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A-6000-135 (10/97)

SAFETY EVALUATION OF OXALIC ACID WASTE RETRIEVAL IN SINGLE-SHELL TANK 241-C-106

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Abstract: This report documents the safety evaluation of the process of retrieving sludge waste from single-shell tank 241-C-106 using oxalic acid. The results of the HAZOP, safety evaluation, and control allocation/decision are part of the report.

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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.

Richland, Washington

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

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EXECUTIVE SUMMARY

Closure of Single-Shell Tank 241-C-106 requires nearly complete removal of the waste remaining in the tank after sluicing has been completed. The goal will be to dissolve as much sludge as feasible (< 360 ft^3). To reach that goal, only 30% of the 9,000 gallons of sludge can remain. Dissolution through the addition of oxalic acid has been determined to offer a high probability of success for mobilizing this waste.

The purpose of this report is to document the evaluation of the safety of the oxalic acid dissolution process in Single-Shell Tank 241-C-106. This is accomplished by:

- Identifying the key configuration and operating assumptions needed to evaluate oxalic acid dissolution.
- Comparing the hazard and operability study results to the hazardous conditions and associated analyzed accidents currently included in the safety basis.
- Evaluating the safety of the oxalic acid dissolution activity with respect to:
  - Accident analyses described in HNF-SD-WM-SAR-067, *Tank Farms Final Safety Analysis Report* (FSAR), and
  - Controls specified in HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements* (TSR).
- Evaluating the existing safety basis control applicability to the hazardous conditions.
- Identifying the need for new controls when the existing controls are judged to not adequately control the risk of the postulated accident.

The hazard and operability study team identified 88 hazardous conditions and 22 more were added and 14 were deleted during reviews of the data, for a total of 96.

These hazardous conditions were mapped to the following FSAR representative accidents:

- Nuclear Criticality
- Mixing Of Incompatible Materials
- Flammable Gas Deflagration
- High-Efficiency Particulate Air (HEPA) Filter Failure
- Tank Failure Due To Vacuum Or Degradation
- Caustic Spray Leak
- Unfiltered Release
- Waste Transfer Leak
- Tank Bump.

No hazardous conditions associated with an FSAR representative accident were found to be unique; they are analogous to existing hazardous conditions. Some hazardous conditions not associated with a representative accident were found to be unique; they were not analogous to existing hazardous conditions. In most cases they were sufficiently similar to an FSAR analyzed accident to be mappable to a representative accident. For these, the existing safety basis controls were judged to be applicable and adequate. Hazardous conditions with only a facility worker impact adequately addressed by the controls established through Tank Farm Contractor safety management programs. For the few hazardous conditions for which existing safety basis controls were judged not to be adequate, a justification for continued operation will be issued that establishes additional controls.

The following is a detailed summary of the control decision/allocation results.

- **Accidents not Assigned to a Representative Accident**

  Facility Worker Hazard - CO_2 Generation Hazards

  The existing safety management programs for facility worker protection address confined space and other asphyxiation hazards. No changes to the program are required.

  Facility Worker Hazard - Exposure to Ionizing Radiation

  Oxalic acid waste retrieval does not introduce any unique radiation protection hazards. Specific measures to protect the facility worker are established as needed using existing procedures and work planning processes. No changes to the program are required.

  Significant Environmental Impact - Primary Tank Leak

  The frequency and consequence of waste tank leaks is not materially altered by the oxalic acid waste retrieval process. Controls specified in the FSAR for protection of the environment are applicable to the oxalic acid waste retrieval process and adequately address environmental risk.

- **Accidents Assigned to a Representative Accident**

  Representative Accident 01, Nuclear Criticality - The use of oxalic acid to retrieve waste is an activity that is not addressed in the current criticality safety evaluation report. The additional analyses will be documented in a new criticality safety evaluation report and a new criticality prevention specification that will establish the necessary requirements to maintain the frequency of the accident "beyond extremely unlikely." No additional key elements for AC 5.7 are needed, although the pH verification requirement is superceded by the criticality prevention specification derived from the criticality safety evaluation report.

  Representative Accident 03, Mixing of Incompatible Material – Tank Pressurization - The preventive control specified in the FSAR cannot be applied to the oxalic acid demonstration project since it requires chemical additions to have a pH of not less than 8. Oxalic acid additions cannot meet the current control. A preventive compensatory measure needs to be applied to insure that each delivery contains the expected oxalic acid before it is added to the tank. In addition, a compensatory measure to limit the rate of addition is required to protect an important analysis assumption. The requirements will be specified in the justification for continued operation for oxalic acid waste retrieval.

Representative Accidents 04/05 – Flammable Gas Deflagrations – DST/SST - The risk for a flammable gas deflagration due to oxalic acid dissolution in SST 241-C-106 and waste transfer to DST 241-AN-106 is not increased above that currently analyzed in the FSAR, assuming the application of current TSR flammable gas controls. In order to facilitate the transition to the documented safety analysis, new TSR flammable gas controls will be proposed in the justification for continued operation for the oxalic acid addition process.

Representative Accident 06 - HEPA Filter Failure – Exposure to High Pressure - The FSAR analysis bounds the consequence for HEPA filter failure. The conditions involved in the waste retrieval process will not increase the frequency of the accident because the FSAR estimated accident frequency is "anticipated" with or without controls. The safety basis controls for the filter failure accident are valid for the conditions associated with oxalic acid waste retrieval. No additional or altered controls are required.

Representative Accident 13, Tank Failure Due to Vacuum or Degradation - The current safety basis has no controls specified for this accident based on an estimated event frequency that is "beyond extremely unlikely" (F0). Controls are imposed for tank failure due to load drop accidents, which would also be applicable during oxalic acid dissolution operations. The evaluation provided by the memo from Closure Project Engineering Support, Appendix E concluded that oxalic acid waste retrieval does not constitute a significant structural degradation threat. Therefore, there is no increase in frequency or consequence and no additional controls are required.

Representative Accident 17, Caustic Spray Leak - The use of oxalic acid to retrieve waste has the potential for the same type of chemical spray leak accidents that the Caustic Spray Leak. AC 5.23 requirements address the risk of this accident. The major difference between the currently analyzed caustic accident and the oxalic acid accident is that oxalic acid has less restrictive evaluation guidelines for the onsite individual as compared to caustic. Therefore the accident involving oxalic acid is bounded by the current analysis. The FSAR analyzed accident frequency is "anticipated" (F3) for caustic spray and pool leak accidents and is judged to be the same for oxalic acid. Since the AC key elements for caustic leaks are intended to mitigate the consequences of spray and pool leaks, the controls are equally valid for oxalic acid. No additional key elements for AC 5.23 are needed. The ph verification requirement provided by Boston 2002 is superceded by a compensatory measure provided in the oxalic acid waste recovery justification for continued operation.

Representative Accident 18A - Tank Bump - The hazardous conditions related to Tank Bump are identical to those currently analyzed in the FSAR. Therefore, no additional evaluation was done in this safety evaluation.

Representative Accident 18B – Unfiltered Release (due to oxalic acid damage to ventilation system) - The comparison of the FSAR analysis consequences for unfiltered release with the consequences calculated for the same accident involving the conditions associated with the oxalic acid waste retrieval process show that the FSAR analysis is bounding. The conditions involved in the waste retrieval process will not alter the frequency of the accident appreciably. The safety basis controls for the unfiltered release accident are valid for the conditions associated with oxalic acid damage to the ventilation system. No additional or altered controls are required.

Representative Accident 18B - Unfiltered Release (due to general causes) - The comparison of the FSAR analysis consequences for unfiltered release with the consequences calculated for the same accident involving the conditions associated with the oxalic acid waste retrieval process show that the FSAR analysis is bounding. The FSAR estimated accident frequency is "Anticipated" with or without controls. The conditions involved in the waste retrieval process will not increase the frequency of the accident. The safety basis controls for the unfiltered release accident are valid for the conditions associated with oxalic acid waste retrieval. No additional or altered controls are required.

Representative Accident 23, Mixing of Incompatible Material – Toxic Vapor Generation- Bounded by FSAR analysis. No controls required.

Representative Accident 33, Waste Transfer Leak - Waste transfers involving oxalic acid dissolution sludge and residues could involve waste transfer leaks. The frequency and consequences of these potential leaks are bounded by the analysis in the FSAR representative accident for waste transfer leaks. The current TSR control set is adequate to address the risk from potential waste leak accidents.

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LIST OF TERMS

AC	administrative control
AIChE	American Institute of Chemical Engineers
AWF	aging waste facility
DSA	documented safety analysis
DST	double-shell tank
FSAR	Final Safety Analysis Report
HAZOP	hazards and operability study
HEPA	high efficiency particulate air [filter]
HIHTL	hose-in-hose transfer line
LCO	Limiting Condition for Operation
M	molar
NFPA	National Fire Protection Association
PFP	Plutonium Finishing Plant
Rep Acc	representative accident
SS	safety significant
SSC	structures, systems, and components
SST	single-shell tank
TSR	Technical Safety Requirement
USQ	unreviewed safety question

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1.0 INTRODUCTION

1.1 PURPOSE

This safety evaluation considers the use of oxalic acid to recover residual waste in single-shell tank (SST) 241-C-106. This is an activity not addressed in the current tank farm safety basis. This evaluation has five specific purposes:

- Identifying the key configuration and operating assumptions needed to evaluate oxalic acid dissolution in SST 241-C-106.
- Documenting the hazardous conditions identified during the oxalic acid dissolution hazard and operability study (HAZOP).
- Documenting the comparison of the HAZOP results to the hazardous conditions and associated analyzed accident currently included in the safety basis, as documented in HNF-SD-WM-TI-764, *Hazard Analysis Database Report.*
- Documenting the evaluation of the oxalic acid dissolution activity with respect to:
  - Accident analyses described in HNF-SD-WM-SAR-067, *Tank Farms Final Safety Analysis Report* (FSAR), and
  - Controls specified in HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements* (TSR).
- Documenting the process and results of control decisions as well as the applicability of preventive and/or mitigative controls to each oxalic acid addition hazardous condition.

This safety evaluation is not intended to be a request to authorize the activity. Authorization issues are addressed by the unreviewed safety question (USQ) evaluation process. This report constitutes an accident analysis.

1.2 BACKGROUND

The retrieval of the residual waste in SSTs is required to achieve interim closure as required by the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1986) milestones M-45, M-45-06A, M-45-05N-T01, M-45-05H, and the waste management requirements of the *Washington Administrative Code* (WAC) 173-303. Milestone M-45 requires the closure of numerous SST farms and states that closure will follow the retrieval of as much tank waste as technically possible with tank waste residues not to exceed 360 ft^3 or the limits of the technology, whichever is less.

SST 241-C-106 was chosen as the first tank to demonstrate waste retrieval that achieves the requirement of milestone M-45. The first step to achieve this goal was to remove accessible waste liquids leaving a heel of solids and sludges. The next step is dissolution of the remaining solids in the tank. Oxalic acid dissolution has been selected to mobilize and retrieve the remaining waste in SST 241-C-106 based upon successful retrievals completed at the Savannah River site and laboratory analysis.

Hanford Site waste tanks are fabricated from mild steel. Oxalic acid has minimal effect on mild steel but will effectively dissolve the solid waste remaining in SST 241-C-106. Oxalic acid rinsing is a common industrial technique for cleaning mild steel tanks.

2.0 DESCRIPTION OF OXALIC ACID DISSOLUTION EQUIPMENT AND PROCESSES

The SST closure is a defined mission objective. The SST closure will follow retrieval of as much tank waste as technically feasible, with waste residues not to exceed 360 ft^3 in each of the 100-series tanks, or the limit of the waste retrieval technology, whichever is less. The SST 241-C-106 oxalic acid dissolution waste retrieval operations are intended to help meet mission objectives.

2.1 DESCRIPTION OF OXALIC ACID DISSOLUTION EQUIPMENT

Components comprising the SST 241-C-106 oxalic acid dissolution system can be divided into several equipment groups. These include the oxalic acid addition equipment, oxalic acid re-circulation/waste transfer equipment, control system, electrical equipment, and ventilation equipment, which are described below.

2.1.1 Oxalic Acid Addition Equipment

Approximately 30,000 gal of oxalic acid will be required for each iteration of the sludge dissolution process in SST 241-C-106. The oxalic acid will be transferred via acid resistant hose from vendor-supplied tank trucks to the tank in approximately 5,000-gal batches.

Oxalic acid will be introduced to SST 241-C-106 through a hose connection located on the C-106 valve and instrument stand. Depending on valve positioning, oxalic acid can enter the tank through either a drop leg, which is part of the pump assembly, or through the mixing eductor. Acid flow will be monitored by a flowmeter located on the C-106 valve and instrument stand and controlled manually through the associated control valve. The flowrate will be initially controlled to nominally 40 gal/min (half the allowed flowrate) to allow for minor fluctuations, operator intervention, etc., until the bulk of the carbonate has reacted with the oxalic acid.

Caustic transfer controls (AC 5.23) as modified by Boston (2002), will be applied to oxalic acid introduction operations to control oxalic acid spray leak toxicological hazards (except for the pH verification). The oxalic acid transfer hose will be sleeved with polyethylene which is compatible with oxalic acid.

2.1.2 Oxalic Acid Re-circulation/Waste Transfer Equipment

The oxalic acid/waste solution will be removed from SST 241-C-106 via the same transfer pumps used for recirculation. Design of the over-ground transfer lines utilizes a hose-in-hose transfer line (HIHTL) assembly. A jumper will connect the discharge line of the tank's transfer pump to a small valve manifold. The manifold will allow waste to be re-circulated back into the tank or transferred to DST 241-AN-106.

In the case of re-circulated waste, an existing HIHTL connects the 241-C-06B heel pit to the 241-C-06A pump pit. A new jumper in the 241-C-06B heel pit will connect the HIHTL to a mixing eductor assembly. When transferring waste to DST 241-AN-106, a dedicated HIHTL will connect the 241-C-06B heel pit to the 241-AN-06A pump pit. A jumper connects the HIHTL to a drop leg which routes waste into the tank.

A series arrangement of two transfer pumps exists within SST 241-C-106. These pumps were installed to remove the remaining pumpable supernatant from the tank. In addition, these pumps will be used to remove new liquid waste generated when raw water is introduced through sluicer nozzles to level piles of solids located on the tank bottom in preparation for oxalic acid dissolution. These pumps will be used during oxalic acid dissolution and waste transfer. A backup transfer pump arrangement has been designed and is being procured to replace the current pumps if they fail during oxalic acid dissolution operations (the existing pumps are not qualified for oxalic acid).

The backup transfer pump is a submersible pump assembly. The pump assembly consists of two single stage submersible centrifugal pumps modified by the factory for oxalic acid service. The backup transfer pump assembly is designed to be easily interchanged with the current transfer pump assembly using the same valve and instrument arrangement. The backup transfer pumps are sized to connect to the existing pump power supply with only a change to the motor starter over current protection (fuses and overloads).

An eductor was chosen as the mixing method for the recirculation of oxalic acid in SST 241-C-106 because the eductor nozzle, intake, and, therefore, liquid jet could be located below the surface of the oxalic acid/waste pool, resulting in little or no generation of aerosols within the tank dome space. The eductor assembly prevents the oxalic acid solution from sitting stagnant. The intention is not to blend, suspend solids, or homogenize the waste with the oxalic acid.

2.1.3 Control System

The control system operational philosophy will remain consistent with the existing transfer system at SST 241-C-106. In addition to the leak detectors in the 241-C-06B heel pit and the 241-C-06A pump pit, leak detectors at DST 241-AN-106 (i.e., the 241-AN-06A pump pit) will be added to the existing SST 241-C-106 transfer system interlocks to cover the transfer route. Oxalic acid flow into SST 241-C-106 will be monitored by a flowmeter located on the C-106 valve and instrument stand and the flowrate will be adjusted manually through the associated control valve. Oxalic acid will be batched into SST 241-C-106 from a tanker truck located outside of the 241-C tank farm.

There are two fundamental modes of operation associated with the SST 241-C-106 waste transfer system. In recirculation mode, waste is routed back to SST 241-C-106 through a mixing eductor. In transfer mode, waste is transferred from SST 241-C-106 to DST 241-AN-106.

2.1.4 Electrical Equipment

Leak detection signals that originate in the 241-AN-06A pump pit will be interlocked with the SST 241-C-106 pumps. The existing leak detectors at the 241-C-06B heel pit and the 241-C-06A pump pit will also be interlocked with the pumps.

2.1.5 Ventilation Equipment

Active ventilation is connected to SST 241-C-106 to remove offgases generated during oxalic acid dissolution. The tank ventilation system is comprised of an inlet HEPA filter and a portable exhauster. The portable exhauster contains a heater, demister, pre-filter, two stages of HEPA filters, a fan, an exhaust stack, an effluent monitoring system, and ventilation stack continuous air monitor interlock system.

2.2 SST 241-C-106 OXALIC ACID DISSOLUTION OPERATIONS

Before starting the oxalic acid dissolution waste retrieval, the activities identified below will be completed:

- Supernatant from the tank will be pumped from SST 241-C-106 to DST 241-AY-102.
- Piles of residual waste in SST 241-C-106 will be knocked down utilizing the existing sluicing equipment to reduce the quantity of oxalic acid needed to cover the waste and provide more oxalic acid contact surface area.
- Caustic will be added to DST 241-AN-106.

The oxalic acid dissolution waste retrieval consists of the following steps:

- Approximately 30,000 gal of oxalic acid is introduced into the tank (no more than 35,000 gal). The soak time for the initial introduction is anticipated to be one day, and then it will be pumped to DST 241-AN-106. The waste stream will be neutralized in DST 241-AN-106.
- Follow-on oxalic acid additions will continue using oxalic acid additions to the tank of approximately 30,000 gal (a truck load is approximately 5,000 gal). Subsequent to the initial oxalic acid soak, all follow-on oxalic acid additions will be allowed to soak for approximately one week before transfer to DST 241-AN-106.
- During the oxalic acid soak period, agitation of the oxalic acid pool is required to facilitate the oxalic acid-waste reaction. The goal is to slowly agitate the entire oxalic acid pool. Agitation is not required during transfer periods.
- Following the last oxalic acid soak and transfer, sluicing with water will be done to wash the residual waste from the walls, the sluicing solution will be pumped to

DST 241-AN-106, and SST 241-C-106 will then be rinsed with a ½ molar caustic solution.

- Transfer lines will be flushed and drained.

3.0 HAZARD IDENTIFICATION

3.1 METHODOLOGY

The hazards identification and evaluation of oxalic acid dissolution of the solid waste in SST 241-C-106 used the HAZOP method. A HAZOP is a systematic process for identifying potential causes and consequences of off-normal conditions in a system or process. The HAZOP uses a team leader to guide an interdisciplinary team of subject matter experts in evaluating a system or process. The HAZOP process is based on "brainstorming" and uses a standardized set of process parameters (e.g., temperature, pressure, flow) and guide words (e.g., high, low, part of, reverse) to facilitate the "brainstorming." Table 3-1 presents a list of process parameters and guide words. HAZOP results are recorded in a tabular format. The definitions of the information developed during the HAZOP process are found in Appendix B.

The expertise and experience of the HAZOP team is of primary importance in establishing the credibility of the analysis because of the largely qualitative nature of the HAZOP process. The attendance roster plus a short resume of each team member is included in Appendix A to document the expertise and experience level of each team member. The HAZOP process is recognized by the American Institute of Chemical Engineers (AIChE) and is described in *Guidelines for Hazard Evaluation Procedures* (AIChE 1992).

One of the important features of a HAZOP is the division of a process or activity into discrete segments called nodes. Node selection is designed to facilitate the hazard identification process by focusing the attention of the team on specific process sections or operating steps. The team applies the HAZOP process to each node in a stepwise fashion. The SST retrieval via saltcake dissolution proof of concept HAZOP was based on the following nodes to capture points in the process where deviations could result in significant consequences.

- **Node A:** Oxalic Acid Supply Cargo Tank (0.5 M to 1.0 M Oxalic Acid, 5,000-gal Cargo Tank)
- **Node B:** Oxalic Acid Pumping/Delivery System (Cargo Tank to SST)
- **Node C:** SST 241-C-106
- **Node D:** Ventilation System, SST 241-C-106
- **Node E:** Transfer Pump
- **Node F:** Oxalic Acid Re-circulation System
- **Node G:** Transfer Line, SST 241-C-106 to DST 241-AN-106
- **Node H:** Waste Receiver Tank (DST 241-AN-106)
- **Node I:** Instrumentation and Controls

Table 3-1. Deviation Guide For Process Variables.

Guide Words / Process Parameter	NO, NOT,1 NONE	LESS, LOW, SHORT	MORE, HIGH, LONG	PART OF	AS WELL AS, ALSO	OTHER THAN, WHERE ELSE	REVERSE
FLOW	No Flow	Low Rate, Low Total	High Rate, High Total	Misdirection, Material in Inappropriate Areas	Contamination, Impurities	Wrong Material	Backflow
PRESSURE	Open to Atmosphere	Low Pressure	High Pressure				Vacuum
TEMPERATURE	Freezing	Low Temperature	High Temperature				Auto-refrigeration
LEVEL	Empty	Low Level	High Level	Low Interface	High Interface		
CONFINEMENT	No Confinement	Degraded Confinement				Bypass Pathway	
TIME PROCEDURE	Skipped or missing Step	Too Short, Too Little	Too Long, Too Much	Action(s) Skipped	Extra Action(s) (Shortcuts)	Wrong Action	Out of Order, Opposite
SPEED	Stopped	Too Slow	Too Fast	Out of Synch		Web or Belt Break	Backward
COMPOSITION/ CONCENTRATION	Missing Ingredient	Less Ingredient/ Low Concentration	More Ingredient/ High Concentration	Missing Ingredient	Contaminant/ Additional Ingredient	Wrong Ingredient	
pH		Low pH	High pH		Additional Acid, Additional Base	Wrong Acid, Wrong Base	
VISCOSITY		Low Viscosity	High Viscosity				
VOLTAGE	No Voltage	Voltage Low	Voltage High	Wrong Waveform	Interference Voltage	Wrong Frequency, AC instead of DC DC instead of AC	Wrong Polarity
CURRENT	No Current	Current Low	Current High			Current Fluctuating	Wrong Polarity
STATIC	No Static Charge (when required)		Static Charge				
AGITATION	No Mixing	Poor Mixing	Excessive Mixing	Mixing Interruption	Foaming		Phase Separation
REACTION	No Reaction	Slow Reaction	Runaway Reaction	Partial Reaction	Side Reaction	Wrong Reaction	Decomposition
STRUCTURAL INTEGRITY	Structural Failure	Less Integrity	More Integrity				
SHIELDING	No Shielding	Less Shielding	More Shielding			Wrong Type of Shielding	
SPECIAL	Utility Failure	External Leak	External Rupture	Tube Leak	Tube Rupture	Startup, Shutdown, Maintenance	

3.2 ASSUMPTIONS

The following assumptions were developed by the HAZOP team to facilitate the initial hazard identification sessions of the HAZOP.

- Where a leak is postulated with a pit overflow, the pit drain is assumed to be blocked.
- Where a leak is postulated into a waste tank from a pit, the pit drains are assumed to be open.
- Where a flammable gas hazard is postulated, an active ignition source is assumed.
- Where a leak or spray is postulated due to the transfer pump pressure, the transfer piping or connections are assumed to be weakened or degraded such that pump pressures could result in a failure.
- Chemicals are assumed to be reactive without documented evidence that proves otherwise.

