TSR administrative control, which requires the evaluation and control of waste transfers and chemical additions to maintain waste conditions that prevent the precipitation of a gel (e.g., tri-sodium phosphate dodecahydrate). Specific controls required to maintain waste conditions that prevent the precipitation of a gel at all times are required to be documented in the waste compatibility assessment for the waste transfer or chemical addition. The method of evaluation of wastes to avoid gel formation is specified in HNF-SD-WM-OCD-015. This new TSR control is not solely focused on phosphate and as discussed in RPP-23600, *Phosphate Solubility Technical Basis*, numerous other compounds have been identified as having the potential to lead to the formation of gels. However, most of these other compounds are either associated with practices no longer used in the tank farms (e.g., partial neutralization) or have not led to the formation of gels in the tank system. Therefore, prevention of gel formation within the tank waste system is focused on prevention of the formation of gels of tri-sodium phosphate dodecahydrate (sodium phosphate). Sodium phosphate tends to form needle-shaped crystals (see Figure 3-3) that result in very high slurry

viscosity, causing what is commonly referred to as a gel, though the slurry is not a gel in the true chemical sense of the word.

**Figure 3-3. Sodium Phosphate Crystals from Tank S-102**  
(Colors Due to Use of Polarized Light with Red I Compensator).



As discussed above, high-phosphate waste is one of the initial screening criteria that are looked for in reviewing a proposed flowsheet. Wastes with a phosphate concentration greater than 0.1 M are flagged as requiring further evaluation to ensure that the waste remains below the sodium phosphate solubility limit at all times during and following a planned transfer. Wastes that initially exceed the phosphate solubility limit may require dilution to ensure they are kept below the solubility limit. The new standard, TFC-ENG-STD-26, *Dilution and Flushing Requirements*, developed during 2004, provides guidance on dilution and flushing to avoid precipitation or deposition of solids, particularly sodium phosphate.

### 3.4.2 Buoyant Displacement Gas Release Events

Tanks that contain significant quantities of solids and liquids can be a problem because trapped (or retained) gas in the solid layer can accumulate to an extent that it can cause large portions of waste to “roll-over” releasing high instantaneous concentrations of flammable gases. This phenomenon has been observed only in tanks that contain high levels of solids and liquids.

This phenomenon is caused by the generation of gases in the waste:

- Hydrogen, through the radiolysis of water, thermolytic decomposition of organic compounds, and corrosion of a tank's carbon steel walls;
- Ammonia and methane from decomposition reactions; and
- Nonflammable gases such as nitrous oxide.

These gases are either released continuously to the tank headspace or are retained in the waste matrix. Retained gas may be released in a spontaneous buoyant displacement or induced GRE that can significantly increase the flammable gas concentration in tank headspace as described in RPP-7771, *Flammable Gas Safety Issue Resolution*.

During the 1990's, significant technical work was performed to understand the BDGRE behavior. The current tank farm safety basis relies upon a process developed from the culmination of this work to categorize waste tanks for BDGRE hazard. The process is described in RPP-10006, *Methodology and Calculations for the Assignment of Waste Groups for the Large Underground Waste Storage Tanks at the Hanford Site*. Tanks are binned into "waste groups" (A, B or C) with the highest hazard and level of control applied to Waste Group A tanks.

Descriptions of the waste groups are provided in RPP-10006. Waste Group A includes DSTs that have a propensity for BDGREs and have sufficient retained gas to achieve 100% of the LFL if all retained gas were released instantaneously. Waste Group B tanks includes tanks that do not have a propensity for BDGREs, but have sufficient retained gas to achieve 100% of the LFL if all retained gas were released instantaneously. Waste Group C tanks are tanks that do not have sufficient retained gas to achieve 100% of the LFL if all retained gas were released instantaneously.

Implementation of the SST retrieval mission requires the most effective use of DST space. This requires the concentration of liquid waste in the 242-A Evaporator to the maximum permissible SpG with the creation of a manageable amount of solids and accumulation of insoluble solids in DSTs to the maximum permissible level. Retrieval and storage of more solids and more concentrated liquid waste in DSTs operates those tanks closer to the Waste Group A criteria. The TFC Authorization Agreement prohibits the creation of new Waste Group A tanks.

The new flowsheet screening tool is able to evaluate a flowsheet and identify any transfers or tanks that are at risk of exceeding the BDGRE criteria, allowing adjustments to be made to plans to avoid these situations.

In practice, situations have occurred where tanks have exceeded Waste Group A criteria. Assessments of the BDGRE methodology have attributed this to the lack of an operating margin between the absolute limits and the operational planning predictions. Operating limits for the BDGRE parameters are needed to prevent this.

The BDGRE criteria contain large conservatisms that need to be addressed before establishing operating limits. Specifically:

- BDGRE criteria are based on avoidance of phenomena (i.e., creation of another tank that behaves like AN-103) rather than avoiding flammable headspace conditions. Extensive documentation that resolved the Flammable Gas Safety Issue demonstrates that the current Waste Group A tanks are safe. This information can be used to revise the current BDGRE criteria upward, accurately reflecting the risk and providing a useable operating margin.



- The Monte Carlo analysis is artificially broad thus creating impossible physical states. Changes are needed to prevent artificial compounding of uncertainty and to increase the operating margin.
- The BDGRE screening methodology needs to include an operating time during which the criteria can be temporarily exceeded. The current methodology assumes that a BDGRE hazard is created instantaneously. Gas generation rates are too low to produce BDGREs for months or years after waste transfer/retrieval.

Work is currently underway to modify the technical basis for the BDGRE screening criteria to address these issues. If the technical work is successful, a safety basis amendment will be implemented.

### **3.4.3 Tank Corrosion Chemistry**

The current DST chemistry limits to prevent corrosion of the tank liner were discussed in Section 2.1.2. These conservative limits have provided assurance that tank corrosion is limited during static storage conditions. Planned tank waste retrievals will utilize large volumes of water for either saltcake dissolution or sluicing of solids. These large water additions will result in dilution of the corrosion inhibiting chemicals in the waste, including hydroxide and nitrite and, if not controlled, can cause waste compositions to deviate from the corrosion chemistry limits. These deviations may be temporary, until the dilute waste is mixed with more concentrated waste to return it to specification, or may require addition of sodium hydroxide or sodium nitrite to maintain the waste within specification. Large additions of sodium hydroxide to the waste are undesirable due to their future impact on the volumes of glass produced in the WTP and the corresponding increase in processing times for tank waste vitrification. The flowsheet screening tools enable deviations from chemistry specifications to be identified at an early stage of process design and adjustments to the proposed retrieval strategy incorporated as appropriate to eliminate or minimize the caustic addition volumes required to maintain the wastes within specification during retrieval.

The work described in Section 2.1.2 to improve the basis for the chemistry specifications, if successful, may enable the specification limits to be relaxed and reduce the volumes of caustic needed to keep wastes within specification during future retrievals.

### **3.4.4 Tank Bump**

In the 1950's and 1960's, fuel reprocessing wastes with high concentrations of heat-producing fission products resulted in tanks that self-boiled. A phenomenon known as "tank bump" occurred in several of these tanks. A tank bump occurs during the rapid release of energy when steam, in the form of a large bubble (or numerous bubbles), passes through the waste surface. These steam eruptions do not threaten the mechanical integrity of the tank, but have led to undesirable discharge of radioactive components.

Three criteria were identified which preclude a tank bump, even after an extended period of no active ventilation (RPP-6213, Rev. 3, *Hanford Waste Tank Bump Accident and Consequence Analysis*). Tanks are excluded from consideration of a tank bump if any one of the following conditions is true:

1. Supernatant depth does not exceed 1 meter.
2. There is an insignificant non-convective layer (<0.3 meter).
3. Total tank heat load can be removed by steady-state conduction through the soil overburden (total tank heat load is less than 11,300 W [38,600 Btu per hour]).

Additionally, tanks can be ruled out if the non-condensable gas generation rate at saturation in the non-convective layer is sufficiently low, such that the ratio of vertical void fraction profile to neutral buoyant void fraction (buoyancy ratio) is less than 1.0. Applying the criteria to tanks in their current condition eliminates all SSTs and DSTs from the tank bump accident.

The retrieval plans for the C-Farm tanks will place at least one of the receiver DSTs outside the criteria for elimination of tank bump. This projected condition was identified as part of the front-end engineering and flowsheet for C-Farm retrievals. Activities are underway to revise the technical basis document and DSA to establish the proper controls for operation of the receiver tanks. Tank waste temperature control through active ventilation is one method of control for prevention of a tank bump accident.

### **3.5 ESTABLISHING CONTROLS**

Once a flowsheet has been developed, it will form the basis for detailed design and for the establishment of controls on operations. The primary document used to provide the transition between the higher level flowsheet requirements and the controls implemented in the field is the process control plan. Using the process flowsheet as its basis, the process control plan is tasked with establishing the controls necessary to both operate the process and to ensure compliance with the “process related” TSRs and environmental permit requirements. The process control plan will be used as the basis for preparing detailed operating procedures that provide the step-by-step instructions for process operation. As a further final compliance check, a final waste compatibility assessment is prepared for each transfer, in accordance with *Tank Farms Waste Transfer Compatibility Program*, HNF-SD-WM-OCD-015, that provides assurance that the waste to be transferred is compliant with the process-related TSRs, and other regulatory, programmatic, and operational criteria that have been established over many years to avoid problems with the transfer of waste. The program has been in place for 14 years and although the program requirements remain largely unaffected by the more dynamic mission, the evaluation process has been streamlined to support more frequent waste transfers. The streamlined screening process was described in Section 3.3.2, and the final assessment process is described below.

More detailed discussions of the process control plan, waste compatibility assessment, and operating procedures are provided in the following sections.