3.3 HAZOP RESULTS

The HAZOP team identified 88 hazardous conditions associated with oxalic acid retrieval of the solids in SST 241-C-106 for closure. The detailed information developed during the initial hazard identification team meeting is presented in Appendix C, Table C-1. The information in Table C-1 is a historical record of the HAZOP hazard identification sessions and is considered raw data, not having been subjected to formal analysis to confirm the postulated events, their consequence, or their frequency of occurrence. Subsequent evaluation of the hazardous conditions resulted in fourteen hazardous conditions being deleted and 22 hazardous conditions being added. This resulted in a total of 96 hazardous conditions. The additional hazardous conditions were included to ensure that a comprehensive set of hazardous conditions were captured. Hazardous conditions were deleted because they were duplicates of other hazardous conditions or were judged not to be a possible accident based on the described event mechanism. Table 3-2 presents a summary and justification of each change to the original HAZOP.

Grouping hazardous conditions is the first step in the hazard evaluation process. The hazardous conditions were grouped in several ways to facilitate the hazard evaluation process. The first grouping was generalized by hazardous condition, (e.g., specific hazardous conditions related to criticality are grouped together under a generalized criticality hazardous condition). Table 3-3 lists the 13 generalized hazardous conditions and provides a node-by-node listing of the number of each type of conditions identified for each node of the analysis. This grouping was done to facilitate rapid identification of information needed to support the safety evaluation process.

Table 3-2. Summary of Differences Between Original HAZOP Results and Final Evaluation Results

HAZOP ID	HAZOP Hazardous Condition (Appendix C, Table C-1)	HAZOP Cause (Appendix C, Table C-1)	Revised ID	Revised Hazardous Condition (Table 5-1)	Revised Cause (Table 5-1)	Reason for Revision
C106-ACID-B-05	Release of hazardous material from acid transfer hose to the ground due to ruptured hose	Freezing cause rupture of acid transfer hose	C106PHASE-II-B-05	Release of radioactive or hazardous materials from service water system to atmosphere due to spray leak from starting slurry transfer pump in tank 241-C-106 during the flush of slurry transfer line	Slurry transfer pump in tank 241-C-106 is started during the flush of slurry transfer line flush line is filled and pressurized resulting in flush line leak or backflow into service water system	HAZOP Hazardous Condition duplicates C106PHASE-II-B-01. New Hazardous Condition created to capture backflow event. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-B-06	Release of hazardous material from the acid transfer hose to the ground due to drips for quick disconnect fittings	Leakage from quick disconnect fittings causes small drips or leaks when making or breaking connections	C106PHASE-II-B-06	Release of radioactive or hazardous materials from service water system to atmosphere due to spray leak from a backflow of tank waste into the service water system	Valve alignment is incorrect or leaking valves cause waste from the re-circulation pump in tank 241-C-106 backflows into service water system resulting in waste leak	HAZOP Hazardous Condition duplicates C106PHASE-II-B-03. New Hazardous Condition created to capture backflow event. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-C-03	Release of hazardous material to the atmosphere due to incompatible chemical reacting with the waste in SST 241-C-106 causing generation of toxic gas or fumes	Acid cargo tank is filled with the wrong chemical resulting in a reaction in 241-C-106	C106PHASE-II-C-03	Release of radioactive or hazardous material from 241-C-106 to the soil column due to tank liner breach	Sluice jet impinges on weak section of tank wall causing minor leak of water or slurry behind liner and subsequent leak to soil column	HAZOP Hazardous Condition duplicates C106PHASE-II-C-01. New Hazardous Condition created to capture tank leak event. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-C-04	Release of hazardous material to the atmosphere due to caustic reacting with the waste in SST 241-C-106 causing generation of toxic gas or fumes	Acid cargo tank is filled with caustic solution resulting in a reaction in 241-C-106	C106PHASE-II-C-04	Release of radioactive or hazardous material from 241-C-106 to the soil column due to tank liner breach	Sluice jet impinges on flashing causing minor leak of water or slurry behind liner and subsequent leak to soil column	HAZOP Hazardous Condition duplicates C106PHASE-II-C-02. New Hazardous Condition created to capture tank leak event. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-C-05	Release of dissolved ammonia to the atmosphere due to oxalic acid changing the solubility	Oxalic Acid addition changes Ammonia solubility releasing ammonia through ventilation system	C106PHASE-II-C-05	Transfer of contaminated sluice water or 241-C-106 waste to 241-C-105 due to backflow of sluice water/slurry through cascade line	Sluice jet impinges on cascade line causing water or 241-C-106 slurry to backflow to 241-C-105	During review of HAZOP Hazardous Condition C106-ACID-C-05 it was noted that there is insufficient ammonia in the remaining waste to pose a hazard. Prior sluicing activities will have released nearly all of the ammonia that was retained in the waste. A new hazardous condition was generated that addressed backflow through cascade line instead. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-C-06	Release of radioactive or hazardous material from the 241-C-106 ventilation system to the atmosphere due to a flammable gas deflagration	Oxalic Acid addition causes a release of flammable gas with ignition and overpressure resulting in damage to the ventilation system and minor dome damage	C106PHASE-II-C-06	Release of ionizing radiation and radioactive gas from tank 241-C-106 to the atmosphere due to criticality in the tank	Excessive solids in slurry flow towards slurry transfer pump	HAZOP Hazardous Condition duplicates C106PHASE-II-C-11. New Hazardous Condition created to capture criticality event not addressed in original HAZOP. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-D-10	Release of radioactive or hazardous materials from tank 241-C-106 to atmosphere due to excessive vacuum	Excessive vacuum caused by human error (closing off inlet damper) in tank from ventilation system resulting in loop seal failure and unfiltered release	C106PHASE-II-D-10	Release of radioactive or hazardous material from the service water lines to the surface due to a backflow of waste	Leaking valves or incorrect valve alignment causes backflow of waste into service water line during slurry pump operation with leak through unmonitored service water system	During review of HAZOP Hazardous Condition C106-ACID-D-10 it was noted that the postulated event will not result in a release. A new hazardous condition was created to capture backflow of waste into service water line that was not addressed in original HAZOP. The reuse of the ID was done to maintain an unbroken numbering system.

Table 3-2. Summary of Differences Between Original HAZOP Results and Final Evaluation Results

HAZOP ID	HAZOP Hazardous Condition (Appendix C, Table C-1)	HAZOP Cause (Appendix C, Table C-1)	Revised ID	Revised Hazardous Condition (Table 5-1)	Revised Cause (Table 5-1)	Reason for Revision
---	---	---	C106PHASE-II-E-06	Release of radioactive or hazardous material from unfiltered release paths and damaged ventilation system to the atmosphere due to a flammable gas deflagration	Installation of new equipment (e.g. slurry pump) causes spark and ignites flammable gas	New Hazardous Condition developed during review of original HAZOP to address flammable gas deflagration not identified in original HAZOP.
C106-ACID-G-01	Release of radioactive or hazardous material from pit due to ruptured transfer line and drain to pit with subsequent overflow	Waste containing excess oxalic acid reacts with transfer line causing rupture and leak to containment	C106PHASE-II-G-01	Release of radioactive or hazardous materials from slurry receiver DST to atmosphere due to unfiltered release through failed HEPA filter	Excessive slurry flow resulting in increased aerosol generation and which loads HEPA filters causing high differential pressure and filter failure	Original HAZOP Hazardous Condition renumbered from C106-ACID-G-01 to C106PHASE-II-G-27. A new hazardous condition was created to capture HEPA filter failure due to aerosol loading that was not addressed in original HAZOP. Renumbered to provide better sequence of accidents.
C106-ACID-G-04	Release of radioactive or hazardous materials from a pit to the ground surface due to a ruptured waste transfer line	Line freezing causes rupture in line with leak to a pit via the encasement with subsequent pit overflow	C106PHASE-II-G-04	Release of radioactive or hazardous materials from tank 241-AN-106 to atmosphere due to unfiltered release through failed HEPA filters	Heat loading from new waste cause loading of HEPA filters which fail by high differential pressure with aerosol release	HAZOP Hazardous Condition duplicates C106PHASE-II-G-02. New Hazardous Condition created to capture heat load caused HEPA filter failure event not addressed in original HAZOP. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-G-06	Release of radioactive or hazardous materials or hazardous waste from transfer line in tank 241-C-106 pit to atmosphere due to leak in line flush connection	Blank flange or hose connection left off flushing connection outside pit after flushing and transfer initiated.	C106PHASE-II-G-06	Release of radioactive or hazardous materials from tank 241-AN-106 through failed filters due to tank bump	Cold water spray into tank (possible result of slurry distribution) chills head space causing tank vacuum inducing resulting tank bump	HAZOP Hazardous Condition duplicates C106PHASE-II-G-23. New Hazardous Condition created to capture tank bump event not addressed in original HAZOP. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-G-07	Release of radioactive or hazardous materials or hazardous waste from line in pit to the surface due to leak caused by mispositioned valve, cover plug in place	Air blow down valves left in flush configuration after flushing, cover plug remains in place on initiation of sluicing process, high capacity drain cover left on and pit overflows.	C106PHASE-II-G-07	Release of hazardous gas to the atmosphere from tank 241-AN-106 due to reaction of slurry with DST waste	Slurry transfer caused hazardous gas release from DST	HAZOP Hazardous Condition near duplicates C106PHASE-II-G-23. New Hazardous Condition created to capture hazardous gas release event not addressed in original HAZOP. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-G-08	Release of radioactive or hazardous material from overground transfer hose to the ground due to a leaking connection	High temperature water flush degrades seal at hose joint connection causing leak to ground surface	C106PHASE-II-G-08	Release of radioactive or hazardous materials from 241-C-106 to the surface through pits and risers due to backflow of waste from slurry receiver tank	Siphon of waste from receiver tank to C-106 overfills tank with leak to ground	HAZOP Hazardous Condition near duplicates C106PHASE-II-G-02. New Hazardous Condition created to capture siphon event not addressed in original HAZOP. The reuse of the ID was done to maintain an unbroken numbering system.
C106-ACID-G-01	Release of radioactive or hazardous material from pit due to ruptured transfer line and drain to pit with subsequent overflow	Waste containing excess oxalic acid reacts with transfer line causing rupture and leak to containment	C106PHASE-II-G-27	Release of radioactive or hazardous material from pit due to ruptured transfer line and drain to pit with subsequent overflow	Waste containing excess oxalic acid reacts with transfer line causing rupture and leak to containment	Hazardous Condition renumbered from C106-ACID-G-01. Renumbered to provide better sequence of accidents.

Table 3-2. Summary of Differences Between Original HAZOP Results and Final Evaluation Results

HAZOP ID	HAZOP Hazardous Condition (Appendix C, Table C-1)	HAZOP Cause (Appendix C, Table C-1)	Revised ID	Revised Hazardous Condition (Table 5-1)	Revised Cause (Table 5-1)	Reason for Revision
C106-ACID-I-01	Release of radioactive or hazardous material from 241-C-106 to the atmosphere due to a flammable Gas deflagration	Oxalic acid aerosols causes in-tank instrumentation failure causing a spark and igniting flammable gas causing damage to the ventilation system	C106PHASE-II-1-01	Release of ionizing radiation and radioactive gas from slurry receiver DST to the atmosphere due to criticality in the tank	Slurry distributor or dropleg piles or concentrates solids in one place resulting in critical mass	During review of HAZOP Hazardous Condition C106-ACID-I-01 it was noted that in-tank instrumentation will not be exposed to acid aerosols in a manner that can result in electrical faults. A new hazardous condition was generated that addressed criticality instead. The reuse of the ID was done to maintain an unbroken numbering system.
---	---	---	C106PHASE-II-1-03	Large release of radioactive or hazardous materials from slurry receiver DST to the atmosphere due to flammable gas deflagration	Influx of cold water spray into tank causing excessive vacuum with a large flammable gas release as a result of slurry distribution; gas is ignited	New Hazardous Condition developed during review of original HAZOP to address DST flammable gas deflagration not identified in original HAZOP.
---	---	---	C106PHASE-II-1-04	Release of radioactive or hazardous materials from tank 241-AN-106 to the atmosphere due to flammable gas deflagration	Transfer of waste from 241-C-106 results in gas release event causes head space gas concentration above lower flammability limit in tank with ignition source	New Hazardous Condition developed during review of original HAZOP to address DST flammable gas deflagration not identified in original HAZOP.
---	---	---	C106PHASE-II-1-05	Release of liquid waste into annulus of slurry receiver DST due to tank equipment penetrating tank liner	Distributor breaks off dropping into tank and penetrates tank liner resulting in leakage to annulus	New Hazardous Condition developed during review of original HAZOP to address DST primary tank damage not identified in original HAZOP.
---	---	---	C106PHASE-II-1-06	Release of radioactive or hazardous materials from tank 241-AN-106 to atmosphere through failed filters due to steam bump	Overheating of waste due to equipment fault/failure or worker error and subsequent steam bump	New Hazardous Condition developed during review of original HAZOP to address DST potential steam bump event not identified in original HAZOP.
---	---	---	C106PHASE-II-1-07	Release of radioactive or hazardous materials from tank 241-AN-106 to atmosphere through failed filters due to tank bump	High waste temperature condition with ventilation balance upset or sudden barometric pressure change causing tank bump	New Hazardous Condition developed during review of original HAZOP to address DST potential steam bump event not identified in original HAZOP.
---	---	---	C106PHASE-II-1-8	Release of toxic material from tank 241-AN-106 to the atmosphere due to mixing of incompatible material	Waste transfer reacts with waste in tank resulting in the release of toxic gasses	New Hazardous Condition developed during review of original HAZOP to address DST toxic gas release not identified in original HAZOP.

Table 3-3. Generalized Hazardous Conditions Related to Oxalic Acid Dissolution in SST 241-C-106.

General Hazardous Condition	Numbers of Hazardous Conditions for Each Node									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**Total**
1. Oxalic Acid Spill	5	4	-	-	-	-	-	-	-	9
2. Oxalic Acid Damage to Tank Concrete Structure	-	2	2	-	2	2	-	-	-	8
3. CO_2 Generation Hazards	-	1	-	-	-	1	1	-	-	3
4. Chemical Reaction—Tank Pressurization	-	-	2	-	-	-	1	1	2	6
5. Chemical Reaction—Toxic Vapor Release	-	-	2	-	-	-	1	1	1	5
6. Criticality	-	-	2	-	-	1	-	2	1	6
7. Flammable Gas Deflagration	-	-	1	-	2	-	-	1	3	7
8. Waste Transfer Leak	-	2	-	1	-	1	18	-	-	22
9. Worker Exposure to Ionizing Radiation	-	-	1	1	2	-	3	-	-	7
10. Primary Tank Leak	-		3	2	-	1	-	1	1	8
11. HEPA Filter Failure—Exposure to High Pressure	-	-	-	4	-	1	3	-	-	8
12. Oxalic Acid Damage to Ventilation System	-	-	-	2	-	-	-	2	-	4
13. Unfiltered Release	-	-	-	2	-	-	-	-	-	2
Operational Upset	-	-	1	-	-	-	-	-	-	1
Total	5	9	14	12	6	7	27	8	8	**96**

Note:

HEPA = high-efficiency particulate air (filter).

The hazardous conditions for oxalic acid waste retrieval were also grouped according to FSAR representative accident (Rep Acc) number. The FSAR convention for all S0 and S1 consequence hazardous conditions is that no Rep Acc number is assigned, except in the case of nuclear criticality. However, in this safety evaluation, all hazardous conditions were assigned a designator to facilitate identification of the unique characteristics of oxalic acid dissolution of tank waste. For hazardous conditions that mapped to a Rep Acc analysis, the FSAR Rep Acc number was assigned with a lower case "x" added. This differentiates the S0/S1 consequence category hazardous conditions from the S2/S3 hazardous conditions that have an upper case "X" in their designations. However, some FSAR analyzed accidents that were initially estimated to have S2/S3 consequences were found to have S1 consequences after the analyses were complete. In these cases the upper case "X" is retained in the Rep Acc designation. A total of 33 hazardous conditions are in the non-Rep Acc S0/S1 consequence category.

The breakdown of these hazardous conditions is:

2 have an F0 initial frequency with no controls.

8 have an S0 initial safety consequence with no controls.

10 have an S1 initial safety consequence and an F1/F2 initial frequency, with no controls.

13 have an S1 initial safety consequence and an F3 initial frequency, with no controls.

For hazardous conditions that could not be mapped to a Rep Acc, the designation "ENV" (environmental only release), "OCC" (common industrial hazards), "RP" (exposure to ionizing radiation only), or "OPU" (operational upset – no release), were assigned and recorded in the Rep Acc column as appropriate. Of the 33 hazardous conditions in the S0/S1 consequence category, 19 are assigned to ENV, OCC, OPU, or RP. The breakdown of these hazardous conditions is:

9 designated as ENV

2 designated as OCC

1 designated as OPU

7 designated as RP

The break down of the hazardous conditions assigned Rep Acc designations is:

6 Nuclear Criticality

8 Mixing Of Incompatible Materials

7 Flammable Gas Deflagration

8 High-Efficiency Particulate Air (HEPA) Filter Failure

5 Tank Failure Due To Vacuum Or Degradation

9 Caustic Spray Leak *Note: Oxalic acid spray leaks are binned under this accident analysis. Oxalic acid spray leaks were found to have similar physical characteristics to caustic spray leaks, permitting binning under this representative accident. Oxalic acid has higher exposure limits as compared to caustic.*

9 Unfiltered Release

22 Waste Transfer Leak

3 Tank Bump *Note: The hazardous conditions related to Tank Bump are identical to those currently analyzed in the FSAR. Therefore, no additional evaluation was done in this safety evaluation.*

4.0 SAFETY EVALUATION

This safety evaluation considers hazardous conditions identified during the hazard evaluation of oxalic acid waste retrieval in SST 241-C-106. These hazardous conditions fall into two categories:

- Hazardous conditions related (mapped) to FSAR analyzed accidents
- Hazardous conditions having the potential for facility worker impact with an "anticipated" frequency (S1-F3).

This evaluation compares the oxalic acid waste retrieval process hazardous conditions to the analyzed accident in the FSAR and the TSR controls. The comparison is intended to:

- Identify unique accidents
- Evaluate whether the new hazardous conditions are bounded by the current accident analyses
- Evaluate if current TSR controls are appropriate and adequate
- Evaluate whether the new hazardous conditions affect equipment important to safety.

The representative hazardous conditions are listed in the FSAR, Appendix C. All hazardous conditions are documented in the hazard analysis database, described in the Hazard Analysis Database Report (HNF-SD-WM-TI-764). The hazard analysis database is considered part of the safety basis. The Rep Acc analyses, including a general description and listing of the associated controls, are documented in the FSAR, Chapter 3.0.

The hazardous conditions identified during the evaluation of the process of oxalic acid waste retrieval in SST 241-C-106 were grouped according to 13 generalized hazardous conditions. These hazardous conditions are presented in Table 3-2.

4.1 SAFETY EVALUATION PROCESS

The process for oxalic acid waste retrieval evaluation was as follows:

- **Grouping Hazardous Conditions By Release Phenomena:** Hazardous conditions were grouped according to similarities in accident phenomena.
- **Creating Generalized Hazardous Conditions:** Generalized hazardous conditions representing a group of hazardous conditions were created based on considerations of release phenomena, material at risk, and accident sequence. These hazardous conditions, where possible, were based on the existing FSAR analyzed accidents. The grouping was done for two reasons:

- The need to identify, unique phenomena and/or accidents not addressed in the current safety basis.
- The need to identify, information needed to establish consequence estimates for unique phenomena and/or accidents not addressed in the current safety basis.

- **Mapping Generalized Hazardous Conditions:** The generalized hazardous conditions were correlated (mapped) to Rep Accs analyzed in the FSAR. If a generalized hazardous condition could not be correlated to a Rep Acc, it represented a potential accident of a different type.
- **Mapping Specific Hazardous Conditions To FSAR Analyzed Accidents:** The individual hazardous conditions identified in the HAZOP were correlated (mapped) to Rep Accs analyzed in the FSAR. If a hazardous condition could not be correlated to a Rep Acc, it represented a potential accident of a different type.
- **Comparing Generalized Hazardous Conditions to FSAR Analyzed Accident:** The generalized hazardous conditions were compared to the FSAR analyzed accident to determine if there were any characteristics that could potentially result in an accident not bounded by FSAR analyzed accident.
- **Comparing Specific Hazardous Conditions to Safety Basis Hazardous Conditions:** The mapped hazardous conditions were compared to existing hazardous conditions in the safety basis as documented in the hazard analysis database. The focus of the comparison was to identify unique characteristics not addressed by current controls.
- **Comparing Specific Hazardous Conditions to FSAR Analyzed Accident:** The mapped hazardous conditions were compared to the FSAR analyzed accidents to determine if any were bounded by the analyzed accidents.
- **Evaluation of Existing Safety Basis Control Applicability:** The generalized hazardous conditions were evaluated against the safety basis controls. Specific parameters for the controls, such as surveillance periods, were evaluated to see if they remained valid. Also, equipment important to safety was evaluated to determine if the probability of failure or the consequence of failure was increased.
- **Identification of New Controls:** Each generalized hazardous condition that was identified as not being adequately addressed by existing safety basis controls was evaluated to determine what control strategy should be applied.

4.2 IDENTIFICATION OF A UNIQUE ACCIDENT

Do any of the newly identified hazardous conditions represent or provide an indication of a new type of accident?

The generalized and specific hazardous conditions developed for oxalic acid waste retrieval in SST 241-C-106. were compared to the hazardous conditions in the hazard analysis database. None of the hazardous conditions associated with an FSAR Rep Acc were found to be unique, insofar as they are analogous to existing hazardous conditions. Some hazardous conditions not associated with a Rep Acc were found to be unique, insofar as they were not analogous to existing hazardous conditions. These hazardous conditions were related to CO_2 generation. Exposure to CO_2 was evaluated as only a facility worker issue. The hazard evaluation and analysis process described in the FSAR does not assign Rep Accs to facility worker-only impact accident scenarios.

4.3 EFFECT ON FSAR ANALYZED ACCIDENTS

Do any of the newly identified hazardous conditions adversely affect the analyzed accident such that there would be a significant increase in the frequency of occurrence, an increase in the consequence of an analyzed accident, or an adverse effect on a TSR or other safety basis control?

Listed below are the evaluations of the 13 generalized hazardous conditions of concern associated with oxalic acid retrieval of the solid waste in SST 241-C-106.

4.3.1 Oxalic Acid Spill

<u>Generalized Hazardous Condition</u>: Exposure to a spray or pool leak of oxalic acid due to ruptured oxalic acid delivery transfer hose. The frequency of this hazardous condition was estimated to be "anticipated" (F3). The consequence of this hazardous condition was estimated to impact the onsite worker (S2).

<u>Related Rep Acc</u>: The Rep Acc most similar to a leak of oxalic acid is Rep Acc 17, Caustic Spray Leak. This accident is addressed in FSAR Section 3.3.2.4.9, "Caustic Spray Leak from Skid-Mounted Delivery System." The technical basis for this accident is a pressurized spray leak of caustic solution during a transfer to a waste tank. The FSAR estimated frequency for a caustic spray leak is "anticipated" (F3), without controls. The analysis evaluates maximum NaOH air concentrations at the onsite and offsite receptor locations. A parametric study was performed using the SPRAY Code to determine the worst-case solution concentration within the expected range of 5% to 50% NaOH. The worst-case small particle release rate was calculated over a range of NaOH concentrations. These calculations accounted for variation in viscosity and density with concentration. Results of the calculations indicated that a 12% solution was optimal regarding NaOH release rate as small particles. No radioactive materials are associated with this event. The results of the analysis show that toxicological consequence evaluation guidelines are exceeded for the onsite worker and potentially exceeded for the offsite individual

in the case of a cargo tanker pressurized rupture. No analysis of any other chemical was developed.