### 3.5.1 Process Control Plans

Process control plans describe and define the specific controls required for a planned process activity or project. Process control plans will normally be prepared for new, non-routine, or complex process activities not fully addressed by existing operating procedures and as such are prepared for all SST retrieval projects and will be prepared for the supplemental treatment projects. The process control plan provides a link between the process and equipment design and the technical operating procedures that control work in the field. The process control plan is a key input document used in preparation of new or revised operating procedures or work packages for a process activity and defines the operational controls to be implemented through technical procedures or work package instructions. The development of process control plans is governed by procedure TFC-ENG-CHEM-C-11, *Process Control Plans*.

The process flowsheet previously described, prepared in accordance with TFC-ENG-CHEM-C-01, is prepared in advance of the process control plan, and will form the basis for the process control plan. Preparation of the process control plan is typically scheduled to follow initial design development to ensure that changes in the process and equipment design do not cause unnecessary rework of the process control plan. The process control plan preparation should precede completion of the final design so that necessary process control features identified during process control plan preparation, such as required instrumentation or sampling capability, are included in the design.

The process control plan will contain a description of the process based on that developed in the process flowsheet report and will discuss the specific controls required to ensure that the process stays within the bounds of the safety basis and environmental permit requirements, together with those required simply to operate the process. It will also provide an overview of the operating philosophy for the process and a discussion of the required response to off-normal conditions.

The safety basis controls section of the process control plan will provide details of any specific requirements that are necessary in order to meet the applicable process-related TSRs. It is not required that all generally applicable TSRs be listed and discussed in the process control plan, such as lock and tag requirements or transfer controls, unless there is a specific process requirement that needs to be met in order to meet the TSR. However, the process control plan author is required to consider all TSRs and whether specific requirements need to be identified in the process control plan to ensure compliance.

As part of the development of the process control plan, further review of the DSA Key Attributes Matrix is required to ensure that any changes in design since the last flowsheet revision have not resulted in conflict with any of the safety basis assumptions or requirements or that no new actions are identified to ensure compliance.

The process control plan will also address any additional requirements identified through the waste compatibility screening/assessment process either through direct incorporation of those requirements as controls or through reference to a separate waste compatibility assessment.

Once prepared, the process control plan will be a key input document used in the preparation of operating procedures that will be used to specifically control work in the field.

TFC-ENG-CHEM-C-11 addresses the reviews necessary to ensure that the controls specified in the process control plan are adequately incorporated in the operating procedures or work package instructions.

### **3.5.2 Waste Compatibility Assessments**

As previously discussed in Section 3.3.2, HNF-SD-WM-OCD-015 is one of the safety management programs required by the DSA and provides a formal process for determining waste compatibility through the preparation of documented waste compatibility assessments (WCAs) for waste transfers. The program meets regulatory requirements for ensuring waste compatibility and is heavily relied upon for ensuring compliance with the “process related” TSRs. The program is well established, having been in place for 14 years and is routinely updated to stay current with changing safety basis requirements. In addition to the screening process using the new compatibility assessment automated tool previously described, documented compatibility assessments continue to be prepared as a pre-requisite to each actual transfer and provide a final assurance of waste compatibility and compliance with the TSRs. The waste compatibility assessment will identify any specific requirements, in addition to those specified by the process control plan. Compliance with the waste compatibility assessment requirements is verified as a transfer pre-requisite in a transfer control checklist that forms part of the operating procedures.

### **3.5.3 Operating Procedures**

Operating procedures provide the final step in the process, providing detailed step-by-step instructions for operation of the retrieval or transfer process. Procedure TFC-ENG-CHEM-C-11, *Process Control Plans*, ensures that the controls specified by the process control plan are integrated into operating procedure development. The operating procedure steps clearly identify those steps that are TSR limits. As a final assurance, transfer procedures contain a checklist that is prepared as a pre-requisite to the transfer that checks that a waste compatibility assessment has been prepared for the transfer and that any requirements specified in that assessment have also been met.

#### 4.0 CONCLUSIONS

The Tank Farms are now in the next phase of a new mission focused on SST waste retrieval, staging for treatment, and eventual transfer to and treatment of waste in the WTP. This new mission poses challenges for both the long-term preservation of the integrity of the DSTs and for the management of tank wastes in such a manner as to maximize space utilization within the constraints of the DST system while efficiently and safely retrieving wastes within the constraints posed by the TSRs.

The TFC has in place a strong DST Integrity Program. That program provides assurance that the useful life of the DSTs can be extended to support the ongoing tank farms mission through the combination of non-destructive examination of the tanks using ultrasonic and visual means and maintenance of tank chemistry within limits that minimize the risks of corrosion of the primary tanks. The TFC continues to improve the program through the use of Expert Panels. Implementation of their recommendations is ongoing and will further strengthen the technical basis for the program.

The TFC has put in place a front-end engineering process that provides an effective way of reducing the risks of waste management. The process is centered on the process flowsheet as the basis for tank retrieval planning. Use of the process flowsheet enables early identification of risks and issues in the proposed process and ensures that the process can be operated within the constraints of the TSRs. This front-end engineering process provides a sound basis for detailed design and the establishment of controls to be applied in the field. The process is designed to receive regular feedback so that lessons learned can be incorporated as needed.

These programs and processes provide confidence that the integrity of the tanks can be preserved and the wastes successfully managed within the constraints of the TSRs.

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