Existing Safety Basis Hazardous Conditions: A search of the hazardous conditions in the hazard analysis database found no specific instances of oxalic acid spills. A number of similar hazardous conditions related to transfer of caustic solutions were identified. Estimated frequencies ranged from F3 to F2 for the types of failures postulated for oxalic acid spills. Onsite worker (S2) safety impact is of concern for these hazardous conditions.

Discussion: Oxalic acid spill conditions were compared to the conditions analyzed for the caustic spray leak Rep Acc. The pressures and temperatures of the oxalic acid will comply with the existing requirements for caustic additions. The hoses used for transfer of oxalic acid to SST 241-C-106 would be of concern in a long-term design life (> 1 yr) or at temperatures > 300 °F but are adequate for short-term use at the expected operating temperature (20 to 25 °C) (RPP-16256, *241-C-106 Acid Dissolution Material Compatibility Assessment*).

Oxalic acid solubility in 20 to 25 °C water limits the maximum concentration to 1 M The physical properties (viscosity, density, and solids fraction) of the oxalic acid solution were compared to the analyses in HNF-SD-WM-CN-065, *Consequence Analysis of NaOH Solution Spray Release During Addition to Waste Tank.* The physical properties of the 1 M oxalic acid solution were found to be similar to either 5% or 10% NaOH. Both the 5% NaOH case and the 10% NaOH case had release rates of at least an order of magnitude lower than the bounding FSAR case. Therefore, the consequences of an oxalic acid leak were judged to be bounded by the sodium hydroxide case.

The toxicological evaluation guidelines were also examined. It was found that the evaluation guidelines for oxalic acid are higher (i.e., less stringent) than for sodium hydroxide (WSMS-SAE-02-0171, *ERPGs and TEELs for Chemicals of Concern*) by a factor of two for offsite "anticipated" conditions and by a factor of four for onsite "anticipated" conditions. Therefore the oxalic acid spill consequences were judged to be bounded by the current caustic spray leak Rep Acc.

The FSAR analyzed accident frequency is "anticipated" (F3) for caustic spray and pool leak accidents. Given that oxalic acid is not used in the long term (i.e., significant hose degradation does not occur), spray and pool leaks for oxalic acid are not expected to have frequencies appreciably different from the FSAR analyzed accident.

Existing Controls: The existing controls associated with this hazardous condition are found in the TSR Administrative Control (AC) 5.23, "Caustic Transfer Controls," and "Authorization for Sodium Hydroxide Transfer Operations in the Tank Farms with Additional Controls" (Boston 2002).

AC 5.23 requires that a program be maintained to control caustic spray leak toxicological hazards. The program has the following applicable program key elements:

a. Polyethylene (or similar) sleeving around delivery piping.

b. Caustic delivery system pressure shall be $\leq$ 125 lb/in^2 gauge or below the cargo tank's specified maximum allowable operating pressure, whichever is less.

c. Steel pipe shall be Schedule 10 or heavier wall thickness; polyethylene hose or other delivery piping shall be designed for appropriate pressure delivery. Caustic transfer piping shall have a wall thickness of $\geq$ 0.109 in.

d. Vendors shall be required to provide documentation that the cargo tanks used for caustic transfers meet U.S. Department of Transportation Specifications 306, 307, 312, 406, 407 or 412 in accordance with Title 49, *Code of Federal Regulations* (CFR), Part 178, "Specifications for Packagings," subparts .345, .346, .347, or .348, as applicable.

e. Traffic barriers shall surround the cargo tank (e.g., traffic cones or stanchions and chains).

Additional requirements related to sodium hydroxide transfer operations in the tank farms are described in Boston (2002) and the safety evaluation report (SER) attached to it. The U.S. Department of Energy (DOE), Office of River Protection, has specified that the controls in Boston (2002) and the SER are to be part of the tank farm safety basis.

Conclusions: The use of oxalic acid to retrieve waste has the potential for the same type of chemical spray leak accidents that the caustic spray leak AC requirements, Boston (2002), and attached SER are intended to address. The major difference is that oxalic acid has less restrictive evaluation guidelines for the onsite individual when compared to caustic. The FSAR analyzed accident frequency is "anticipated" (F3) for caustic spray and pool leak accidents and is the same for oxalic acid. Since the AC program key elements for caustic leaks are intended to mitigate the consequences of sprays and pools, the controls are equally valid for oxalic acid. No additional program key elements for AC 5.23 are needed. Relief from the pH verification requirement in Boston 2002 is necessary. A compensatory measure is required.

4.3.2 Oxalic Acid Damage to Tank Concrete Structure

Generalized Hazardous Condition: Release of radioactive or hazardous material from an SST due to oxalic acid from a surface spill or vapor space aerosols damaging the SST 241-C-106 concrete dome. The frequency of this hazardous condition was estimated to be "extremely unlikely" (F1). The consequence of this hazardous condition was estimated to impact the Offsite Individual (S3).

Related Rep Acc: The related Rep Acc is 13, "Tank Failure due to Vacuum or Degradation." This accident is addressed in FSAR Section 3.4.2.1, "Tank Failure Due to Excessive Loads," Rep Acc 12, as a sub accident. The technical basis for this accident is a collapse of a tank dome due to tank structural aging or excessive vacuum.

Excessive vacuum does not result in releases from the domes of DSTs or SSTs because the concrete tank walls and domes can withstand the postulated maximum vacuum conditions caused by fire, ventilation system failure, and cooling of the dome space from water spray.

DST and SST worst-case scenarios for tank structural aging also do not result in dome collapse. The dome would remain intact, although the tank walls may fail and there could be dome shifting. In the FSAR for the analysis of tank failure from a load drop bounds the consequences for accidents caused by aging and corrosion, and excessive vacuum. The load drop accident was estimated to occur at an "unlikely" (F2) frequency, without controls. The consequence of this accident was calculated to not exceed onsite or offsite evaluation guidelines for radiological dose consequences. The evaluation guidelines for toxic material exposure to onsite receptors are exceeded. Offsite evaluation guidelines are not challenged. There are no controls specified for dome failure due to excessive vacuum or degradation.

Existing Safety Basis Hazardous Conditions: One hazardous condition, ID CCF-17 (SST dome collapse caused by rebar corrosion) was found in the hazard analysis database, which could be considered similar to the hazard created by oxalic acid damage to tank concrete structures.

Discussion: Oxalic acid has the potential to degrade concrete structures. The extent to which oxalic acid aerosols would react with the exposed concrete in the SST dome has been evaluated in a memo (Appendix E). The conclusion from this memo is that the amount of oxalic acid that can reach the dome would be small. Aerosol deposition mechanisms do not support movement of large quantities of oxalic acid. The small amount of oxalic acid that could reach the dome is judged in the evaluation memo, Appendix E, to be inadequate to affect the strength of the concrete. Therefore the oxalic acid waste retrieval process impact on the FSAR Rep Acc "Tank Failure due to Vacuum or Degradation," does not increase the frequency of the FSAR analyzed accident. Consequences of dome collapse are not affected by the cause of the collapse.

Existing Controls: No TSR controls are applied to dome collapse caused by degradation or vacuum, although controls are applied for load drop events.

Conclusions: No controls were established from the results of the current accident analysis for dome collapse caused by degradation or vacuum. The evaluation memo, Appendix E, concludes that oxalic acid waste retrieval does not constitute a significant structural degradation threat; therefore, there is no increase in frequency or consequence and no additional controls are required.

4.3.3 CO_2 Generation Hazards

Generalized Hazardous Condition: Facility worker injury due to exposure to CO_2 gas due to oxalic acid reaction with concrete structures or carbonate waste. The frequency of this hazardous condition was estimated to be "unlikely" (F2). The consequence of this hazardous condition was estimated to impact only the facility worker (S1).

Related Rep Acc: Hazardous conditions affecting only the facility workers (S1) are not evaluated as Rep Accs identified in the safety basis. Therefore, worker exposure to CO_2 is not related to a Rep Acc.

Existing Safety Basis Hazardous Conditions: Several instances of asphyxiation caused by insufficient oxygen were found in the hazardous conditions in the hazard analysis database; however, there are no hazardous conditions specific to CO_2 generation.

Discussion: The addition of oxalic acid to SST 241-C-106 will result in the generation of CO_2 gas as the oxalic acid reacts with carbonate in the sludge. Carbon dioxide is a facility worker safety issue in regards to its asphyxiant properties. Gases that pose an asphyxiation threat are a commonly encountered industrial hazard. The contractually mandated company safety management programs (SMP) address commonly encountered industrial hazards.

Existing Controls: TSR AC 5.24, "Safety Management Programs." Specifically those programs associated with industrial hygiene address this hazard.

Conclusions: The activity does not involve confined spaces where facility workers would normally be present. The SMPs for facility worker protection address confined space and other asphyxiation hazards. No additional controls are required.

4.3.4 Chemical Reaction—Tank Pressurization

Generalized Hazardous Condition: Release of radioactive or hazardous material from SST headspace due to gas generation from reaction of tank waste with oxalic acid. The frequency of this hazardous condition was estimated to be "extremely unlikely" (F1). The consequence of this hazardous condition was estimated to impact the onsite worker (S2).

Related Rep Acc: The related Rep Acc is 03, "Mixing of Incompatible Material – Tank Pressurization." This accident is addressed in FSAR Section 3.3.2.4.12, "Mixing of Incompatible Material – Tank Pressurization." The FSAR estimated frequency for this accident is "anticipated" (F3), without controls. The offsite radiological dose and toxicological exposure consequences are below the evaluation guidelines, but the onsite radiological dose and toxicological exposure consequences are above the guidelines.

Existing Safety Basis Hazardous Conditions: There are no hazardous conditions in the hazard analysis database specific to oxalic acid reaction with tank waste. There are many identified hazardous conditions where a chemical reaction occurs causing tank pressurization and release of radioactive or hazardous material. Except for specificity of oxalic acid, the hazardous conditions currently listed in the hazard analysis database are similar in nature to those associated with oxalic acid dissolution of tank solids.

Discussion: These conditions are similar to the "Mixing of Incompatible Materials – Tank Pressurization" Rep Acc in the FSAR. The current bounding tank pressurization accident assumes an inadvertent addition of 12 M nitric acid that causes boiling in a double-contained receiver tank (DCRT). The steam generated results in failure of the HEPA filter and a release of steam and aerosol. Analysis of an inadvertent nitric acid addition during sludge dissolution activities is given below. In addition, the addition of oxalic acid to SST 241-C-106 will result in the generation of gas as the oxalic acid reacts with carbonate in the sludge to create carbon dioxide. Carbon dioxide generation could result in tank pressurization sufficient to fail the HEPA filters resulting in an unfiltered release of headspace gases and waste aerosols. Laboratory scale sludge dissolution tests (*Final Report for Tank 241-C-106 Sludge Dissolution, Phase II* [Herting 2003]) show that oxalic acid dissolution has the potential to generate significant quantities of carbon dioxide, which could result in tank pressurization. The actual rate of addition (40 gal/min or less) will limit the rate of carbon dioxide production to less than 240 ft^3/min (Appendix E), which is less than active ventilation flow rates; therefore, the rate of addition is an important assumption that requires protection.

The consequences of an inadvertent addition of nitric acid is of concern because of the possibility of the neutralization reaction causing the waste to boil and release significant quantities of steam and waste aerosols. This accident is evaluated in the calculation that follows.

The neutralization reaction is shown below:

$$NaOH + HNO_3 \quad NaNO_3 + H_2O$$

Gram moles of nitric acid available:

$$(5{,}000 \text{ gal nitric acid}) (3.785 \text{ L/gal}) (12 \text{ gram moles/L}) = 2.27 \times 10^5 \text{ gram moles}$$

where:

5,000 gal	= the expected delivery size
3.785 L/gal	= conversion factor (*CRC Handbook of Chemistry and Physics* [Weast 1981]).

Total heat of reaction:

$$(2.27 \times 10^5 \text{ gram moles}) (13.79 \text{ kcal/gram mole}) (4.184 \text{ kJ/kcal}) = 1.31 \times 10^7 \text{ kJ}$$

where:

13.79 kcal/gram mole	= heat of reaction released (HNF-SD-WM-CN-073, *Chemical Reaction in a DCRT*)
4.184 kJ/kcal	= conversion factor (Weast 1981).

Assuming the starting temperature of the waste-acid mixture is 40 °C, the energy required to heat the mixture to the boiling point is calculated as follows:

$$(110 - 40\ ^\circ C) (4.2 \text{ kJ/kg}\ ^\circ C) (25{,}000 \text{ gal}) (3.785 \text{ L/gal}) (1.1 \text{ kg/L}) = 3.06 \times 10^7 \text{ kJ}$$

where:

110 °C	= assumed boiling point of the waste-acid mixture
4.2 kJ/kg °C	= specific heat of water (Weast 1981)

1.1 kg/L	= assumed density of the waste-acid mixture.
14,000 gal	= total volume of sludge and oxalic acid (sludge volume from HNF-EP-0182, *Waste Tank Summary Report*)

Because the energy produced by the reaction is consumed before the mixture approaches the boiling point there would be no significant tank pressurization or waste release.

Oxalic acid addition also creates the potential for a tank pressurization event due to CO_2 generation. Laboratory scale sludge dissolution tests in Herting (2003) show that oxalic acid dissolution has the potential to generate significant quantities of carbon dioxide, which could result in tank pressurization. The actual rate of oxalic acid addition will determine the rate of carbon dioxide production. For example, it is estimated that an 80 gal/min oxalic acid addition rate results in a production rate of CO_2 of less than 477 ft^3/min (Appendix F). The radiological consequence is obtained by using the basic oxalic acid – carbonate reaction:

$$H_2C_2O_4 + CO_3^{-2} = CO_{2(gas)} + H_2O + C_2O_4^{-2}$$

This equation shows that 1 mole of oxalic acid ($H_2C_2O_4$) reacts with 1 mole of carbonate (CO_3^{-2}) to produce 1 mole of carbon dioxide gas (CO_2). Since radiological consequences are based on the total release, the total amount of carbon dioxide gas that can be generated during the operation is:

Oxalic acid concentration is nominally 1 g mole/liter in a saturated solution:

$$(30{,}000 \text{ gal})\ (3.785 \text{ L/gal})\ (1 \text{ g mole/L})\ (44.01 \text{ g/g mole}) = 5.00 \times 10^6 \text{ g}$$

where:

44.01 is the molecular weight of carbon dioxide.

Note: While only two cargo tankers are expected to be unloaded in a single shift, the unfiltered release radiological consequences are conservatively based on a complete 30,000 gal batch of oxalic acid.

Calculating the aerosol release:

$$(5.00 \times 10^6 \text{ g})\ (5 \times 10^{-5})\ (0.8)\ /\ (1{,}520 \text{ g/L}) = 1.32 \times 10^{-1} \text{ L}$$

where:

5×10^{-5} is the bounding airborne release fraction for the release of dissolved gases at pressures less than 50 lb/in^2. (DOE-HDBK-3010-94)

0.8 is the respirable fraction for the release of dissolved gases at pressures less than 50 lb/in^2. (DOE-HDBK-3010-94)

1,520 g/L is the density of the sludge. (BBI, *Best Basis Inventory*)

Assuming the resulting aerosol is 23% SST solids and 77% oxalic acid (9,000 gal sludge mixed with 30,000 gal oxalic acid), the onsite consequences of such a release are:

$$(1.32 \times 10^{-1} \text{ L}) (3.28 \times 10^{-2} \text{ s/m}^3) (2.44 \times 10^3 \text{ Sv/L}) (3.33 \times 10^{-4} \text{ m}^3\text{/s}) = 3.5 \times 10^{-3} \text{ Sv}$$

where:

2.44×10^3 Sv/L is the onsite unit liter dose for 23% SST solids aerosols. (RPP-5924)
3.28×10^{-2} s/m^3 is the onsite atmospheric dispersion coefficient. (RPP-5924)
3.33×10^{-4} m^3/s is the breathing rate. (RPP-5924)

Assuming the resulting aerosol is 23% SST solids and 77% oxalic acid, the offsite consequences of such a release are:

$$(1.32 \times 10^{-1} \text{ L}) (2.22 \times 10^{-5} \text{ s/m}^3) (3.82 \times 10^3 \text{ Sv/L}) (3.33 \times 10^{-4} \text{ m}^3\text{/s}) = 3.7 \times 10^{-6} \text{ Sv}$$

where:

3.82×10^3 Sv/L is the offsite unit liter dose for 23% SST solids aerosols. (RPP-5924)
2.22×10^{-5} s/m^3 is the offsite atmospheric dispersion coefficient. (RPP-5924)
3.33×10^{-4} m^3/s is the breathing rate. (RPP-5924)

The onsite radiological guideline for an anticipated release is 5.0×10^{-3} Sv and the offsite guideline is 1.0×10^{-3} Sv. Comparing the consequences to the guidelines shows that the consequences for the unfiltered release remain within evaluation guidelines.

Existing Controls: The existing TSR controls include a ventilation stack continuous air monitor (CAM) interlock system and HEPA filter controls. The specific control for this accident is found in the AC 5.12, "Transfer Controls." The applicable key element for chemical compatibility requires that chemical additions are ≥ pH of 8. Relief needs to be requested from this control to allow addition of oxalic acid to the tank.

Conclusions: The preventive control applied in the FSAR cannot be applied to the oxalic acid demonstration project because it requires chemical additions to have a pH of no less than 8. Oxalic acid additions cannot meet the current control. Although an inadvertent addition would not exceed evaluation guidelines, a preventive compensatory measure recommended to ensure that each delivery contains the expected oxalic acid before it is added to the tank. In addition, a compensatory measure to limit the rate of addition is required to protect an important analysis assumption. These requirements will need to be specified in the justification for continued operation (JOCK) for oxalic acid waste retrieval.

4.3.5 Chemical Reaction—Toxic Vapor Release

Generalized Hazardous Condition: Release of radioactive or hazardous material from SST headspace due to gas generation from reaction of tank waste with oxalic acid. The frequency of this hazardous condition was estimated to be "anticipated" (F3). The consequence of this hazardous condition was estimated to impact only the facility worker (S1).

Related Rep Acc: The related Rep Acc is 23, "Mixing of Incompatible Material – Toxic Vapor Generation." This accident is addressed in FSAR Section 3.3.2.4.11, "Mixing of Incompatible Material – Toxic Vapor Generation." The technical basis for this accident is the addition of caustic to adjust tank hydroxide concentration. This scenario was judged to be the most severe case of mixing materials to cause an intentional pH change.

The accident scenario without controls assumed a rapid uncontrolled addition of caustic (sodium hydroxide) to liquid waste of low pH in a DCRT. This resulted in the release of ammonia due to the solution becoming more basic. This scenario was considered representative because liquids pumped from the SST farms tend to be low pH solutions and require the addition of caustic. This accident was qualitatively assigned a frequency of "anticipated" (F3) because pH measurements in the supernatant of some SSTs are less than 9.27.

No onsite or offsite radiological dose consequences are calculated for this accident because it only involves toxic material. The onsite and offsite calculated sum-of-fractions for the ammonia concentrations were below the evaluation guidelines for an "anticipated" (F3) event (WHC-SD-WM-SARR-011, *Toxic Chemical Considerations for Tank Farm Releases*). Therefore, no SSCs or TSR controls were required. Because the consequences of the accident scenario without controls are well below the evaluation guidelines, no additional consequence analysis (i.e., accident scenario with controls) was performed.

Existing Safety Basis Hazardous Conditions: There are several hazardous conditions in the hazard analysis database that are related to generation of toxic vapors. However, only one hazardous condition was identified for an onsite release associated with toxic vapor generation in a DST and none were identified for an SST. The currently identified hazardous conditions do not address toxic vapor releases due to chemical reactions caused by oxalic acid additions or transfers.

Discussion: The oxalic acid waste retrieval hazardous conditions involving toxic gas generation are mapped to the current Rep Acc "Mixing of Incompatible Material – Toxic Vapor Generation." However, the accident analysis only evaluates releases of ammonia due to caustic addition to a low pH tank and the consequence analysis results are below evaluation guidelines. The HAZOP for oxalic acid waste dissolution identified several hazardous conditions that resulted in generation of toxic gases other than ammonia. The gases were Kn_{ox} and CO_2. Carbon dioxide generation is addressed in Sections 4.3.3 and 4.3.4. The Kn_{ox} hazardous condition identified in the HAZOP had consequences estimated that only resulted in facility worker impact. Based on the results reported in Herting (2003), releases of Kn_{ox} are expected to be small enough that the ammonia release scenario consequence bounds this condition.

Existing Controls: There are no related TSR-level or defense-in-depth controls because the calculated releases for the identified accident scenario are below evaluation guidelines.

Conclusions: No controls are required due to the low consequences

4.3.6 Criticality

Generalized Hazardous Condition: Release of radioactive or hazardous materials from SST or DST headspace due to oxalic acid reactions concentrating fissile material or selectively removing poisons causing an unplanned criticality. The frequency of this hazardous condition was estimated to be "anticipated" (F3). The consequence of this hazardous condition was estimated to impact the onsite worker (S2).

Related Rep Acc: The related Rep Acc is 01, "Nuclear Criticality." The technical basis for nuclear criticality safety of waste stored in underground tanks at the Hanford Site is summarized in FSAR Section 3.3.4.1, "Nuclear Criticality." A hypothetical accident caused by a mistransfer from the Plutonium Finishing Plant (PFP) was analyzed as the bounding accident. The accident was judged to have a frequency of occurrence of "beyond extremely unlikely" (F0). The frequency of occurrence is based on the normal waste storage activities that only involve mechanical processes (i.e., no chemical processes). The worst-case consequences calculated for a hypothetical criticality only impact the facility worker (S1) (i.e., do not challenge offsite or onsite evaluation guidelines). The control strategy adopted for this accident is an AC for nuclear criticality that takes the form of nuclear criticality safety evaluation reports (CSER). The key aspects of this program are designed to protect the assumptions in the CSER so that the accident frequency remains "beyond extremely unlikely." Any activities involving processes that affect the analysis assumptions require further analysis before approval is granted.

Existing Safety Basis Hazardous Conditions: There are no identified hazardous conditions in the hazard analysis database associated with chemically removing neutron poisons or selectively concentrating fissile material.

Discussion: Per AC 5.7, a criticality safety evaluation (HNF-15682, *CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using Oxalic Acid Dissolution*) was performed for liquid transfers from SST 241-C-106 to DST 241-AN-106 using an oxalic acid dissolution method that included the following activities:

- Oxalic acid insertion into SST 241-C-106
- Sludge material redistribution in SST 241-C-106
- Transfer of oxalic solution from SST 241-C-106 to DST 241-AN-106
- Discharge of oxalic solution into DST 241-AN-106, including redistribution of waste.

The analysis concluded that a nuclear criticality has a frequency that is "beyond extremely unlikely" (F0) for these activities. As is the case in the current safety basis, to ensure the analysis frequency result is valid, certain assumptions specified in the new CSER will require protection.

Existing Controls: The existing controls associated with this hazardous condition are found in AC 5.7, "Nuclear Criticality Safety," which requires that a program shall be maintained for ensuring WASTE remains subcritical. The applicable program key elements of this AC are:

a. Criticality limits and controls shall be documented in CSERs and implemented in criticality prevention specifications (CPS) and procedures.

b. Procedures shall be established for recovery from a CPS nonconformance.

c. Criticality safety training shall be provided for operations and technical personnel.

d. For transfers into the tank farms from non-tank farm facilities (e.g., PFP, B Plant) the following pretransfer conditions shall be met:

- The pH shall be ≥ 8. (this control will need to be waived for oxalic acid addition)

Conclusions: The use of oxalic acid to retrieve waste is addressed in CSER HNF-15682. Controls protecting analysis assumptions will be imlemented. The preventive pH control applied in the FSAR cannot be applied to the SST 241-C-106 oxalic acid waste retrieval project because it requires the waste to have a pH of not less than 8. This control will need to be waived. No additional key elements for AC 5.7 are needed.

4.3.7 Flammable Gas Deflagration

Generalized Hazardous Condition: Release of radioactive or hazardous materials from headspace in SST 241-C-106 or DST 241-AN-106 due to a deflagration involving flammable gas generation or release from addition of oxalic acid to the tank. The frequency of this hazardous condition was estimated to be "unlikely" (F2). The consequence of this hazardous condition was estimated to impact the offsite individual (S3).

Related Rep Accs: The related Rep Accs are 04, "Flammable Gas Deflagrations – DST," and 05, "Flammable Gas Deflagrations – SST." FSAR Section 3.4.2.2, "Flammable Gas Deflagrations," addresses this hazardous condition. Flammable gas deflagrations due to steady-state accumulation and flammable gas release events are considered. The FSAR estimates the frequency of flammable gas deflagrations in SSTs and DSTs to be "anticipated" (F3) with the radiological and toxicological consequences exceeding the offsite and onsite radiological and toxicological consequences, without application of controls. With the application of flammable gas controls, flammable gas deflagrations are prevented. The FSAR estimates the frequency of a flammable gas deflagration with potential failure of controls to be "extremely unlikely" (F1).

Existing Safety Basis Hazardous Conditions: For DSTs, two hazardous conditions were listed in the Hazard Analysis Database (HNF-SD-WM-TI-764) related to chemical reactions causing a flammable gas deflagration. One concerned over-pressurization and the other were related to a reaction-causing ignition. There were no instances identified for addition of chemicals that resulted in gas generation or additional or rapid gas release. There were no references to oxalic acid addition for any hazardous conditions associated with a flammable gas deflagration in a DST.

For SSTs, six hazardous conditions were listed in the hazard analysis database related to chemical reactions causing a flammable gas deflagration. One hazardous condition concerned over-pressurization, one related to a misroute, one to an exothermic reaction in the sludge, one to a reaction in isolated or abandoned equipment, and two related to over-pressurization. There were no references to oxalic acid of any sort associated with a flammable gas deflagration in an SST.

Discussion: The potential for a flammable gas deflagration in SST 241-C-106 or DST 241-AN-106 due to flammable gas generation or release from addition of oxalic acid to the SST 241-C-106 and transfer to DST 241-AN-106 was further evaluated. RPP-13547, *Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere*, concludes that neither steady state nor gas release event (GRE) conditions can render the SST 241-C-106 headspace flammable. Using reasonable assumptions the calculations show that the tank cannot approach 25% of the lower flammability limit (LFL), assuming passive ventilation. The evaluation states that given the large margin in the flammable gas calculations, additional evaluations are not required to conclude that the tank cannot attain a flammable atmosphere.

Gas release measurement tests were also performed with sludge from SST 241-C-106 and DST 241-AY-102 as documented in Herting (2003). These tests can be used to show that oxalic acid dissolution of the waste in SST 241-C-106 did not result in any significant hydrogen generation. The results show that the gas released is primarily CO_2, with traces of hydrogen (H_2) and methane (CH_4). There was evidence that some of the H_2 and CH_4 detected from the tests could be from previously generated gas dissolved in the waste. The H_2/CO_2 and CH_4/CO_2 ratios were much higher in the samples of gas collected before the start of the tests (i.e., before the oxalic acid addition). As such, the tests demonstrate that no new flammable gas generation mechanisms of concern would be caused by oxalic acid dissolution that could negate the conclusions that steady state or GREs could not create a flammable gas concentration in SST 241-C-106 that could ignite.

The FSAR identified SST 241-C-106 as a Facility Group 3 tank and DST 241-AN-106 as a Facility Group 2 tank. Recent analysis as documented in RPP-10006, *Methodology and Calculations for the Assignment of Waste Groups for the Large Underground Waste Storage Tanks at the Hanford Site*, identifies SST 241-C-106 and DST 241-AN-106 as being Waste Group C tanks. Waste Group C tanks are all DSTs and SSTs not included in waste groups A or B (i.e., those that do not have sufficient retained gas to approach 100% LFL if all of their respective retained gas were released). As such, flammable gas deflagrations due to oxalic acid dissolution of waste in SST 241-C-106 and transfer to DST 241-AN-106 does not create new unanalyzed flammable gas conditions, and the current TSR flammable gas controls are adequate to prevent flammable gas deflagrations, consistent with the FSAR flammable gas deflagration accident analysis conclusions.

The accident consequences with controls indicate that source term and radiological consequences are the same as without controls. The controls for this accident are targeted at preventing the coincidence of flammable gas and ignition sources. The oxalic acid waste retrieval process does not impact the control strategy identified for this accident nor does it alter any key assumptions or source terms. Thus, there can be no increase in consequences associated with these activities. The FSAR accident analysis assumes a frequency category of "anticipated" (without controls) and the frequency estimated for the oxalic acid waste retrieval process is unlikely.

Existing Controls: The existing controls in the safety basis address flammable gas deflagration. Application of these controls would prevent flammable gas deflagrations. However, the documented safety analysis (DSA) has been submitted to DOE for review and approval. In order to facilitate the transition from the FSAR to the DSA, the DSA flammable gas controls are proposed for the oxalic acid dissolution process for SST 241-C-106 because this activity will be continuing through the time that the DSA will be implemented. As such, a detailed discussion on the existing TSR controls is not provided, as these controls will be superseded by the JCO controls for flammable gas.

Conclusions: The risk for a flammable gas deflagration due to oxalic acid dissolution in SST 241-C-106 and waste transfer to DST 241-AN-106 is not increased above that currently analyzed in the FSAR, assuming the application of current TSR flammable gas controls. In order to facilitate the transition to the DSA, new TSR flammable gas controls will be proposed in the JCO for the oxalic acid addition process for SST 241-C-106. The current FSAR flammable gas controls will be applied to DST 241-AN-106 including the waste group re-evaluation requirement.

4.3.8 Waste Transfer Leak

Generalized Hazardous Condition: Release of radioactive or other hazardous materials due to a waste transfer leak to the atmosphere or ground surface during oxalic acid recirculation or during a waste transfer. The frequency of this hazardous condition was estimated to be "anticipated" (F3). The consequence of this hazardous condition was estimated to impact the onsite worker (S2).

Related Rep Accs: The related Rep Accs are 33A, "Waste Transfer Leak into Structure," 33B, "Waste Transfer Leak into Soil," 33C, "Waste Transfer Leak onto Soil Surface or into Atmosphere," and 33D, "Waste Transfer Leak due to Misroute." FSAR Section 3.3.2.4.7, "Waste Transfer Leak," addresses these hazardous conditions. The FSAR estimates the frequency of waste transfer leaks to be "anticipated" (F3), with the radiological and toxicological consequences exceeding the evaluation guidelines for the onsite receptor, but well below evaluation guidelines for the offsite receptor. The accident frequency remains "anticipated" with the application of controls. TSR controls are mandated to mitigate the consequences of waste transfer leaks.

Existing Safety Basis Hazardous Conditions: There is only one chemical reaction related hazardous condition identified in the hazard analysis database associated with a waste transfer leak into a structure. This has to do with multiple transfers through a HIHTL resulting in damage to the primary hose due to chemical incompatibility. There are a number of hazardous conditions related to corrosion-induced damage to piping.

There is one low-pH related hazardous condition in the hazard analysis database related to a waste transfer leak into soil (subsurface leak). This condition is a failure to adjust the pH for a PUREX transfer that results in a leak. There are a number of hazardous conditions related to corrosion-induced damage to piping.

There is one identified hazardous condition related to a waste transfer leak onto the soil surface or into the atmosphere. This condition is associated with an incompatible material causing a failure of the inner and outer hoses of a HIHTL. There are a number of instances where the cause of a leak is not specific, listed as failure from various causes.

The hazardous conditions identified for a misroute are similar in nature to those identified for the oxalic acid dissolution process.

Discussion: The effects of the dissolution operations were evaluated against Rep Acc "Waste Transfer Leak." Results from the sludge dissolution tests (Herting 2003) were used to calculate the radionuclides present in the transferred waste.

For supernatant, the unit-liter dose (ULD) was calculated using data from (Herting 2003). This data is considered to be more representative of what the SST 241-C-106 waste/oxalic acid mixture being transferred to DST 241-AN-106. The ULDs were calculated to be:

1.46×10^3 Sv/L (onsite); 1.60×10^3 Sv/L (offsite)

The maximum supernatant ULD analyzed for the FSAR Waste Transfer Leak Accident is:

1.72×10^3 Sv/L (onsite); 1.72×10^3 Sv/L (offsite)

For solids, the ULD consequences were calculated using Herting (2003):

1.64×10^4 Sv/L (onsite); 1.80×10^4 Sv/L (offsite)

Maximum solids ULD Analyzed for the FSAR Waste Transfer Leak Accident is:

1.70×10^6 Sv/L (onsite); 1.70×10^6 Sv/L (offsite)

From these results it is concluded that the parameters reported in the FSAR and evaluated in RPP-5667, *Stochastic Consequence Analysis for Waste Leaks*, bound the conditions seen during oxalic acid dissolution. Toxicological consequences are not calculated in RPP-5667. It is assumed in the FSAR that the onsite toxicological consequences are exceeded based on the analysis of radiological consequences. The same assumption is conservatively applied to waste transfers during oxalic acid dissolution. Even with conservative assumptions, the oxalic acid waste retrieval process remains bounded by the accident analysis. Thus, there would be no increase in the potential radiological or toxicological consequences of a waste transfer leak during oxalic acid dissolution recirculation or waste transfers than analyzed in the FSAR.

Waste will be recirculated within SST 241-C-106 through an existing HIHTL. Waste will be transferred through HIHTL to DST 241-AN-106. The HIHTL used will be a dedicated route between SST 241-C-106 and DST 241-AN-106. The waste transfer oxalic acid/slurry mixture is not expected to cause HIHTL corrosion to failure during the waste transfer process. As the FSAR estimated frequency of waste transfer leaks is "anticipated" with controls, there would be no increase in the FSAR estimated frequency of waste transfer leaks due to waste transfers following oxalic acid dissolution in SST 241-C-106.

Controls for waste transfer leaks are equally applicable to the oxalic acid waste retrieval process as to normal tank farm waste transfers.

Existing Controls: The TSR and structures, systems, and components (SSC) currently identified in the safety basis address waste transfer leaks. The oxalic acid waste retrieval process will not introduce factors that would invalidate these controls. These TSR controls include service water pressure detection systems; transfer leak detection systems; backflow prevention systems; transfer controls; encasement seal loop controls; emergency preparedness; process instrumentation and measuring and testing equipment; transfer pump administrative lock controls; transfer system cover removal controls; SMPs; and waste transfer system design features.

LCO 3.1.2, "Service Water Pressure Detection Systems," requires the service water pressure detection system to be operable.

LCO 3.1.3, "Transfer Leak Detection Systems," requires the transfer leak detection systems to be operable.

Material compatibility assessments (RPP-16256) have been performed on safety-related components such as transfer leak detection systems. The assessments determined that the safety-related components will perform their required safety functions.

LCO 3.1.6, "Backflow Prevention Systems," requires the backflow prevention systems to be operable.

Material compatibility assessments (RPP-16256) have been performed on safety-related components such as backflow prevention systems. The assessments determined that the safety-related components will perform their required safety functions.

AC 5.12, "Transfer Controls," includes program key elements for transfer system configuration management, operating requirements, and waste compatibility controls.

AC 5.13, "Encasement Seal Loop Controls" requires verification that prior to waste transfers, that all encasement seal loop drain line isolation valves associated with physically connected piping provides an open drain path to the pit.

AC 5.14, "Emergency Preparedness," provides program key elements for required elements to be addressed, seismic events, fire, waste leaks, waste leaks due to excavation, and verification of SSC status following significant, relevant, natural phenomena events.

AC 5.19, "Process Instrumentation and Measuring and Test Equipment," includes program key elements for identifying and tracing TSR-related instrumentation, instrumentation and equipment functional tests or calibrations, and records of instrumentation and equipment functional testing or calibration.

AC 5.20, "Transfer Pump Administrative Lock Controls," provides program key elements for demonstration of administrative lock of a waste transfer pump, reference to applicable LCOs for service water pressure detection systems, transfer leak detection systems, and backflow prevention systems.

AC 5.22, "Transfer System Cover Block Removal Controls," provides program key elements for radiation protection and hazardous material protection measures being in place prior to transfer system cover removal, and establishment of procedures to identify operator responses to the detection of a leak with a transfer system cover is off.

AC 5.24, "Safety Management Program," provides program key elements for the radiation protection program; hazardous material protection program; radioactive and hazardous waste management program; testing, surveillance, and maintenance program; fire protection program; and interfacing facilities program.

The TSRs also include design features as specified for transfer systems.

Conclusions: Waste transfers involving oxalic acid dissolution sludge and residues could involve waste transfer leaks. The frequency and consequences of these potential leaks are adequately addressed in the FSAR Rep Acc for waste transfer leaks, and the current TSR control set is adequate to address the risk from potential accidents.

4.3.9 Worker Exposure to Ionizing Radiation

Generalized Hazardous Condition: Worker exposure to ionizing radiation due to replacement or repair of equipment damaged or otherwise affected by oxalic acid. The frequency of this hazardous condition was estimated to be "anticipated" (F3) and the consequence was estimated to result in impact to only the facility worker (S1).

Related Rep Acc: Hazardous conditions affecting only the facility workers are not evaluated as Rep Accs in the safety basis; therefore, worker exposure to ionizing radiation is not related to a Rep Acc.

Existing Safety Basis Hazardous Conditions: There are a large number of hazardous conditions listed in the hazard analysis database related to worker exposure.

Discussion: Replacement of equipment or responding to upset conditions related to the oxalic acid dissolution process should not be materially different from any other similar tank farm operation.

Existing Controls: The AC 5.24, "Safety Management Programs," for radiation protection controls radiation exposure resulting from operations involving tank waste.

Conclusions: Oxalic acid waste retrieval does not introduce any unique radiation protection hazards. Specific measures to protect the facility worker are established as needed using existing procedures and work planning processes. No changes to the program are required.

4.3.10 Primary Tank Leak

Generalized Hazardous Conditions: Two generalized hazardous conditions are developed for primary tank leak events.

For DSTs, the hazardous condition is a release of tank waste from a DST primary tank to the annulus due to oxalic acid damage to the primary tank structure. The frequency for this hazardous condition is estimated to be "beyond extremely unlikely" (F0) based on the assumption that there is enough excess NaOH in the tank to maintain the waste at a pH > 8. The consequence is estimated to be below any level of concern (S0).

For SSTs, the hazardous condition is a release of tank waste from an SST to soil column due to oxalic acid damage to SST liner or reopening an existing leak sealed by tank waste or corrosion products. The frequency of this hazardous condition was estimated to be "anticipated" (F3) and the consequence was estimated to have no significant impact on any receptor (S0). However, the environmental impact was estimated to have the potential for significant release onsite (E2).

Related Rep Acc: Uncontrolled releases of radioactive material having only significant environmental impact (i.e., S0) are not evaluated as a Rep Acc. A release of tank waste from a damaged tank represents a major environmental impact (E2/E3) with no worker safety consequence (S0). Tank leaks into the soil are evaluated in FSAR Section 3.3.2.4.7, "Waste Transfer Leak," as previously discussed in Section 4.3.8.

Existing Safety Basis Hazardous Conditions: There are no hazardous conditions listed in the hazard analysis database of the FSAR related to chemical damage and subsequent waste leaks from SSTs. There were several hazardous conditions identified for mechanical damage to the SST liner. There were no specific hazardous conditions in the hazard analysis database identified for chemical damage to a DST primary tank. However, there were several hazardous conditions listed for failure of the primary tank with no specific cause.

Discussion: Carbon steels are generally rated unsatisfactory for use involving long-term oxalic acid exposure. Corrosion rates of greater than 50 mils/yr can be expected (RPP-16256). However, due to the short life of this project, the creation of a major leak from the SST liner or DST primary tank is not an immediate concern.

SST 241-C-106 is a sound tank, having been subjected to many hours of sluicing with fairly high-energy sluice jets. Thus, it is probable that existing leaks or structurally weak areas would have been identified.

The estimated frequency of an SST leak is "anticipated" (F3) based on the fact that a number of SSTs have leaked in the past. The oxalic acid waste retrieval process will not increase the frequency of tank failure appreciably.

Releases of radioactive waste to the environment are undesirable. Retrieving the waste from SSTs and achieving closure conditions has as its purpose the reduction of the likelihood of new tank leaks releasing waste to the soil subsurface. However, the environmental consequences from a leak that occurs as a result of oxalic acid waste retrieval in an SST will be no worse than any other SST leak.

Existing Controls: Controls that address hazardous conditions with the potential for severe environmental consequences (E2/E3) and no significant impacts on the public or onsite worker (S0/S1) are discussed in FSAR Section 3.3.2.3.4. Table 4-1 (FSAR Table 3.3.2.3.4-1, Environmental Controls) lists the specific FSAR controls credited for environmental protection. Controls not applicable to waste tank leaks to the soil subsurface as a result of the oxalic acid waste retrieval process are in italics. These environmental controls are implemented by tank farm operating programs and procedures.

Conclusions: The frequency and consequences of waste tank leaks are not altered by the oxalic acid waste retrieval process. Controls specified in the FSAR for protection of the environment are applicable to the oxalic acid waste retrieval process and adequately address environmental risk.

Material compatibility assessments (RPP-16256) have been performed on safety-related components such as transfer leak detection systems. The assessments determined that the safety-related components will perform their required safety functions.

Table 4-1. Environmental Controls.

Environmental controls	Comment
HEPA filters and annual aerosol testing	DSTs (including AWF tanks), SSTs, *DCRTs, catch tanks*[a], *204-AR Waste Unloading Facility, 244-CR Vault*, and portable exhausters
Waste tank confinement	Maintain negative pressure for actively ventilated waste tanks
Tank and pipe corrosion and integrity controls	Includes draining and flushing of lines, cathodic protection, waste pH and temperature (absolute and delta) controls
	Includes maintaining a minimum tank waste level when the ventilation system is operating to prevent uplifting of the tank bottom steel liner.
Leak detection systems	Includes pits, DSTs (including AWF tanks), SST monitoring wells, *and the RCSTS encasement leak detection systems*
DST Integrity Program	Includes visual and ultrasonic inspections of the DSTs
In-tank operations controls	*Includes design and operating controls on rotary mode core sampling and equipment handling to prevent penetration of the tank*
	For push mode core sampling: - *Hydraulic safety interlock testing and activation*[b] - *Modification to core drill trucks prohibited to prevent exceeding design pressure and downward force limits*[b]
Spill prevention and response	–

Notes:

[a]*Except catch tanks 241-A-302A, 241-TX-302C, 241-U-301B, 241-UX-302A, and 241-ER-311 which have no HEPA filtration systems.*

[b]*Defined in Wagoner, J. D., 1997, Clarification of Direction Related to the Generic Implications of the Use of Justification for Continued Operation (JCO) in the Unreviewed Safety Question (USQ) Process and Its Impact on Push Mode Core Sampling (PMCS) (letter 97-MSD-186 to H. J. Hatch, Fluor Daniel Hanford, Inc., March 8), U.S. Department of Energy, Richland Operations Office, Richland, Washington.*

AWF = aging waste facility.
DCRT = double-contained receiver tank.
DST = double-shell tank.
HEPA = high-efficiency particulate air (filter).
RCSTS = replacement cross-site transfer system.
SST = single-shell tank.

4.3.11 HEPA Filter Failure—Exposure to High Pressure

Generalized Hazardous Condition: Release of radioactive or hazardous materials from damaged HEPA filter due to aerosol generation during oxalic acid recirculation causing moisture buildup on HEPA filter with failure due to high differential pressure. The frequency of this hazardous condition was estimated to be "extremely unlikely" (F1). The consequence of this hazardous condition was estimated to only impact the facility worker (S1).

Related Rep Acc: The related Rep Acc analyzed in the tank farms safety basis is 06, "HEPA Filter Failure—Exposure to High Temperature or Pressure," which is summarized in FSAR Section 3.3.2.4.2, "High-Efficiency Particulate Air Filter Failure – Exposure to High Temperature or Pressure." The analysis assumes that an event occurs within a waste tank resulting in sufficient pressure to fail all prefilters and HEPA filters present in the ventilation system configuration. It is further assumed that a fraction of the inventory of tank waste accumulated on filters and ventilation system ductwork is released. Failure of the filters results in an unfiltered release pathway.

The FSAR estimated frequency of a HEPA filter failure due to high temperature or high pressure is "anticipated" (F3), with or without the application of controls. The onsite and offsite radiological consequences for SSTs with passive ventilation are below the evaluation guidelines for all release durations. The onsite and offsite toxicological consequences for all configurations and release durations are below the evaluation guidelines. The offsite radiological consequences for SSTs with active ventilation and DSTs are below the evaluation guidelines for all release durations. However, the onsite consequences for SSTs with active ventilation and DSTs are above the evaluation guidelines for a release duration of 1 yr.

Existing Safety Basis Hazardous Conditions: There are two hazardous conditions in the hazard analysis database associated with oxalic acid dissolution that are linked to high pressure induced failure of HEPA filters. One was due to aerosols collecting on the filter with failure caused by the high differential pressure, and the other was caused by using a compressor to blow down the transfer line and over pressurize the HEPA filter in the receiver DST.

Discussion: The airborne release fraction used in WHC-SD-WM-CN-054, *Waste Tank Ventilation System Waste Material Accumulations,* to determine the amount of respirable material released from the HEPA filter as a result of exposure to high pressure is 1.0×10^{-2}. This bounding value is based on information presented in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Section 5.4.2, for HEPA filters subjected to explosive stresses (shock, blast, and venting). This is not altered for HEPA filter failure scenarios developed for oxalic acid dissolution.

According to HNF-SD-WM-CN-099, *Radiological and Toxicological Analyses of Tank 241-AY-102 and Tank 241-C-106 Ventilation Systems*, Attachment 5, the total consequence consists of 0.018 rem from the instantaneous release of waste from the filter failure plus the consequence of a 10-min unfiltered release following filter failure.

The calculation for the unfiltered release consequences in the FSAR is based on the following parameters:

Headspace partition fraction:	1×10^{-10} (based on RHO-RE-SA-216, *Characterization of Airborne Radionuclide Particulates in Ventilated Liquid Waste Tanks*,).
Ventilation flow rate:	7,000 ft^3/min (3.3×10^3 L/sec) (HNF-SD-WM-CN-099)
χ/Q:	3.41×10^{-2} sec/m^3 (WHC-SD-WM-SARR-016)
ULD:	2.2×10^5 Sv/L (HNF-SD-WM-CN-099)
Breathing Rate:	3.3×10^{-4} m^3/sec (WHC-SD-WM-SARR-016)

The calculated dose from the unfiltered release is:

$$(1 \times 10^{-10})(3.3 \times 10^{3} \text{ L/sec})(3.41 \times 10^{-2} \text{ sec/m}^{3})(3.3 \times 10^{-4} \text{ m}^{3}\text{/sec})(2.2 \times 10^{5} \text{ Sv/L})$$
$$(10 \text{ min})(60 \text{ sec/min}) = 4.9 \times 10^{-4} \text{ Sv} = 0.049 \text{ rem}$$

And the total dose consequence for the FSAR analysis is 0.018 rem + 0.047 rem = 0.065 rem.

The parameters for the SST 241-C-106 oxalic acid dissolution operation would be as follows:

Headspace partition fraction:	1×10^{-8} (based on the RHO-RE-SA-216 for "agitated" tank waste. This agitated waste partition fraction is judged to be an appropriate and conservative choice for SST 241-C-106 oxalic acid dissolution operations.)
Ventilation flow rate:	1,000 ft^3/min (4.7×10^2 L/sec)
χ/Q:	3.28×10^{-2} sec/m^3 (from RPP-13482, *Atmospheric Dispersion Coefficients and Radiological/Toxicological Exposure Methodology for Use in Tank Farms*)
ULD:	8.7×10^3 Sv/L (based on 30 vol% solids, with a solids ULD = 2.9×10^4 Sv/L and a liquids ULD of 2.7×10^1 Sv/L. These ULD values are for SST 241-C-106, based on RPP-5924, *Radiological Source Terms for Tank Farms Safety Analysis*).
Breathing Rate:	3.3×10^{-4} m^3/sec

The result is an onsite radiological dose from a 10 minute unfiltered release of:

$$(1 \times 10^{-8})(4.7 \times 10^{2} \text{ L/sec})(3.28 \times 10^{-2} \text{ sec/m}^{3})(3.3 \times 10^{-4} \text{ m}^{3}\text{/sec})$$
$$(8.7 \times 10^{3} \text{ Sv/L})(10 \text{ min})(60 \text{ sec/min}) = 2.7 \times 10\text{-}4 \text{ Sv} = 0.027 \text{ rem}$$

And the total dose consequence for the an HEPA filter failure during oxalic acid waste retrieval is 0.018 rem + 0.027 rem = 0.045 rem.

These results show this accident is bounded by the current analysis. Because the filter-loading portion of the onsite dose is based on 200 mrem/h surveillance, changes in the unit-liter dose (ULD) are not expected to change the contribution from this source substantially.

Existing Controls: The existing controls associated with this hazardous condition are found in the AC 5.18, "HEPA Filter Controls," and LCO 3.1.4, "Ventilation Stack Continuous Air Monitor (CAM) Interlock Systems." The ventilation stack CAM interlock systems are designated as a safety-significant SSC.

AC 5.18 requires that a program shall be maintained to limit the radioactive material inventories on HEPA filters and prefilters, high-efficiency gas adsorber (HEGA) filters, and high-efficiency mist eliminators (HEME) to protect the source term assumptions in the accident analyses. The program also ensures the capability of HEPA filters to mitigate the consequences of specific accident scenarios. The applicable program key elements of this control are:

a. VERIFY periodically that the HEPA filter (inlet and exhaust) and exhaust prefilter housing radiation level is ≤ 200 mrem/h on contact. Replace the HEPA filters and prefilters before filter housing radiation levels exceed 200 mrem/h.

LCO 3.1.4, "Ventilation Stack Continuous Air Monitor (CAM) Interlock Systems," is established to mitigate the consequences of a long-term unfiltered release. The LCO applies to permanent and temporary ventilation systems. The LCO requires the ventilation stack CAM interlock systems to be operable for SSTs with active ventilation and for the primary tank stack CAMs for DSTs and AWF tanks.

Material compatibility assessments (RPP-16256) have been performed on safety-related components such as the ventilation stack CAM interlock systems. The assessments determined that the safety-related components will perform their required safety functions.

Conclusions: The comparison of the FSAR analysis consequences for HEPA filter failure with the consequences calculated for the same accident involving the conditions associated with the oxalic acid waste retrieval process show that the FSAR analysis is bounding. The HEPA filter failure accident is based on a hypothetical situation that results in a pressure pulse that fails the filter. The conditions involved in the waste retrieval process will not alter the frequency of the accident. The safety basis controls for the filter failure accident are valid for the conditions associated with oxalic acid waste retrieval. No additional or altered controls are required.

4.3.12 Oxalic Acid Damage to Ventilation System

Generalized Hazardous Condition: Release of radioactive or hazardous materials from damaged ventilation system due to degradation caused by oxalic acid aerosols. The frequency of this hazardous condition was estimated to be "anticipated" (F3). The consequence of this hazardous condition was estimated to only impact the facility worker (S1).

Related Rep Acc: The related Rep Acc is 18B, Unfiltered Release. See the discussion for the unfiltered release portion of the HEPA filter failure accident in Section 4.3.11, above, for analysis details.

Existing Safety Basis Hazardous Conditions: There are several unfiltered release hazardous conditions identified in the hazard analysis database related to damage to HEPA filters and ventilation systems. In some of these the mechanism of damage is not specific and would be representative for damage by oxalic acid attack.

Discussion: See discussion in Section 4.3.11, above.

Existing Controls: Stack CAM interlocks were chosen as a mitigative control for the unfiltered release accident. The CAM Interlock Systems are designated as a safety-significant SSC. The existing controls for stack CAM interlocks are found in the TSR LCO 3.1.4, "Ventilation Stack Continuous Air Monitor (CAM) Interlock Systems." The LCO requires the ventilation stack CAM interlock systems to be operable for the primary tank stack CAMs for DSTs and AWF tanks and for SSTs with active ventilation. AC 5.18, "HEPA Filter Controls," is also applicable.

Conclusions: See conclusions in Section 4.3.11, above.

4.3.13 Unfiltered Release

Generalized Hazardous Condition: Release of radioactive or hazardous materials from unfiltered leak paths in tank or ventilation structures due to equipment failure, natural phenomena, or human error. The frequency of this hazardous condition was estimated to be "anticipated" (F3). The consequence of this hazardous condition was estimated to only impact the facility worker (S1).

Related Rep Accs: The related Rep Acc are 18B, Unfiltered Release; 10, Natural Phenomena – High Wind; and 14, Natural Phenomena – Seismic. See 4.3.12, above, for details.

Existing Safety Basis Hazardous Conditions: The hazardous conditions identified in the Hazard Analysis Database (HNF-SD-WM-TI-764) for oxalic acid dissolution are identical in nature to those related to the Rep Accs.

Discussion: This accident is identical to the unfiltered release accident analyzed in Section 4.3.12, above. Only the initiator is different.

Existing Controls: See existing controls in Section 4.3.11, above.

Conclusions: The comparison of the FSAR analysis consequences for unfiltered release with the consequences calculated for the same accident involving the conditions associated with the oxalic acid waste retrieval process show that the FSAR analysis is bounding. The conditions involved in the waste retrieval process will not alter the frequency of the accident appreciably. The safety basis controls for the unfiltered release accident are valid for the conditions associated with oxalic acid waste retrieval. No additional or altered controls are required.

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5.0 CONTROL ALLOCATION

5.1 METHODOLOGY

The control decision/allocation process described herein was used to identify the set of controls required to either prevent or mitigate the hazardous conditions identified in the HAZOP. The control decision/allocation process centers on a review by knowledgeable individuals (see Appendix A) who evaluate the hazardous conditions and the selection of controls. The control decision/allocation process follows the steps outlined in FSAR section 3.3.1.5, "Control Identification."

Two control decision/allocation meetings were held. In both meetings the control decision/allocation team considered each of the generalized hazardous conditions developed from the results of the hazard evaluation, making appropriate changes based on additional knowledge or review of similar hazardous conditions already analyzed as part of the safety basis. Table 5-1 shows the combination of consequence and frequency where controls are not required, must be considered, or are required.

Table 5-1. Risk Matrix[a]

Likelihood	Consequence			
	S0	S1	S2	S3
F3 Anticipated	None required[d]	Controls considered[b]	Controls required[c]	Controls required[c]
F2 Unlikely	None required[d]	None required[d]	Controls considered[b]	Controls required[c]
F1 Extremely Unlikely	None required[d]	None required[d]	Controls considered[b]	Controls considered[b]
F0 Beyond Extremely Unlikely	None required[d]	None required[d]	None required[d]	None required[d]

Notes:

[a]Derived from Table 3.3.1.5-2 of the FSAR.
[b]Controls are considered for identification of safety structures, systems, and components and technical safety requirements.
[c]Identification of controls is required for safety structures, systems, and components and technical safety requirements.
[d]Controls are not required to prevent or mitigate hazardous conditions.
HNF-SD-WM-SAR-067, *Tank Farms Final Safety Analysis Report (FSAR),* Revision 3-O, CH2M HILL Hanford Group Inc., Richland Washington.

As a starting point in the control decision process, hazardous conditions directly related to an FSAR analyzed accident were given a preliminary suite of controls from the TSRs. The team then reviewed the proposed safety basis controls and any other relevant information. A consensus was reached on control selection and adequacy to prevent or mitigate the identified potential hazardous conditions.. If existing controls were not sufficient or inadequate for any reason, the control decision/allocation team proposed new or modified controls.

5.2 ALLOCATED CONTROLS

The results of the control decision/allocation meeting are documented in Table 5-2. A number of changes were made to the initial listing of hazardous conditions (see Appendix C, Table C-1). These changes are documented in Table 5-2 with discussion of the changes in the remarks for each hazardous condition.

Justification for individual frequency and consequence categories are documented in the Remarks column in Table 5-2. Definitions of the information presented in this table are included in Appendix B.

In accordance with Tank Farm FSAR methodology, all S0 and S1-F0/F1/F2 hazardous conditions do not require controls and the entry in the table is left blank. Also by convention, S0/S1 hazardous conditions are not associated with (assigned to) Rep Accs (Rep Acc), with the exception of criticality related hazardous conditions (Rep Acc 01, Nuclear Criticality), regardless of the frequency or consequence values. Note that all S2/S3 hazardous conditions regardless of frequency of occurrence, are assigned a Rep Acc designation.

5.2.1 Hazardous Conditions Not Assigned to a Representative Accident

The Tank Farm FSAR convention for all S0 and S1 consequence hazardous conditions is that no Rep Acc number is assigned, except those associated with criticality. However, in this safety evaluation, all hazardous conditions were assigned a designator to facilitate identification of the unique characteristics of oxalic acid dissolution of tank waste. The coding scheme is detailed in Section 3.3. The Rep Acc column of Table 4-2 records this coding.

The 13 hazardous conditions with an S1 consequence and an F3 frequency are adequately governed by SMPs to control the risk to the facility worker.

The hazardous conditions designated "OCC" or "RP" require consideration of controls as required by Table 4-1. The hazardous conditions designated "RP" are essentially the same as those that are part of the Hazard Evaluation Database. These hazardous conditions are adequately addressed by the Tank Farm Contractor (TFC) SMP for Radiation Control.

The "OCC" designated hazardous conditions are associated with the facility worker hazards that results from CO_2 that is evolved from the reaction of oxalic acid with carbonate in the waste. The presence of CO_2 represents an asphyxiation risk. The SMPs address this as a standard industrial hazard.

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-C-06	01X	Radioactive fission gases	Release of ionizing radiation and radioactive gas from tank 241-C-106 to the atmosphere due to criticality in the tank	Excessive solids in slurry flow towards slurry transfer pump	Release of radioactive gasses and direct radiation (neutrons)	None required	AC: Nuclear Criticality Safety	None required	None required	Controls based on accident analysis (Nuclear Criticality). And - HNF-15682, CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using oxalic acid dissolution.	S1	F0	E1	Changed S2 to S1 based on analyzed accident, Section 3.3.2.4 in FSAR. F0 based on control decision meeting showing that meeting CSER (HNF-15682) requirements makes criticality incredible. Note: Exemption from criticality pH limit is required.	A-1-a
C106PHASE -II-C-07	01X	Radioactive fission gasses	Release of radioactive or hazardous material from 241-C-106 to the atmosphere due to inadvertent criticality	Addition of oxalic acid to 241-C-106 selectively removes poisons from solids or concentrates fissile material resulting in inadvertent criticality	Criticality produces steam bump causing over pressurization and subsequent release	None required	AC: Nuclear Criticality Safety Compensatory Measure: Oxalic acid identification by test for each delivery of oxalic acid	None required	None required	Controls based on accident analysis (Nuclear Criticality). And - HNF-15682, CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using oxalic acid dissolution.	S1	F0	E1	Changed S2 to S1 based on analyzed accident, Section 3.3.2.4 in FSAR. Changed F3 to F0 based on control decision meeting showing that meeting CSER (HNF-15682) requirements makes criticality incredible. Removed "of ventilation system" from consequence as ventilation system is only a part of the tank that is pressurized and can release material. Note: Exemption from criticality pH limit is required.	A-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-F-06	01X	Fission product aerosols and tank headspace aerosols	Release of radioactive or hazardous material from 241-AN-106 due to criticality	Misroute into overground transfer line during recirculation transfers 1 M oxalic acid to receiver tank causing criticality	Criticality produces steam bump causing over pressurization and subsequent release	None required	AC: Nuclear Criticality Safety	None required	None required	Controls based on accident analysis (Nuclear Criticality). And - HNF-15682, CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using oxalic acid dissolution	S1	F0	E1	Changed S2 to S1 based on analyzed accident, Section 3.3.2.4 in FSAR. Changed F3 to F0 based on control decision meeting showing that meeting CSER (HNF-15682) requirements makes criticality incredible. Deleted "of ventilation system" from cause. Criticality caused events are not expected to cause ventilation system failure. Note: Exemption from criticality pH limit is required.	A-1-a
C106PHASE -II-H-04	01X	Fission product gases	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to inadvertent criticality	Transfer of waste containing oxalic acid to 241-AN-106 selectively removes poisons from solids or concentrates fissile material resulting in inadvertent criticality	Criticality produces steam bump causing over pressurization and subsequent release	None required	AC: Nuclear Criticality Safety	None required	None required	Controls based on accident analysis (Nuclear Criticality). And - HNF-15682, CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using oxalic acid dissolution	S1	F0	E1	Changed S2 to S1 based on analyzed accident, Section 3.3.2.4 in FSAR. Changed F3 to F0 based on control decision meeting showing that meeting CSER (HNF-15682) requirements makes criticality incredible. Deleted "of ventilation system" from cause. Criticality caused events are not expected to cause ventilation system failure. Note: Exemption from criticality pH limit is required.	A-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-H-05	01X	Fission product gases	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to inadvertent criticality	Inadvertent transfer of 1 M oxalic acid solution to 241-AN-106 selectively removes poisons from solids or concentrates fissile material resulting in inadvertent criticality	Criticality produces steam bump causing over pressurization of ventilation system and subsequent release	None required	AC: Nuclear Criticality Safety	None required	None required	Controls based on accident analysis (Nuclear Criticality). And - HNF-15682, CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using oxalic acid dissolution	S1	F0	E1	Changed S2 to S1 based on analyzed accident, Section 3.3.2.4 in FSAR. Changed F3 to F0 based on control decision meeting showing that meeting CSER (HNF-15682) requirements makes criticality incredible. Note: Exemption from criticality pH limit is required.	A-1-a
C106PHASE-II-I-01	01X	Radioactive fission gasses	Release of ionizing radiation and radioactive gas from slurry receiver DST to the atmosphere due to criticality in the tank	Slurry distributor or dropleg piles or concentrates solids in one place resulting in critical mass	High energy Waste release to atmosphere	None required	AC: Nuclear Criticality Safety	None required	None required	Controls based on accident analysis (Nuclear Criticality). And - HNF-15682, CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using oxalic acid dissolution	S1	F0	E1	S1/E1 based on analyzed accident, Nuclear Criticality. F0 based on control decision meeting showing that meeting CSER (HNF-15682) requirements makes criticality incredible. Note: Exemption from criticality pH limit is required.	A-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-C-01	03X	Tank waste	Release of radioactive or hazardous material to the atmosphere due to incompatible chemical reacting with the waste in 241-C-106 causing overpressure and possible failure of the HEPA filters	Acid cargo tank is filled with the wrong chemical resulting in a reaction in 241-C-106	Release of radioactive and hazardous materials	None required	Compensatory Measure: Oxalic acid identification by test for each delivery of oxalic acid	None required	None required	JCO for oxalic acid dissolution waste retrieval in C-106 will specify the testing requirements to ensure that oxalic acid is received.	S2	F3	E2	S2/E2 based on analysis in Section 3.3.2.4.12 of the Tank Farm FSAR. Changed from S3 to S2. F3 is based on anticipated worker error at chemical supply depot. Procurement specifications require supplier QA documentation that chemical specified is what was ordered. Most of the waste will have been removed as the result of initial liquid transfers. Deleted "from damaged ventilation system" as other release points are possible as well. Note: Exemption from pH limit is required.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-C-02	03x	Tank waste	Release of radioactive or hazardous material to the atmosphere due to heat of dilution of caustic in 241-C-106 causing overpressure and possible failure of the HEPA filters	Acid cargo tank is filled with Caustic resulting in a reaction in 241-C-106	Release of radioactive and hazardous materials	None required	Compensatory Measure: Oxalic acid identification by test for each delivery of oxalic acid	None required	None required	JCO for oxalic acid dissolution waste retrieval in C-106 will specify the testing requirements to ensure that oxalic acid is received.	S1	F3	E1	S1 is based on consensus of HAZOP team that caustic would not react with waste in 241-C-106 to the extent that it would affect more than the facility worker. F3 is based on worker error at chemical supply depot. Procurement specifications require supplier QA documentation that chemical specified is what was ordered. Deleted "from damaged ventilation system" as other release points are possible as well. Note: Exemption from pH limit is required.	B-1-a
C106PHASE-II-H-01	03X	Reaction products and tank headspace aerosols	Release of radioactive or hazardous material from waste receiver tank to the atmosphere due to transfer of waste containing excess oxalic acid reaction with tank waste causing overpressure of ventilation system and unfiltered release	Waste containing oxalic acid reacts with waste in 241-AN-106 generating heat or gasses resulting in over pressurization of the ventilation system	Release of radioactive or hazardous material through damaged HEPA filter	None	None	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F1	E2	S2/E2 is based on analyzed accident, HEPA Filter Failure-Exposure to High Temperature or Pressure. F1 is based on consensus of HAZOP team that oxalic acid containing waste reacting with receiver tank waste containing excess caustic to the extent that the HEPA filter is failed is an extremely unlikely event.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-I-02	04X	HEPA filter loading and tank headspace loading	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to a flammable Gas deflagration	Inadvertent transfer of 1 M oxalic acid solution caused failure of in-tank instrumentation causing a spark which ignites flammable gas	Waste release to atmosphere	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F1	F2	S2\F2 based on accident analysis, Flammable Gas Deflagration – DST. F1 is based on a consensus of the HAZOP team that aerosol generation from a transfer of oxalic containing waste into a tank containing excess caustic would be extremely unlikely to degrade in tank instrumentation to the extent that that a spark source would be created.	A-1-a
C106PHASE-II-H-02	04X	Tank waste	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to a flammable gas deflagration from waste transfer containing oxalic acid causing release of flammable gas (with ignition source)	Waste transfer containing oxalic acid to 241-AN-106 causes release of flammable gas resulting in flammable gas ignition with minor dome damage	Release of radioactive or hazardous material	SC: DST/AWF Primary Tank Vent Sys	LCO: DST/AWF Tank Vent Syss AC: Flammability Cntrls AC:Ign Cntrls AC:Flam Gas Mon Cntrls	None required	AC: Emergency Prep (Fire and Waste Leak)	Controls based on accident analysis (Flammable Gas Deflagration – DST).	S3	F3	E3	S3 is based on analyzed accident, Flammable Gas Deflagration. F3 based on analyzed accident, Flammable Gas Deflagration. Deleted "from damaged ventilation system" as other release points are possible as well.	A-1-a
C106PHASE-II-I-03	04X	Tank headspace aerosols and HEPA filter loading	Large release of radioactive or hazardous materials from slurry receiver DST to the atmosphere due to flammable gas deflagration	Influx of cold water spray into tank causing excessive vacuum with a large flammable gas release as a result of slurry distribution; gas is ignited	Waste release to atmosphere	None required	None required	None required	None required	No controls required based on low accident frequency.	S3	F0	E3	S3/E3 based on analyzed accident, Flammable Gas Deflagration. F0 based on consensus of HAZOP team that there not enough difference between slurry or sluice water temperature and tank headspace temperature to create sufficient vacuum to induce large gas release event.	A-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-I-04	04X	Tank headspace aerosols and HEPA filter loading	Release of radioactive or hazardous materials from tank 241-AN-106 to the atmosphere due to flammable gas deflagration	Transfer of waste from 241-C-106 results in gas release event causes head space gas concentration above lower flammability limit in tank with ignition source	Aerosolized radioactive waste release to atmosphere	None required	None required	None required	None required	No controls required based on low accident frequency.	S3	F0	E3	S3/E3 based on analyzed accident, Flammable Gas Deflagration. F0 based on consensus of HAZOP team that the heat loading caused by transfer of the remaining waste in 241-C-106 is, in and of itself, insufficient to induce a gas release event.	A-1-a
C106PHASE -II-C-11	05X	Tank waste	Release of radioactive or hazardous material from SST to atmosphere due to a flammable gas deflagration	A stronger acid instead of oxalic acid is shipped causing a generation of hydrogen gas (with ignition source) which ignites, damaging ventilation system with minor dome damage	Release of tank aerosols and HEPA loading	None required	Compensatory Measure: Oxalic acid identification by test for each delivery of oxalic acid	None required	None required	JCO for oxalic acid dissolution waste retrieval in C-106 will specify the testing requirements to ensure that oxalic acid is received.	S2	F2	E2	S2/E2 based on analyzed accident, Flammable Gas Deflagration. F2 based on the analysis documented in RPP-13547, Rev. 0, Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere that concluded that the waste volume in 241-C-106 is insufficient to generate sufficient gas to reach lower flammability limit with barometric breathing.	A-1-a
C106PHASE -II-E-03	05X	Tank waste	Release of radioactive or hazardous material from tank 241-C-106 to the atmosphere due to flammable gas deflagration	A hot spot or spark from transfer pump ignites flammable gas released during sluicing causing failure of the ventilation system and continued unfiltered release	Release of tank waste to atmosphere	None required	Compensatory Control: Waste Group Controls	None required	None required	JCO for oxalic acid dissolution waste retrieval in C-106 will specify the flammable gas deflagration controls.	S2	F2	E2	S2/E2 is based on analyzed accident, Flammable Gas Deflagration. F2 based on the analysis documented in RPP-13547, Rev. 0, Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere that concluded that the waste volume in 241-C-106 is insufficient to generate sufficient gas to reach lower flammability limit with barometric breathing.	A-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-E-06	05X	Tank headspace aerosols and HEPA filter loading.	Release of radioactive or hazardous material from unfiltered release paths to the atmosphere due to a flammable gas deflagration	Installation of new equipment (e.g. slurry pump) causes spark and ignites flammable gas	Waste release to atmosphere	None required	Compensatory Measure: Passive Ventilation Controls	None required	None required	JCO for oxalic acid dissolution waste retrieval in C-106 will specify the flammable gas deflagration controls.	S2	F2	E2	S2/E2 based on analyzed accident, Flammable Gas Deflagration F2 based on the analysis documented in RPP-13547, Rev. 0, Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere that concluded that the waste volume in 241-C-106 is insufficient to generate sufficient gas to reach lower flammability limit with barometric breathing. Deleted "from damaged ventilation system" as other release points are possible as well.	A-1-a
C106PHASE -II-D-02	06X	Tank waste	Release of radioactive or hazardous materials from tank 241-C-106 to atmosphere through failed filters due to moisture buildup	Moisture buildup on filters from acid recirculation causes excessive back pressure and failure	Waste release to atmosphere	None	None	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F2	E2	S2/E2 is based on analyzed accident, HEPA Filter Failure-Exposure to High Pressure or Temperature. F2 is based on experience with past practice sluicing Project W-320 with similar vent flow rates. Active vent system contains a de-mister.	B-1-a
C106PHASE -II-D-05	06X	Tank headspace aerosols and HEPA filter loading.	Release of radioactive or hazardous material from tank 241-C-106 to the atmosphere due to HEPA filter failure caused by high pressure	A leak in the slurry pump caused by a failed component or mis-assembly causes excessive aerosols which plug the HEPA causing failure by high differential pressure	Release of tank waste to the atmosphere	None	None	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F3	E2	S2/E2 conservatively based on analyzed accident, HEPA Filter Failure-Exposure to High Temperature or Pressure. This would be S1/E1 for a passively ventilated system. F3 based on aerosol generation and filter loading during sluicing.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-D-11	06X	Tank vapor space aerosols and HEPA filter loading	Release of radioactive or hazardous material to the atmosphere from damaged ventilation system due to temperature induced overpressure	Caustic flush of tank following last acid addition is wrong concentration causing heat generation and over pressurization of ventilation system and HEPA failure	Release of vapor space aerosols and HEPA filter loading	None	None	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F3	E2	S2/E2 based on analysis in Section 3.3.2.4.12 of the Tank Farm FSAR. Changed F1 to F3 based on control decision process. F3 is consistent with no controls accident.	B-1-a
C106PHASE-II-D-12	06X	Tank vapor space aerosols and HEPA filter loading	Release of radioactive or hazardous material SST headspace due to excess CO_2 generation	Initial addition of oxalic acid causes large release of CO_2 resulting in overpressure and HEPA filter failure	Release of vapor space aerosols and HEPA filter loading Potential facility worker hazard due to asphyxiation	None	Compensatory Measure: Delivery rate requirement	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip Compensatory Measure: Control on oxalic acid addition rate	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure). JCO for oxalic acid dissolution waste retrieval in C-106 will specify the oxalic acid addition rate.	S2	F3	E2	S2/E2 based on analysis in Section 3.3.2.4.2 of the Tank Farm FSAR. Changed F1 to F3 based on control decision process. F3 is consistent with no controls accident. Note: Exemption from pH limit is required.	B-1-a
C106PHASE-II-F-07	06X	Tank vapor space aerosols and HEPA filter loading	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to overpressure and failed HEPA filter	Misroute into overground transfer line during recirculation transfers 1 M Oxalic acid to receiver tank causing chemical reaction and overpressurization of ventilation system	Release of vapor space aerosols and HEPA filter loading	None	None	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip Compensatory Measure: Control on oxalic acid addition rate	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F3	E2	S2/E2 is based on analyzed accident, HEPA Filter Failure-Exposure to High Temperature or Pressure. F3 based on anticipated worker error.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-G-01	06X	Tank headspace aerosols and HEPA filter loading.	Release of radioactive or hazardous materials from slurry receiver DST to atmosphere due to unfiltered release through failed HEPA filter	Excessive slurry flow resulting in increased aerosol generation which loads HEPA filters causing high differential pressure and filter failure	Release of vapor space aerosols and HEPA filter loadings	None required	None required	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F2	E2	S2/E2 conservatively based on analyzed accident, HEPA Filter Failure-Exposure to High Temperature or Pressure. F2 based on aerosol generation from slurry transfer into tank unlikely to generate excessive aerosols.	B-1-a
C106PHASE -II-G-04	06X	Tank headspace aerosols	Release of radioactive or hazardous materials from tank 241-AN-106 to atmosphere due to unfiltered release through failed HEPA filters	Heat loading from new waste cause loading of HEPA filters which fail by high differential pressure with aerosol release	Waste release to atmosphere	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F0	E2	S2/E2 conservatively based on analyzed accident, HEPA Filter Failure-Exposure to High Temperature or Pressure. F0 based on limited heat loading from 2000 gal of waste from C-106. C-106 currently unventilated with no problems.	B-1-a
C106PHASE -II-G-20	06X	Tank headspace aerosols	Release of radioactive or hazardous material from the receiver tank to the atmosphere due to HEPA filter failure due to high pressure	Compressed air used to blow down transfer line exceeds the HEPA filter capacity in the receiver tank causing filter failure and release of contaminants	Release of DST headspace aerosols and HEPA filter loading	None	None	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F2	E2	S2/E2 is based on analyzed accident, HEPA Filter Failure-Exposure to High Temperature or Pressure. F2 is based on consensus of HAZOP team that it is unlikely that a compressor of a size to overpower the ventilation system would be used.	B-1-a
C106PHASE -II-B-07	13X	Tank waste	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid surface spill above SST during initial addition damages concrete tank dome resulting in dome collapse	Release of tank waste	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F0	E2	S2/E2 is based on analyzed accident, Tank Failure due to Excessive Loads F0 is based on control decision meeting consensus that the short duration of acid presence coupled with low reactivity of oxalic acid with concrete. Changed from F1.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-C-12	13X	Tank waste	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid aerosol from splash and spatter during initial acid addition damages concrete tank dome resulting in dome collapse	Release of tank waste	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F0	E2	S2/E2 is based on analyzed accident, Tank Failure due to Excessive Loads F0 is based on control decision meeting consensus that the short duration of acid presence coupled with low reactivity of oxalic acid with concrete. Changed from F1.	B-1-a
C106PHASE -II-E-04	13X	Tank waste	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid spray/aerosol from failed transfer pump damages concrete tank dome resulting in dome collapse	Release of tank waste	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F0	E2	S2/E2 is based on analyzed accident, Tank Failure due to Excessive Loads F0 is based on control decision meeting consensus that the short duration of acid presence coupled with low reactivity of oxalic acid with concrete. Changed from F1.	B-1-a
C106PHASE -II-E-05	13x	Tank headspace aerosols	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid spray/aerosol from failed transfer pump component damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	---	---	---	---	---	S1	F0	E1	S1 is based on limited release from unfiltered pathway through soil cover over tank. F0 is based on control decision meeting consensus that the short duration of acid presence coupled with low reactivity of oxalic acid with concrete. Changed from F2.	B-1-a
C106PHASE -II-F-01	13X	Tank waste	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid aerosol from re-circulation of acid during dissolution damages concrete tank dome resulting in dome collapse	Release of tank waste	None required	None required	None required	None required	No controls required based on low accident frequency.	S3	F0	E3	S3 is based on analyzed accident, Tank Failure due to Excessive Loads F0 is based on control decision meeting consensus that the short duration of acid presence coupled with low reactivity of oxalic acid with concrete. Changed from F1.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-A-01	17X	Oxalic acid in cargo tank	Release of hazardous material (oxalic acid) from the acid cargo tank to the ground surface due to a ruptured cargo tank	Failure to open vent causes cargo tank to collapse when pumped	Pool leak of oxalic acid	None required	None required	None required	AC: Caustic Trans Cntrls Note: Exemption from pH limit is required. AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Caustic Spray Leak).	S2	F3	E1	S2/E1 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. Changed from S1. F3 based on anticipated worker error.	C-2-a
C106PHASE-II-A-02	17X	Oxalic acid in cargo tank	Release of hazardous material from the cargo tank to the ground surface due to a ruptured tank	Oxalic Acid is pumped or drained out of the acid cargo tank at a rate too high for the vent causing a vacuum and collapse of the cargo tank	Pool leak of oxalic acid	None required	None required	None required	AC: Caustic Trans Cntrls Note: Exemption from pH limit is required. AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Caustic Spray Leak).	S2	F3	E1	S2/E1 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. Changed from S1. F3 is conservatively based on not knowing the capacity of the transfer pump. If the pump were not capable of pumping faster than the vent (creating a vacuum) then this would be an F0.	C-2-a
C106PHASE-II-A-03	17X	Oxalic acid in cargo tank	Release of hazardous material from the cargo tank to the ground surface due to a ruptured acid cargo tank	Oxalic Acid delivery truck is driven too fast causing it to tip over and rupture the cargo tank while traveling on the Hanford Site	Pool leak of oxalic acid	None required	None required	None required	AC: Emergency Preparedness	Controls based on accident analysis (Natural Phenomena - Seismic).	S2	F3	E1	S2/E1 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. F3 based on anticipated traffic/driving related accidents. This is not a unique condition and is applicable to any activities involving transportation of hazardous material.	C-2-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-A-04	17X	Oxalic acid in cargo tank	Release of hazardous material from the tank to the ground surface due to a ruptured acid cargo tank	Oxalic Acid Deliver truck is driven on a steep slope or other driving hazard such as avoiding oncoming traffic causing overturning and rupture of the cargo tank while traveling on the Hanford Site	Pool leak of oxalic acid	None required	None required	None required	AC: Emergency Preparedness	Controls based on accident analysis (Caustic Spray Leak).	S2	F3	E1	S2/E1 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. F3 based on anticipated traffic/driving related accidents. This is not a unique condition and is applicable to any activities involving transportation of hazardous material.	C-2-a
C106PHASE-II-B-01	17X	Oxalic acid in cargo tank	Release of hazardous material from a acid transfer hose to the atmosphere due to ruptured transfer hose	High pump pressure causes rupture of hose connecting pump to the 241-C-106 delivery hose	Spray leak of hazardous material (0.5M-1.0M oxalic acid solution)	None required	None required	None required	AC: Caustic Trans Cntrls Note: Exemption from pH limit is required. AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Caustic Spray Leak).	S2	F3	E2	S2/E2 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. F3 based on anticipated hose failures. Hose connection potential of failure due to misassembly or by being bumped.	C-2-a
C106PHASE-II-B-02	17X	Oxalic acid in cargo tank	Release of hazardous material from a damaged acid transfer pump to the atmosphere due to ruptured oxalic acid transfer pump seals	Blocked flow condition causes pump to continuously re-circulate oxalic acid Solution resulting in high temperatures and rupture of pump seals	Spray leak of hazardous material (0.5M-1.0M oxalic acid solution)	None required	None required	None required	AC: Caustic Trans Cntrls Note: Exemption from pH limit is required. AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Caustic Spray Leak).	S2	F3	E2	S2/E2 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. F3 based on high probability of blocked flow (misaligned valve, kinked hose).	C-2-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-B-03	17X	Oxalic acid in cargo tank	Release of hazardous material from leaking transfer piping to the atmosphere due to bad connection in piping during oxalic acid addition to SST 241-C-106	Improperly connected oxalic acid transfer piping leaks	Spray leak of hazardous material	None required	None required	None required	AC: Caustic Trans Cntrls Note: Exemption from pH limit is required. AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Caustic Spray Leak).	S2	F3	E2	S2/E2 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. F3 based on anticipated worker error in assembling piping.	C-2-a
C106PHASE-II-B-04	17X	Oxalic acid in cargo tank	Release of hazardous material from a ruptured transfer pipe to the atmosphere due to acid degrading the strength of the piping	Oxalic Acid reacts with transfer piping resulting in degraded strength and rupture or leak	Spray leak of hazardous material (0.5M-1.0M oxalic acid solution)	None required	None required	None required	AC: Caustic Trans Cntrls Note: Exemption from pH limit is required. AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Caustic Spray Leak).	S2	F2	E2	S2/E2 based on Caustic Spray Leak bounding accident, Section 3.3.2.4.9 of the Tank Farm FSAR. F2 based on conclusion of HAZOP team that oxalic acid would not react with normally available flexible hoses or mild steel primary transfer lines.	C-2-a
C106PHASE-II-A-05	17x	Oxalic acid in cargo tank	Release of hazardous material from the tank to the ground surface due to a leaking valve on acid cargo tank	Leaking valve on cargo tank during transport	Pool leak of acid on the road	None	None	None	None	No Safety SSCs or TSRs required – facility worker risk addressed by company Safety Management Programs.	S1	F3	E1	S1 based on limited pool size at any one place for moving vehicle. F3 based on anticipated worker error in not closing valve or anticipated valve failure.	C-2-a
C106PHASE-II-G-06	18AX	HEPA filter loading and tank headspace aerosols	Release of radioactive or hazardous materials from tank 241-AN-106 through failed filters due to tank bump	Cold water spray into tank (possible result of slurry distribution) chills head space causing tank vacuum inducing resulting tank bump	Waste release to atmosphere	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F0	E2	S2/E2 based on analyzed accident, Unfiltered Release. F0 based on insufficient heat loading in tank waste to raise dome space temperature above ambient slurry or service water temperature such that spray would cause a large pressure drop.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-I-06	18AX	HEPA filter loading and tank headspace aerosols	Release of radioactive or hazardous materials from tank 241-AN-106 to atmosphere through failed filters due to steam bump	Overheating of waste due to equipment fault/failure or worker error and subsequent steam bump	Waste release to atmosphere	SS: Temp. Monitoring Sys.	LCO: DST/AWF Tank Waste Temp. Cntrls AC: Process Instrument/Measure/Test Equip	None required	None required	Controls based on accident analysis (Tank Bump).	S2	F2	E2	S2/E2 based on analyzed accident, Unfiltered Release. F2 based on FSAR, Sect. 3.4.2.11 for steam bump as accident initiator for unfiltered released due to tank overpressure.	B-1-a
C106PHASE -II-I-07	18AX	HEPA filter loading and tank headspace aerosols	Release of radioactive or hazardous materials from tank 241-AN-106 to atmosphere through failed filters due to tank bump	High waste temperature condition with ventilation balance upset or sudden barometric pressure change causing tank bump	Waste release to atmosphere	SS: Temp. Monitoring Sys.	LCO: DST/AWF Tank Waste Temp. Cntrls AC: Process Instrument/Measure/Test Equip	None required	None required	Controls based on accident analysis (Tank Bump).	S2	F2	E2	S2/E2 based on analyzed accident, Unfiltered Release. F2 based on FSAR, Section 3.4.2.11 for steam bump as accident initiator for unfiltered released due to tank overpressure.	B-1-a
C106PHASE -II-D-06	18BX	Tank headspace aerosols and HEPA filter loading.	Release of radioactive or hazardous materials to the atmosphere due to seismically induced structural failure of the ventilation system	Seismic event causes failure of ventilation system	Tank dome space aerosols and HEPA loading release to atmosphere	None required	None required	None required	AC: Emergency Preparedness	Controls based on accident analysis (Natural Phenomena – Seismic)	S2	F1	E2	S2/E2 based on analyzed accident, Unfiltered Release. F1 based on seismic event of sufficient magnitude to seriously damage portable ventilation system such that releases would reach the 100-meter receptor considered extremely unlikely.	B-1-a
C106PHASE -II-H-08	18BX	Tank headspace aerosols	Release of radioactive or hazardous materials from tank 241-AN-106 ventilation system to atmosphere due to failed HEPA filter	Oxalic acid aerosols from splash and splatter during transfer damage HEPA filter with subsequent unfiltered release	Waste release to atmosphere	None required	None required	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S2	F2	E2	S2/E2 is based on analyzed accident, Unfiltered Release. F2 based on consensus of HAZOP team that aerosol generation from a drop leg would be unlikely to damage HEPA filters.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-B-08	18Bx	Tank headspace aerosols	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid surface spill during initial addition damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	---	---	---	---	---	S1	F2	E1	S1 is based on limited release from damaged dome through soil cover. F2 is based on consensus of HAZOP team that soil would neutralize acid prior to reaching concrete dome making damage enough to create an unfiltered leak path would be unlikely.	C-1-a
C106PHASE -II-C-13	18Bx	Tank headspace aerosols	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid aerosol from splash and splatter during initial acid addition damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	---	---	---	---	---	S1	F2	E1	S1 is based on limited release from damaged dome through soil cover. F2 is based on consensus of HAZOP team that damage to tank dome from oxalic acid aerosols sufficient to cause unfiltered release paths is unlikely.	C-1-a
C106PHASE -II-D-07	18Bx	Tank waste	Release of radioactive or hazardous materials from ventilation ducting due to high winds or tornado	High winds or tornado resulting in failed ventilation ducting and unfiltered release	Waste release to atmosphere						S1	F2	E1	S1 based on limited release from damaged ventilation system. F2 based on anticipated high wind.	C-1-a
C106PHASE -II-D-08	18Bx	Tank waste	Release of radioactive or hazardous materials from tank 241-C-106 ventilation system to atmosphere due to ventilation system leak	Ducting corrosion, instrumentation damage or seal deterioration caused by oxalic acid aerosols	Waste release to atmosphere	None required	None required	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: Process Instrument/Measure/Test Equip	Controls based on an accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S1	F3	E1	S1 based on limited release from small leaks in ventilation system. F3 based on anticipated corrosion or deterioration of HEPA seals in ventilation system with a small release affecting facility worker only.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-D-09	18Bx	Tank waste	Release of radioactive or hazardous materials from tank 241-C-106 ventilation system to atmosphere due to failed HEPA filter	Oxalic acid aerosols damage HEPA filter with subsequent unfiltered release	Waste release to atmosphere	None required	None required	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: HEPA Filter Cntrls AC: Process Instrument/Measure/Test Equip	Controls based on an accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S1	F3	E1	S1 is based on consensus of HAZOP team that damage to HEPA filter from oxalic acid attack would be limited in nature and would affect only the facility worker. F3 is based on unknown compatibility of HEPA filter and oxalic acid. De-entrainer will limit exposure of HEPAs to acid.	B-1-a
C106PHASE-II-F-02	18Bx	Tank headspace aerosols	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid aerosol from re-circulation of acid during dissolution damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	---	---	---	---	---	S1	F2	E1	S1 is based on limited release from unfiltered pathway through soil cover over tank. F2 is based on consensus of HAZOP team that damage to tank dome from oxalic acid aerosols sufficient to cause unfiltered release paths is unlikely.	C-1-a
C106PHASE-II-H-07	18Bx	Tank headspace aerosols	Release of radioactive or hazardous materials from tank 241-AN-106 to atmosphere due to ventilation system leak	Ducting corrosion or seal deterioration caused by oxalic acid aerosols caused by splash and splatter during transfer	Waste release to atmosphere	None	None	SS: Vent Stack CAM Intrlk Syss	LCO: Vent Stack CAM Intrlk Syss AC: Process Instrument/Measure/Test Equip	Controls based on an accident analysis (HEPA Filter Failure-Exposure to High Temperature or Pressure).	S1	F2	E1	S1 based on limited release from small leaks in ventilation system. F2 based on consensus of HAZOP team that aerosol generation from a drop leg would be unlikely to damage HEPA filters.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-C-09	23X	NO_x from tank headspace	Release of hazardous material from SST ventilation system to atmosphere due to Oxalic acid reacting with tank waste creating NOx	Addition of oxalic acid to 241-C-106 reacts with nitrites in tank waste creating NOx.	Release of NOx through SST ventilation system	None	None	None	None	No Safety SSCs or TSRs required – facility worker risk addressed by company Safety Management Programs.	S1	F3	E1	S1 is based on consensus of HAZOP team that liquid retrieval prior to acid dissolution in tank will leave insufficient nitrites to affect more than the facility worker. F3 is based on HAZOP team knowledge that this reaction will occur.	B-1-a
C106PHASE -II-C-10	23X	CO_2 from tank headspace	Worker is exposed to high concentrations of CO_2 resulting in severe injury or death due to asphyxiation	Oxalic Acid reacts with sodium carbonate in 241-C-106 producing CO_2 gas that is released through risers	Worker exposure to high concentrations of CO_2	None	None	None	Compensatory Measure: Control on oxalic acid addition rate	JCO for oxalic acid dissolution waste retrieval in C-106 will specify the rate acid may be added to the tank.	S1	F3	E1	S1 is based on HAZOP team consensus that CO_2 buildup will not affect co-located workers. F1 changed to F3 based on control decisions for no controls case and consistency with other hazardous conditions of similar character.	C-1-a
C106PHASE -II-I-08	23X	Toxic gasses	Release of toxic material from tank 241-AN-106 to the atmosphere due to mixing of incompatible material	Waste transfer reacts with waste in tank resulting in the release of toxic gasses	Toxic gas released through ventilation system	---	---	---		---	S1	F0	E1	S1/E1 based on analyzed accident, Mixing of Incompatible Material, Toxic Vapor Generation. F0 based on consensus of HAZOP team that sluiced waste will be compatible with any waste in the DST receiver tank.	C-1-a
C106PHASE -II-G-07	23X	Toxic gas	Release of hazardous gas to the atmosphere from tank 241-AN-106 due to reaction of slurry with DST waste	Slurry transfer caused hazardous gas release from tank	Hazardous gas release to atmosphere	None	None	None	None	No safety SSCs or TSRs required - facility worker risk addressed by company Safety Management Programs.	S1	F3	E1	S1/E1 based on limited release of hazardous gas released from slurry transfer. F3 based on anticipated release of ammonia. Changed "failure of ventilation system" to "reaction of slurry with DST waste" in hazardous condition to more accurately reflect the cause.	C-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-H-03	23X	Ammonia gas in tank waste	Release of ammonia from 241-AN-106 to the atmosphere due to transferred waste containing Oxalic acid causing a release of hazardous gas or fumes	Waste containing oxalic acid transfer to 241-AN-106 causes release of ammonia through the ventilation system	Release of ammonia from the DST ventilation system	None	None	None	None	No safety SSCs or TSRs required - facility worker risk addressed by company Safety Management Programs.	S1	F3	E1	S1 is based on worker exposure to ammonia. F3 based on limited ammonia release from waste transfer is anticipated.	C-1-a
C106PHASE -II-G-02	33AX	Tank waste	Release of radioactive or hazardous material from pit to ground surface due to waste transfer leak	High pressure results in rupture of hose-in-hose that drains back through the encasement hose to a pit which overflows	Waste Transfer Leak	None required	None required	SS: OGT Encas and Connect SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Encas Seal Loop Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F3 is based on no limitations for replacement of existing transfer pump.	C-2-b
C106PHASE -II-G-08	33AX	Tank waste	Release of radioactive or hazardous materials from 241-C-106 to the surface through pits and risers due to backflow of waste from slurry receiver tank	Siphon of waste from receiver tank to C-106 overfills tank with leak to ground	Tank waste leak to ground surface	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F0	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F0 based on potential for back siphon of waste from receiver tank.	C-2-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-G-09	33AX	Tank waste	Release of radioactive liquid from overflow of pit on receiver DST to soil surface due to transfer line leak	Jumper break or improper installation in pit with the drain plugged resulting in overflow of pit	Radioactive liquid and hazardous liquid release to surface	None required	None required	SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error. Includes pit in C-103.	C-2-b
C106PHASE-II-G-10	33AX	Tank waste	Release of radioactive liquid from overflow of pit on receiver DST to soil surface due to transfer line leak	Jumper break or improper installation in pit with drain open and pit cover off	Radioactive liquid and hazardous liquid release to surface	None required	None required	SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error.	C-2-b
C106PHASE-II-G-11	33AX	Tank waste	Release of radioactive or hazardous materials from pit to atmosphere due to spray leak from jumper	Seismic event damages jumper and breaches cover block by ground motion resulting in spray release	Aerosolized radioactive waste release to atmosphere	None required	None required	None required	AC: Emergency Preparedness	Controls based on accident analysis (Natural Phenomena - Seismic).	S2	F2	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F2 is based on seismic event of sufficient magnitude to damage a jumper is considered unlikely.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-G-19	33AX	Tank waste	Release of radioactive or hazardous materials to the atmosphere due to flammable gas deflagration in the waste transfer line	Plugging of transfer line occurs, flammable gas builds up and is ignited resulting in a breach of transfer line; pumping is started (collection in pit)	Surface waste leak	None required	None required	SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F1	E2	S2/L2 is based on analyzed accident, Waste Transfer Leak. F1 is based on consensus of HAZOP team that generating enough flammable gas to reach the LFL in the transfer line plus having an ignition source is extremely unlikely.	A-1-a
C106PHASE-II-G-24	33AX	Tank waste	Release of radioactive or hazardous material from pit due to inadvertent startup of a transfer pump	Inadvertent start up of existing vertical turbine transfer pump in 241-C-106 causes spray leak in pit	Release of tank waste	None required	None required	SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error.	B-1-a
C106PHASE-II-G-27	33AX	Tank waste	Release of radioactive or hazardous material from pit due to ruptured transfer line and drain to pit with subsequent overflow	Waste containing excess oxalic acid reacts with transfer line causing rupture and leak to containment	Waste transfer leak	None required	None required	SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F1	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F1 is based on consensus of the HAZOP team that oxalic acid will not react with transfer line such that it would cause a line rupture.	

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-G-12	33BX	Tank waste	Release of radioactive or hazardous waste due to seismic induced damaged to a transfer line	Seismic event damages overground transfer line by ground motion resulting in spray release	Surface Waste Leak				AC: Emergency Preparedness	Controls based on accident analysis (Waste Transfer Leak).	S2	F1	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F1 based on seismic event of sufficient magnitude to damage hose-in-hose transfer line considered extremely unlikely.	B-1-a
C106PHASE-II-G-13	33BX	Tank waste	Release of radioactive or hazardous material to the ground surface or atmosphere from a damaged overground transfer line due to wind blown missile	Missile caused by high wind or tornado penetrates overground transfer line causing surface or spray leak	Surface leak of radioactive waste	None required	None required	SS: OGT Encas and Connect SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Encas Seal Loop Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F2	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F2 is based on consensus of HAZOP team that high winds it is unlikely that high winds could cause penetration of a hose-in-hose system.	B-1-a
C106PHASE-II-G-15	33Bx	Tank waste in transfer line	Release of radioactive or hazardous material from a ruptured transfer hose to the atmosphere due to high compressed air pressure	Compressed air blowdown ruptures transfer line with release to atmosphere	Release of tank waste to the atmosphere	---	---	---	---	---	S1	F2	E1	S1/E1 is based compressed air hazard evaluation. F2 is based on consensus of HAZOP team that using a portable compressor with large enough capacity to damage a hose-in-hose transfer line is unlikely.	B-1-a

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-G-18	33BX	Tank waste	Small release of radioactive or hazardous materials from the transfer line to the atmosphere due to flammable gas deflagration in line, transfer started	Buildup of solids and flammable gas in transfer line with ignition resulting in breach of transfer line; pumping is started without knowledge of breach	Surface Waste Leak	None required	None required	SS: OGT Encas and Connect SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Encas Seal Loop Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F1	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F1 is based on consensus of HAZOP team that generating enough flammable gas to reach the LFL in the transfer line plus having an ignition source is extremely unlikely.	A-1-a
C106PHASE-II-G-22	33Bx	Tank waste in transfer lines	Release of radioactive or hazardous material from ruptured transfer line to ground surface	Compressed air flush done during transfer causes water hammer which ruptures line or damages connection	Release of tank waste	None	None	None	None	No safety SSCs or TSRs required - facility worker risk addressed by company Safety Management Programs.	S1	F3	E1	S1/E1 is based compressed air hazard evaluation. F3 is based on available energy of compressed air system to cause water hammer.	B-1-a
C106PHASE-II-G-26	33BX	Tank waste	Release of radioactive or hazardous material from a transfer line due to a leaking fitting or instrument	Acid degrades or damages in line pressure/flow transducers causing leak	Release of oxalic acid and dissolved tank waste	None required	None required	SS: OGT Encas and Connect SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Encas Seal Loop Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F3 based on anticipated material incompatibility.	C-2-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-F-04	33Bx	Tank waste and oxalic acid	Worker exposure to radioactive or hazardous material due to ruptured above ground transfer line	Oxalic acid recirculation line ruptures (improper assembly or other failure) with pool leak of oxalic acid with dissolved tank waste	Release of oxalic acid and dissolved tank waste	None required	None required	SS: OGT Encas and Connect SS: Trans Leak Detect Syss SS: Master Pump Shutdown Sys	LCO: Trans Leak Detect Syss AC: Trans Cntrls AC: Encas Seal Loop Cntrls AC: Emergency Prep AC: Process Instrument/Measure/Test Equip AC: Trans Sys Cover Removal Cntrls	Controls based on accident analysis (Waste Transfer Leak).	S1	F3	E1	S1 based on HAZOP team consensus that pool leak of oxalic acid with the limited amount of waste available in 241-C-106 would affect only the facility worker. F3 based on anticipated misassembly of transfer line.	C-2-b
C106PHASE-II-B-05	33DX	Tank waste	Release of radioactive or hazardous materials from service water system to atmosphere due to spray leak from starting slurry transfer pump in tank 241-C-106 during the flush of slurry transfer line	Slurry transfer pump in tank 241-C-106 is started during the flush of slurry transfer line; flush line is filled and pressurized resulting in flushline leak or backflow into service water system	Aerosolized radioactive waste release to atmosphere	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Trans Pump Admin Lock Cntrls	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Emergency Prep AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F3 based on anticipated worker error.	C-2-b
C106PHASE-II-B-06	33DX	Tank waste	Release of radioactive or hazardous materials from service water system to atmosphere due to spray leak from a backflow of tank waste into the service water system	Valve alignment is incorrect or leaking valves cause waste from the re-circulation pump in tank 241-C-106 backflows into service water system resulting in waste leak	Aerosolized radioactive waste release to atmosphere	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Trans Pump Admin Lock Cntrls	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Emergency Prep AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F3 based on anticipated worker error.	C-2-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-D-10	33DX	Tank waste	Release of radioactive or hazardous material from the service water lines to the surface due to a backflow of waste	Leaking valves or incorrect valve alignment causes backflow of waste into service water line during slurry pump operation with leak through unmonitored service water system	Leak of tank waste to the surface	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Trans Pump Admin Lock Cntrls	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Emergency Prep AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F3 based on sluice water system design taking no credit for backflow preventer. Water pump has higher head thank slurry pump, however slurry pump is higher pressure than water line pressure without booster pump.	C-2-b
C106PHASE -II-G-03	33DX	Tank waste	Release of radioactive or hazardous material from 241-C-106 to the ground surface due to siphon of waste from the AN farm receiver tank	Waste transfer pump shuts down resulting in a siphon of waste from the receiver tank to 241-C-106	Waste Transfer Leak	None required	None required	None required	None required	No controls required based on low accident frequency.	S2	F0	E2	S2/E2 is based on analyzed accident, Waste Transfer Leak. F0 is based on design that will dump waste into tank with drop leg well above the waste surface.	C-2-b
C106PHASE -II-G-23	33DX	Tank waste	Release of radioactive or hazardous material from service water line to atmosphere due to misroute	Back flow of waste into raw water flush line causes leak through open piping to ground surface	Release of tank waste	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Trans Pump Admin Lock Cntrls	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Emergency Prep AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F3 is based on worker error in valve configuration.	C-2-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-G-25	33DX	Tank waste	Release of radioactive or hazardous material from cargo tank due to misroute	Misroute back to water flush or acid cargo tank during waste transfer results in tank overflow	Release of tank waste	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Trans Pump Admin Lock Cntrls	SS: Pressure Switch Intrlk or Alarm Syss (Service Water Lines)	LCO: Service Water Pressure Detect Syss AC: Emergency Prep AC: Process Instrument/Measure/Test Equip	Controls based on accident analysis (Waste Transfer Leak).	S2	F3	E2	S2/E2 based on analyzed accident, Waste Transfer Leak. F3 based on anticipated worker error in valve alignment.	C-2-b
C106PHASE -II-G-16	33Dx	Tank waste in compressed air system	Worker exposure to ionizing radiation due to back flow of waste into compressed air system	Radioactive liquid gravity flows into compressed air system during line blowdown activities	Worker exposure to ionizing radiation	None	None	None	None	No safety SSCs or TSRs required - Facility worker risk controlled by TFC SMPs (Radiological Control).	S1	F3	E1	S1 is based on worker exposure to ionizing radiation only. F3 is based on relative elevations that would facilitate a backflow condition.	C-2-b
C106PHASE -II-C-03	ENV	Tank waste	Release of radioactive or hazardous material from 241-C-106 to the soil column due to tank liner breach	Sluice jet impinges on weak section of tank wall causing minor leak of water or slurry behind liner and subsequent leak to soil column	Release of tank waste to soil column	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S0	F2	E2	S0 based on depth of release that will not affect workers. E2 based on release of tank waste to soil column. F2 based on tank being at the end of design life.	C-3-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-C-04	ENV	Tank waste	Release of radioactive or hazardous material from 241-C-106 to the soil column due to tank liner breach	Sluice jet impinges on flashing causing minor leak of water or slurry behind liner and subsequent leak to soil column	Release of tank waste to soil column	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S0	F3	E2	S0 based on depth of release that will not affect workers. E2 based on release of tank waste to soil column. F3 based on tank on tank design where the lead flashing does not provide a seal when a jet of liquid impinges directly on the underside. Sluicer design limits sluice nozzle from reaching horizontal.	C-3-b
C106PHASE-II-C-08	ENV	Tank waste	Release of radioactive or hazardous material to ground from leaking SST due to acid reaction with tank liner and resulting leak	Addition of oxalic acid to 241-C-106 causes reaction with tank liner or dissolution of rust or tank waste plug in an existing leak path with resultant waste release to the soil column	Leak of tank waste to ground subsurface	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S0	F3	E3	S0 is based on direct worker exposure. E3 is based on waste release to soil column. F3 is conservatively based by the HAZOP team on unknown existence of small, sealed leak paths in liner.	C-3-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-D-03	ENV	Tank waste	Release of radioactive or hazardous materials from tank 241-C-106 to soil column due to vacuum induced tank damage	Ventilation system fan on with tank level too low and or inlet damper closed results in vacuum uplift of tank bottom and leak to soil column	Waste release to ground	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S0	F3	E3	S0 based on no exposure to workers. E3 based on waste leak to soil column. F3 based on active ventilation system capable of uplifting tank bottom.	C-3-b
C106PHASE-II-D-04	ENV	Tank waste	Release of radioactive or hazardous materials from tanks connected 241-C-106 via cascade lines to the soil column due to vacuum induced tank damage	Ventilation system fan on with tank level too low and or inlet damper closed results in vacuum uplift of tank bottom of interconnected tanks and leak to soil column	Waste release to ground	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S0	F1	E3	S0 based on no exposure to workers. E3 based on waste leak to soil column. F1 based on flow restriction of cascade line coupled with anticipated leak paths around a closed ventilation damper plus having to have all in leakage to all cascaded tanks blocked off makes this an extremely unlikely condition.	C-3-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE -II-F-05	ENV	Tank waste	Release of radioactive or hazardous material to soil column from waste tank due to misdirected spray of oxalic acid	Recirculation spray hits above tank liner causing a release to ground of contamination through concrete cold joints	Release of radioactive or hazardous material to soil	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S0	F3	E2	S0 based on no worker exposure. E2 based on possibility for significant release of contamination to soil column. F3 based on ability to spray above liner with no mechanical or administrative restrictions on recirculation spray nozzle.	C-3-b
C106PHASE -II-G-05	ENV	HEPA filter loading and tank headspace aerosols	Worker exposure to hazardous material (CO^2 asphyxiant) due to acid reaction with soil or tank	Oxalic acid spill from ruptured transfer line reacts with soil or concrete structures releasing CO^2 gas	Release of CO^2 gas which replaces air reducing oxygen content	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S1	F1	E2	S1 is based on HAZOP team consensus that CO^2 buildup will not affect co-located workers. E2 is based on HAZOP team consensus that oxalic acid spill could be a serious environmental problem. F1 is based on consensus of HAZOP team that limited amount of CO^2 generation plus no normally accessible enclosed spaces during acid dissolution and transfers make this an extremely unlikely event	C-2-b

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-H-06	ENV	Tank waste	Release of radioactive or hazardous material to DST annulus from leaking DST primary tank due to acid reaction with tank liner and resulting leak	Addition of waste containing oxalic acid to 241-AN-106 causes reaction with tank liner and resultant leak to annulus	Leak of tank waste to ground subsurface	None required	None required	None required	None required	No Safety SSCs or TSRs - Hazardous Conditions with significant environmental impact but low safety consequence (S0/S1) are addressed by Environmental Controls specified in Tank Farms FSAR Section 3.3.2.3.4, Environmental Protection (Table 3.3.2.3.4-1).	S0	F1	E3	S0 is based on no worker exposure. E3 is based on no release to environment. Changed from E0 to reflect the accident consequence in the no controls case. F0 changed to F1 to reflect the no controls case. Original F0 is based on consensus of HAZOP team that oxalic acid will not attack mild steel in a tank waste environment that normally contains an excess of caustic. However, long-term acid presence may result in leak to the soil subsurface.	C-3-b
C106PHASE-II-I-05	ENV	Tank waste	Release of liquid waste into annulus of slurry receiver DST due to tank equipment penetrating tank liner	Distributor breaks off dropping into tank and penetrates tank liner resulting in leakage to annulus	Loss of tank	None required	None required	None required	None required	No controls required based on low accident frequency.	S0	F0	E2	S0 based on no worker exposure E2 based on estimated consequence of tank bottom breach. Changed from E0 to conform to FSAR consequence designation protocol. F0 based on consensus of HAZOP team that slurry distributor is not massive enough to penetrate tank bottom.	C-3-b
C106PHASE-II-B-09	OCC	CO_2 gas	Worker exposure to hazardous material (CO_2 asphyxiant) due to acid reaction with soil or tank structures causes serious injury	Oxalic acid spill during initial addition reacts with soil or concrete structures releasing CO_2 gas	Release of CO_2 gas which replaces air reducing oxygen content	---	---	---	---	---	S1	F2	E1	S1 is based on limited exposure to facility workers only. F2 is based on consensus of HAZOP team that CO_2 buildup would be unlikely in the open areas above a tank.	NA

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-F-03	OCC	CO_2 gas in tank headspace	Worker exposure to hazardous material (CO_2 asphyxiant) due to acid reaction with soil or tank structures causes serious injury	Oxalic acid spill from damaged aboveground recirculation line reacts with soil or concrete structures releasing CO_2 gas	Release of CO_2 gas which replaces air reducing oxygen content	---	---	---	---	---	S1	F1	E1	S1 is based on HAZOP team consensus that CO_2 buildup will not affect co-located workers. E2 changed to E1 based on this hazardous condition meant to capture worker safety issue rather than environmental consequence. E2 was based on HAZOP team consensus that oxalic acid spill could be a serious environmental problem. F1 is based on consensus of HAZOP team that limited amount of CO_2 generation plus there are no normally accessible enclosed spaces during acid dissolution and transfers.	NA
C106PHASE-II-C-05	OPU	Tank waste	Transfer of contaminated sluice water or 241-C-106 waste to 241-C-105 due to backflow of sluice water/slurry through cascade line	Sluice jet impinges on cascade line causing water or 241-C-106 slurry to backflow to 241-C-105	Addition of waste into 241-C-105	---	---	---	---	No controls required for S0 event. Controls are not required as established by the Risk Matrix, Table 3.3.1.5-2 in the FSAR. By established convention, the related field in the Hazard Analysis Database is left blank.	S0	F3	E0	S0 based on no release to surface and no dose to workers. E0 based on no release of waste as 241-C-105 is considered to be a sound tank. F3 based on cascade line being open and accessible by the jet with no indexing limiter. This hazard would cause a program delay because of the prohibition of adding waste to a SST.	NA

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-C-14	RP	Residual tank waste in equipment	Worker exposure to ionizing radiation during replacement of equipment damaged by Oxalic acid	Oxalic acid leak in pit damages equipment resulting in additional worker exposure during repair activities	Worker exposure to ionizing radiation	None	None	None	None	No safety SSCs or TSRs required - Facility worker risk controlled by TFC SMPs (Radiological Control).	S1	F3	E1	S1 is based on facility worker exposure only. F3 is based on anticipated damage to pit equipment from oxalic acid exposure.	NA
C106PHASE-II-D-01	RP	Residual tank waste in filters	Worker exposure to ionizing radiation when changing HEPA filters in 241-C-104 and 241-C-105	Active ventilation system in 241-C-106 draws additional air through the cascade lines to 241-C-104 and 241-C-105 HEPAs causing additional filter changes and unplanned exposure	Worker exposure to ionizing radiation	---	---	---	---	---	S1	F2	E1	S1 based on facility worker exposure only. F2 based on operational history from past practice sluicing (Project W-320) showing only minimal pressure changes in cascaded tanks when active ventilation in 241-C-106 was operating.	NA
C106PHASE-II-E-01	RP	Tank waste trapped in transfer pump	Worker exposed to ionizing radiation when replacing a damaged transfer pump	Oxalic acid damages transfer pump which must be replaced causing unplanned dose to workers	Worker exposure to ionizing radiation	None	None	None	None	No safety SSCs or TSRs required - Facility worker risk controlled by TFC SMPs (Radiological Control).	S1	F3	E1	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated reaction of transfer pump to oxalic acid.	NA
C106PHASE-II-E-02	RP	Tank waste trapped in transfer pump	Worker exposed to ionizing radiation when replacing a damaged transfer pump	Electric motor hooked up backwards driving pump in reverse damages pump which must be replaced causing unplanned dose to workers	Worker exposure to ionizing radiation	None	None	None	None	No safety SSCs or TSRs required - Facility worker risk controlled by TFC SMPs (Radiological Control).	S1	F3	E1	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated worker error in hooking up pump.	NA

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN
C106PHASE-II-G-14	RP	Tank waste in transfer line	Personnel exposure to ionizing radiation due to excavation or construction activities uncovering shielding on hose-in-hose transfer lines	Error causes removal of shielding above hose-in-hose transfer line resulting in worker exposure to ionizing radiation	Unplanned exposure to ionizing radiation	None	None	None	None	No safety SSCs or TSRs required - Facility worker risk controlled by TFC SMPs (Radiological Control).	S1	F3	E1	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated worker error.	NA
C106PHASE-II-G-17	RP	Tank waste in transfer line	Worker exposure to ionizing radiation due to unplugging transfer line	Excess solids causes line plug, worker exposure clearing plug	Worker exposure to ionizing radiation	None	None	None	None	No safety SSCs or TSRs required - Facility worker risk controlled by TFC SMPs (Radiological Control).	S1	F3	E1	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated pick up of solids by transfer pump.	NA
C106PHASE-II-G-21	RP	Tank waste in transfer lines	Personnel exposure to ionizing radiation due to high winds	High winds uncover overground transfer lines	Worker exposure to ionizing radiation	None	None	None	None	No safety SSCs or TSRs required - Facility worker risk controlled by TFC SMPs (Radiological Control).	S1	F3	E1	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated high winds. Note, it would be extremely unlikely that wind would move the 2-in. thick steel shielding plates.	NA

Table 5-2. Control Allocation for Oxalic Acid Waste Recovery In SST 241-C-106.

ID	Rep Acc	Material at Risk	Hazardous Condition	Cause	Consequence	Prev SSC	Prev TSR	Mit SSC	Mit TSR	Control MEMO	Initial Safety Cons NC	Initial Freq NC	Env Cons	Remarks	BIN

Notes:

HNF-15682, 2003, *CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using Oxalic Acid Dissolution*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.
HNF-SD-WM-SAR-067, 2003, *Tank Farms Final Safety Analysis Report*, Rev. 3L, CH2M HILL Hanford Group, Inc., Richland, Washington.
HNF-SD-WM-TSR-006, 2003, *Tank Farms Technical Safety Requirements*, Rev. 2O, CH2M HILL Hanford Group, Inc., Richland, Washington.

AC = administrative control.
AWF = aging waste facility.
CAM = continuous air monitor.
CSER = criticality safety evaluation report.
DST = double-shell tank.
FSAR = final safety analysis report.
HAZOP = hazard and operability analysis.
HEPA = high-efficiency particulate air.
LCO = limiting condition for operation.
LFL = lower flammability limit.
NA = not applicable.
OCT = overground transfer.
SMP = safety management program.
SC = safety class.
SS = safety significant
SSC = structures, systems, and components.
SST = single-shell tank.
TFC = Tank Farm Contractor.
TSR = technical safety requirement.

5.2.2 Summary of Controls for Generalized Hazardous Conditions

All hazardous conditions related to nuclear criticality and any hazardous condition with an initial safety consequence of S2 or S3, regardless of frequency, are assigned a Rep Acc. There are 6 nuclear criticality and 58 higher consequence (S2 or S3) hazardous conditions related to one of the following analyzed accidents:

- Flammable Gas Deflagration (7 Conditions)
- High-Efficiency Particulate Air (HEPA) Filter Failure (8 Conditions)
- Mixing Of Incompatible Materials (8 Condition)
- Tank Failure Due To Vacuum Or Degradation (4 Conditions)
- Caustic Spray Leak (8 Conditions)
- Unfiltered Release (2 Conditions)
- Waste Transfer Leak (18 Conditions)
- Tank Bump (3 Conditions) *Note: The hazardous conditions related to Tank Bump are identical to those currently analyzed in the FSAR. Therefore, no additional evaluation was done in this Safety Evaluation.*

5.2.2.1 Oxalic Acid Spill. The AC 5.23 key elements for caustic leaks are valid for oxalic acid. However, pH verification in Boston (2002) is suspended by a compensatory measure in the oxalic acid waste recovery JCO.

5.2.2.2 Oxalic Acid Damage to Tank Concrete Structure. The current safety basis has no controls specified for this accident based on an estimated event frequency that is "beyond extremely unlikely" (F0). Oxalic acid waste retrieval does not constitute a significant structural degradation threat. No controls are required.

5.2.2.3 CO_2 Generation Hazards. No controls are required for onsite or offsite radioactive material exposure consequences due to this hazard. The TFC SMPs for facility worker protection address confined space and other asphyxiation hazards.

5.2.2.4 Chemical Reaction—Tank Pressurization. A preventive compensatory measure is necessary to ensure that each delivery contains the expected oxalic acid. The compensatory measure will be specified in the oxalic acid waste retrieval JCO. An analysis assumption was also identified as requiring protection. The maximum oxalic acid delivery rate will also be specified in the oxalic acid waste recovery JCO.

5.2.2.5 Chemical Reaction—Toxic Vapor Release. No controls required for this hazardous condition.

5.2.2.6 Criticality. Addition of oxalic acid to the waste in SST 241-C-106 requires analyses in the form of a CSER based on the requirements of AC 5.7, Nuclear Criticality. A new CPS based on the CSER will establish the necessary requirements to maintain the frequency of the accident "beyond extremely unlikely." No additional key elements for AC 5.7 are needed, although the pH verification requirement is superseded by the CPS defined from the CSER.

5.2.2.7 Flammable Gas Deflagration. In order to facilitate the transition to the DSA, new TSR flammable gas controls will be proposed in the JCO for the oxalic acid addition process in SST 241-C-106. The current TSR control set is adequate and sufficient to address flammable gas hazards in DST 241-AN-106.

5.2.2.8 Waste Transfer Leak. The current TSR control set is adequate and sufficient to address the risk from potential waste leak accidents.

5.2.2.9 Worker Exposure to Ionizing Radiation. Specific measures to protect the facility worker are established through the TFC SMPs as needed using existing procedures and work planning processes.

5.2.2.10 Primary Tank Leak. Controls specified in the FSAR for protection of the environment are applicable to the oxalic acid waste retrieval process and adequately address environmental risk.

5.2.2.11 HEPA Filter Failure—Exposure to High Pressure. The safety basis controls for the filter failure accident are valid and sufficient for the conditions associated with oxalic acid waste retrieval.

5.2.2.12 Oxalic Acid Damage to Ventilation System. The safety basis controls for the unfiltered release accident due to oxalic acid damage are valid and sufficient for the conditions associated with oxalic acid waste retrieval.

5.2.2.13 Unfiltered Release (Due To General Causes). The safety basis controls for the unfiltered release accident are valid and sufficient for the conditions associated with oxalic acid waste retrieval.

6.0 CONCLUSIONS

6.1 SUMMARY

No hazardous conditions that related to an FSAR Rep Acc were found to be unique; they are analogous to existing hazardous conditions. Some hazardous conditions not associated with a Rep Acc (S1/F3/E1) were found to be unique.

In most cases associated with an FSAR analyzed accident (i.e., mappable to a Rep Acc) the existing safety basis controls were judged to be applicable and adequate to control the risk. Hazardous conditions with only facility worker impact were judged to be adequately addressed by the controls established through TFC SMPs. For the few hazardous conditions for which existing safety basis controls were not judged to be applicable, a JCO will be issued that establish compensatory measures.

6.2 DETAILED CONCLUSIONS

6.2.1 Accidents not Assigned to a Representative Accident

Facility Worker Hazard - CO_2 Generation Hazards

The existing SMPs for facility worker protection address confined space and other asphyxiation hazards. No changes to the program are required.

Facility Worker Hazard - Exposure to Ionizing Radiation

Oxalic acid waste retrieval does not introduce any unique radiation protection hazards. Specific measures to protect the facility worker are established as needed using existing procedures and work planning processes. No changes to the program are required.

Significant Environmental Impact - Primary Tank Leak

The frequency and consequence of waste tank leaks is not materially altered by the oxalic acid waste retrieval process. Controls specified in the FSAR for protection of the environment are applicable to the oxalic acid waste retrieval process and adequately address environmental risk.

Material compatibility assessments have been performed on safety-related components such as waste tank structure. The assessments determined that the safety-related components will perform their required safety functions.

6.2.2 Accidents Assigned to a Representative Accident

Rep Acc 01, Nuclear Criticality

The use of oxalic acid to retrieve waste is an activity that is not addressed in the current CSER. The additional analyses will be documented in a new CSER and a new CPS that will establish the necessary requirements to maintain the frequency of the accident "beyond extremely unlikely." No additional key elements for AC 5.7 are needed, although the pH verification requirement is superceded by the CPS derived from the CSER.

Rep Acc 03, Mixing of Incompatible Material – Tank Pressurization

The preventive control specified in the FSAR cannot be applied to the oxalic acid demonstration project since it requires chemical additions to have a pH of no less than 8. Oxalic acid additions cannot meet the current control. A preventive compensatory measure needs to be applied to insure that each delivery contains the expected oxalic acid before it is added to the tank. In addition, a compensatory measure to limit the rate of addition is required to protect an important analysis assumption. The requirements will be specified in the JCO for oxalic acid waste retrieval.

Rep Accs 04/05 – Flammable Gas Deflagrations – DST/SST

The risk for a flammable gas deflagration due to oxalic acid dissolution in SST 241-C-106 and waste transfer to DST 241-AN-106 is not increased above that currently analyzed in the FSAR, assuming the application of current TSR flammable gas controls. In order to facilitate the transition to the DSA, new TSR flammable gas controls will be proposed in the JCO for the oxalic acid addition process.

Rep Acc 06 - HEPA Filter Failure – Exposure to High Pressure

The FSAR analysis bounds the consequence for HEPA filter failure. The conditions involved in the waste retrieval process will not increase the frequency of the accident because the FSAR estimated accident frequency is "anticipated" with or without controls. The safety basis controls for the filter failure accident are valid for the conditions associated with oxalic acid waste retrieval. No additional or altered controls are required.

Material compatibility assessments have determined that the safety-related components will perform their required safety functions.

Rep Acc 13, Tank Failure Due to Vacuum or Degradation

The current safety basis has no controls specified for this accident based on an estimated event frequency that is "beyond extremely unlikely" (F0). Controls are imposed for tank failure due to load drop accidents, which would also be applicable during oxalic acid dissolution operations. The evaluation provided by the memo from Closure Project Engineering Support, Appendix E concluded that oxalic acid waste retrieval does not constitute a significant structural degradation threat. Therefore, there is no increase in frequency or consequence and no additional controls are required.

Rep Acc 17, Caustic Spray Leak

The use of oxalic acid to retrieve waste has the potential for the same type of chemical spray leak accidents that the Caustic Spray Leak. AC 5.23 requirements address the risk of this accident. The major difference between the currently analyzed caustic accident and the oxalic acid accident is that oxalic acid has less restrictive evaluation guidelines for the onsite individual as compared to caustic. Therefore the accident involving oxalic acid is bounded by the current analysis. The FSAR analyzed accident frequency is "anticipated" (F3) for caustic spray and pool leak accidents and is judged to be the same for oxalic acid. Since the AC key elements for caustic leaks are intended to mitigate the consequences of spray and pool leaks, the controls are equally valid for oxalic acid. No additional key elements for AC 5.23 are needed. The ph verification requirement provided by Boston (2002) is superceded by a compensatory measure provided in the oxalic acid waste recovery JCO.

Rep Acc 18A - Tank Bump

The hazardous conditions related to Tank Bump are identical to those currently analyzed in the FSAR. Therefore, no additional evaluation was done in this safety evaluation.

Rep Acc 18B – Unfiltered Release (due to oxalic acid damage to ventilation system)

The comparison of the FSAR analysis consequences for unfiltered release with the consequences calculated for the same accident involving the conditions associated with the oxalic acid waste retrieval process show that the FSAR analysis is bounding. The conditions involved in the waste retrieval process will not alter the frequency of the accident appreciably. The safety basis controls for the unfiltered release accident are valid for the conditions associated with oxalic acid damage to the ventilation system. No additional or altered controls are required.

Material compatibility assessments have determined that the safety-related components will perform their required safety functions.

Rep Acc 18B - Unfiltered Release (due to general causes)

The comparison of the FSAR analysis consequences for unfiltered release with the consequences calculated for the same accident involving the conditions associated with the oxalic acid waste retrieval process show that the FSAR analysis is bounding. The FSAR estimated accident frequency is "Anticipated" with or without controls. The conditions involved in the waste retrieval process will not increase the frequency of the accident. The safety basis controls for the unfiltered release accident are valid for the conditions associated with oxalic acid waste retrieval. No additional or altered controls are required.

Material compatibility assessments have determined that the safety-related components will perform their required safety functions.

Rep Acc 23, Mixing of Incompatible Material – Toxic Vapor Generation

Bounded by FSAR analysis. No controls required.

Rep Acc 33, Waste Transfer Leak

Waste transfers involving oxalic acid dissolution sludge and residues could involve waste transfer leaks. The frequency and consequences of these potential leaks are bounded by the analysis in the FSAR Rep Acc for waste transfer leaks. The current TSR control set is adequate to address the risk from potential waste leak accidents.

Material compatibility assessments have determined that the safety-related components will perform their required safety functions.

7.0 REFERENCES

49 CFR 178, "Specifications for Packagings," *Code of Federal Regulations*, as amended.

AIChE (1992), *Guidelines for Hazard Evaluation Procedures*, American Institute of Chemical Engineers, New York, New York.

BBI, *Best Basis Inventory*, [database accessed June 10, 2003], internet address: http://twins.pnl.gov:8001.

Boston, H. L., 2002, "Authorization for Sodium Hydroxide Transfer Operations in the Tank Farms with Additional Controls," (letter 02-OSO-025/0202121 to E. S. Aromi, CH2M HILL Hanford Group, Inc., dated May 30), U.S. Department of Energy, Office of River Protection, Richland, Washington.

DOE-HDBK-3010-94, 1994, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, U.S. Department of Energy, Washington, D.C.

Ecology, EPA, and DOE, 1986, *Hanford Federal Facility Agreement and Consent Order*, U.S. Environmental Protection Agency, U.S. Department of Energy, and Washington State Department of Ecology, Olympia, Washington.

Herting, D. L, 2003, *Final Report for Tank 241-C-106 Sludge Dissolution, Phase II*, (letter FH-0301877 to D. A. Reynolds, CH2M HILL Hanford Group, Inc., dated May 8) Fluor Hanford, Richland, Washington.

HNF-15682, 2003, *CSER 03-011: Transfer from Tank 241-C-106 to Tank 241-AN-106 Using Oxalic Acid Dissolution*, Rev. 0, Fluor Hanford, Inc., Richland Washington.

HNF-EP-0182, *Waste Tank Summary Report*, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-SD-WM-CN-065, 2002, *Consequence Analysis of NaOH Solution Spray Release During Addition to Waste Tank*, Rev. 2D, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-SD-WM-CN-073, 2001,*Chemical Reaction in a DCRT*, Rev. 3, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-SD-WM-CN-099, 1998, *Radiological and Toxicological Analyses of Tank 241-AY-102 and Tank 241-C-106 Ventilation Systems*, Rev. 1E, Fluor Daniel Northwest, Inc., Richland, Washington.

HNF-SD-WM-SAR-067, 2003, *Tank Farms Final Safety Analysis Report*, Rev. 3L, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-SD-WM-TSR-006, 2003, *Tank Farms Technical Safety Requirements*, Rev. 2O, CH2M HILL Hanford Group, Inc., Richland, Washington.

PNNL, 2002, *Tank Waste Information Network System*, September 18, Tank Characterization Database, available at http://twins.pnl.gov/data/data.asp.

RHO-RE-SA-216, *Characterization of Airborne Radionuclide Particulates in Ventilated Liquid Waste Tanks*, Rockwell Hanford Operations, Richland, Washington.

RPP-5667, 2001, *Stochastic Consequence Analysis for Waste Leaks*, Rev. 0C, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-5924, 2003, *Radiological Source Terms for Tank Farms Safety Analysis*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-5926, 2003, *Steady-State Flammable Gas Release Rate Calculation and Lower Flammability Level Evaluation for Hanford Tank Waste*, Rev. 2A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-10006, 2003, *Methodology and Calculations for the Assignment of Waste Groups for the Large Underground Waste Storage Tanks at the Hanford Site*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13482, 2003, *Atmospheric Dispersion Coefficients and Radiological/Toxicological Exposure Methodology for Use in Tank Farms*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13628, 2003, *ALARA Review in Support of 241-C-106 Retrieval Operations*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-16256, 2003, *241-C-106 Acid Dissolution Material Compatibility Assessment*, Rev 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended

Weast, 1981, *CRC Handbook of Chemistry and Physics*, CRC Press, Inc., Boca Raton, Florida.

WHC-SD-WM-CN-054, 1996, *Waste Tank Ventilation System Waste Material Accumulations*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-SARR-011, 1996, *Toxic Chemical Considerations for Tank Farm Releases*, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

WSMS-SAE-02-0171, 2002, *ERPGs and TEELs for Chemicals of Concern*, Rev. 19, Westinghouse Safety Management Solutions,

APPENDIX A

HAZARDS AND OPERABILITY STUDY TEAM BIOGRAPHICAL INFORMATION

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Team Lead

William H. Grams — B.S. in Mining Engineering; M.S. in Mechanical Engineering. Mr. Grams has more than 20 years of experience in the nuclear industry, all of it with the disposal of high and low-level radioactive waste. He has over 15 years of experience at the Hanford Site including authorization basis (AB) assessments of new activities, accident analysis and release calculations, unreviewed safety question (USQ) screening and determinations, hazard assessments, and AB revisions. Other nuclear-related experience includes low-level waste certification, waste management assessments and audits, preparation of characterization requirements for low-level waste, preparation of design requirements for waste tank retrieval systems, and identification of regulatory requirements.

Acid Retrieval of Single-Shell Tank 241-C-106 Solids HAZOP Team Members:

W. Blaine Barton —

John F. Bores — B.S. Civil Engineering, B.S. Business Management. Twenty-two years of engineering and construction experience, including nuclear facities projects such as the Basalt Waste Isolation Project, Hanford Waste Vitrification Plant Project, and Hanford Tank Farms. Current work assignment includes quality assurance support for capital projects associated with immobilized waste and single-shell tank waste retrieval.

Keith E. Carpenter — B.S. Mechanical Engineering. Over 12 years experience in the design, construction, and operation of equipment related to the safe storage and transfer of radioactive waste material. Five years experience in project management of minor and major plant upgrades and systems.

Calvin H. Delegard — Resume not available

Michael P. Flasch — B.S. in Nuclear Engineering; Mr. Flasch has approximately 30 years of experience in the nuclear industry including 25 years of experience in the commercial nuclear power industry. He has experience in several areas including Engineering, Operations, and Quality Assurance. He has functioned as the Vice President of Engineering at two commercial nuclear utilities as a contracted employee from the Institute of Nuclear Power Operations. His nuclear-related experience includes considerable application of evolution and assessment responsibilities.

Robert D. Gustavson — Resume not available.

James L. Huckaby — PhD. in Chemical Engineering; M.S. in Chemical Engineering; B.S. in Chemistry. Mr. Huckaby has over 10 years of experience at the Hanford Site working on waste tank safety and single-shell tank (SST) retrieval issues. He has experience with SST headspace vapor and gas characterization, mixing dynamics, and ventilation rates.

James W. Jabara — Resume not available.

Thomas H. May — Resume not available.

Paul Patterson — Senior Reactor Operator, Hanford N Reactor; DOE Senior Technical Trainer; Certified DOE Reactor Control Room Simulator and Oral Board Examiner. Mr. Patterson has over 20 years of experience in nuclear power plant and facility operations, training, safety analysis, and risk management and procedure development. As a Senior Reactor Operator, his responsibilities included maintaining reactor safety during all modes of operation from the reactor control room. He has instructed reactor operator and senior reactor operator candidates and facility management in reactor process operations, heat transfer, and fluid flow, reactor physics fundamentals, and accident analysis and safety basis. As a consultant, facilitator, and technical writer, he supported various Hanford, Idaho National Engineering Laboratory, and Los Alamos National Laboratory projects over the past 13 years. He has led TSR implementation, hazard analysis, FSAR chapters 2, 3, 4 and 5 preparation for multiple facilities at Hanford and Los Alamos National Laboratory, and has facilitated standard risk management sessions and designed and facilitated multiple sessions focused on single issue (e.g., USQ, Alternatives Generation Analysis, etc.). He has participated in operational readiness reviews, designed and developed training and qualification programs, presented specialized training programs, and supported process and facility operating procedure development as well as performing on-shift process engineer duties during final stages of facility testing startup.

Scott R. Pierce — M.S. and B.S. in Mechanical Engineering; Registered Professional Engineer in the States of Washington and New Mexico; Mr. Pierce has 12 years of experience in the design, installation and testing of new systems and facilities. He has participated in the design of multiple facilities at Hanford, the Los Alamos National Laboratory, and the Lawrence Livermore National Laboratory. He has experience in all phases of design including pre-conceptual, conceptual, definitive design, and construction. He also has experience in the startup, testing, and operation of plants and facilities. Mr. Pierce has participated in several Operational Readiness Reviews for the U.S. Department of Energy. He has a strong background in piping (ASME B&PV Section III, B31.1/3, UPC, etc.), ventilation (ASME N509, N510, AG-1), and cooling systems. He also has performed prototype fabrication and development of mechanical devices for the nuclear industry. Mr. Pierce has hands-on experience with lasers, optics, and imaging hardware, as well as the development of software.

John G. Propson — B.S. in Electrical Engineering, Registered Professional Engineer in the State of Washington; Mr. Propson has more than 29 years of experience in the nuclear industry. He has over 17 years of engineering experience at the Hanford Site of which 12 years were related to Tank Farm activities. Other related nuclear experience includes 12 years of engineering experience in the design, construction, operation and maintenance of commercial nuclear power plant facilities.

Daniel A. Reynolds — M.S. in Chemical Engineering, Qualification Card as a Hanford Site Tank Farms Process Engineer, Professional Engineer in the State of Washington. Mr. Reynolds has worked at the Hanford Site for over 25 years. Most of his Hanford experience has been associated with the Tank Farms, mainly in the area of tank waste chemistry. Specific experience is in gathering chemistry-related data for the source terms used in the Safety Basis analysis.

Mr. Reynolds also has worked extensively on the Flammable Gas Program and the Organic-Nitrate Safety Program as part of the Tank Farms Safety Basis.

Ryan D. Smith — B.S. Mechanical Engineering. Six years of experience at the Hanford Site with the last three years specific to Nuclear Safety and Licensing (NS&L) support. NS&L Engineer for the Interim Stabilization, Characterization, and Vadose Zone programs. Extensive knowledge in flammable gas-related issues related to pumping waste to and from tank farm facilities. Key team member in establishing the safety basis for Interim Stabilization and reconciliation of the Los Alamos National Labs Safety Assessment with the Tank Waste Remediation Systems (TWRS) Basis for Interim Operations (BIO). Assisted in the transition of the TWRS BIO to the Final Safety Analysis Report as well as ongoing safety basis maintenance and clarification support.

Sheldon M. Stahl — B.S. in Secondary Ed., Mathematics Major; Mr. Stahl has more than 28 years of engineering experience in nuclear industries including commercial power plant design and construction, radioactive waste storage and remediation, nuclear material production facility decontamination and decommissioning, and nuclear weapons processing. He has seven years of experience at the Hanford Site in the Nuclear Safety Department for the Tank Farms. He was previously manager of the Tank Farms USQ Process Group and TWRS Safety Analysis Report (SAR) Engineering Group. He has performed multiple hazards and accident analyses and USQ evaluations for the Hanford Site, Pantex Plant, and Rocky Flats Site. He has developed numerous Safety Analysis Report documents, Justifications for Continued Operation (JCO), and Technical Safety Requirements (TSR). He was the Alternate Chairperson of the Rocky Flats Site Operational Review Committee, responsible for review and approval of site-wide authorization basis issues disposition, USQs, and JCOs, and evaluation of site safety management programs. He developed site policy and procedures for site implementation of DOE Orders 5480.21 (USQs), 22 (TSRs), and 23 (SARs). He developed and presented site USQ evaluator training courses, and recommended certification of site USQ Qualified Evaluators. He drafted, recommended, and reviewed site communications with DOE regulators. He performed management assessments of site USQ processes and evaluators. Other nuclear-related experience includes over 10 years as a Senior Quality Assurance Engineer, and ASQC certified QA auditor.

David W. Strasser — Resume not available.

Richard D. Williams — Resume not available.

W. F. Zuroff — BGS Degree University of Idaho; Mr. Zuroff has more than 30 years of experience in the nuclear industry including nuclear operations, instrument maintenance and plant engineering. He has over 15 years experience at the Hanford Site including equipment design, testing, operations, and USQ evaluations. Other nuclear-related experience includes preparation of design requirements, procurement specifications for nuclear monitoring systems.

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APPENDIX B

DEFINITIONS

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Definitions of information listed in Table 5-1 and C-1:

- **Item ID**: The item identification (ID); used to record a unique identifier for the hazardous condition.

- **Node**: The division of a process or activity into discrete segments is called a node. Each node represents a specific part of the process or activity. This division into nodes is designed to facilitate the hazard identification process.

- **Process Variable**: The characteristics of a process, such as flow, pressure, or temperature, which are used to define proper operation.

- **Guideword**: The guideword is the description of the divergence from the desired value for a given process variable, such as low to describe temperature below normal or optimum.

- **Hazardous Condition**: The hardware failures, operational faults, or conditions that could result in undesired consequences. The Hazardous Condition is a concise statement combining the Cause, Consequence, and Mode of radioactive material release.

- **Possible Cause of Deviation**: The causes that lead to the deviation from the process variable and resultant Hazardous Condition.

- **Immediate Consequence**: The potential consequences that could result from the postulated deviation.

- **Suggested Systems, Structures, and Components (SSCs)**: Potential systems, structures, and components are existing engineered features (hardware items) identified by the hazard and operability study (HAZOP) team that have the potential to mitigate or prevent the hazardous condition of concern. The engineered features are candidates for designation as safety-significant items for hazardous conditions that pose a significant threat to the health of facility workers and onsite personnel or safety-class for hazards that pose a significant threat to offsite individuals. These items should not be construed as being the "official" controls that would eventually be credited in the safety basis.

- **Suggested Technical Safety Requirements (TSRs)**: Technical safety requirements are existing controls identified by the HAZOP team that have the potential to mitigate or prevent the hazardous condition of concern. These items should not be construed as being the "official" administrative features that would eventually be credited in the safety basis.

- **Consequence Category (Con Cat)**: The consequence category is a code designator for the level of safety consequence associated with a hazardous condition. The consequence ranking is a "first cut," qualitative estimate of the safety severity of the consequences assuming no controls are present. The following system is used:

S0 Negligible safety concerns for the facility worker.

S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker.

S2 Potential significant radiological dose consequences or chemical exposure to onsite workers located outside the facility.

S3 Potential significant radiological dose consequences or chemical exposure to the offsite population.

Unless otherwise noted in the table, the environmental consequence is considered to have the same value as the safety consequence (e.g. S2 corresponds to E2). The environmental consequence ranking is a "first cut," qualitative estimate of the environmental severity of the hazardous condition assuming no controls are present. The following system is used:

E0 No significant environmental effect outside the facility confinement systems.

E1 Limited environmental discharge of hazardous material outside the facility.

E2 Large environmental discharge of hazardous material within the plant site boundary.

E3 Significant environmental discharges of hazardous material outside the plant site boundary.

- **Frequency Category (Freq Cat)**: The frequency category is a "first cut," qualitative estimate of the likelihood of the hazardous condition assuming no controls are present. The following system is used:

F3 Events that are expected to occur one or more times during the lifetime of the facility, categorized as "anticipated" events. The frequency range associated with this category is > 1E-02/yr.

F2 Events that could occur during the lifetime of the facility, but with low probability. Such events are categorized as "unlikely" and fall in the range of 1E-04/yr to 1E-02/yr.

F1 Events not expected to occur during the lifetime of the facility, categorized as "extremely unlikely." The frequency range associated with this category is 1E-06/yr to 1E-04/yr.

F0 Events categorized as "beyond extremely unlikely," with a frequency less than 1E-06/yr. Events in this category (such as meteor strike) are so unlikely they generally do not require special controls.

- **Remarks**: Miscellaneous observations or clarifying comments for a given item.
- **BIN:** A code that describes the release attributes of the hazardous condition.

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APPENDIX C

HAZARDS AND OPERABILITY STUDY RAW DATA TABLE

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Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node A: Acid Supply Cargo Tank (0.5M to 1.0M Oxalic Acid, 5000 gallon Cargo Tank)											
C106-ACID -A-01	A	Pressure	Vacuum	Release of hazardous material (Oxalic Acid) from the acid cargo tank to the ground surface due to a ruptured cargo tank	Failure to open vent causes cargo tank to collapse when pumped	Pool leak of Oxalic Acid	Vacuum Breaker	None Identified	S1	F3	S1 is based limited release from ruptured tank F3 based on anticipated worker error. Vacuum breaker can be verified closed by operations thru driver before pumping (work package).
C106-ACID -A-02	A	Flow	High Rate	Release of hazardous material from the cargo tank to the ground surface due to a ruptured tank	Oxalic Acid is pumped or drained out of the acid cargo tank at a rate too high for the vent causing a vacuum and collapse of the cargo tank	Pool leak of Oxalic Acid	Vacuum Breaker	None Identified	S1	F3	S1 is based on a limited release of acid from a DOT approved transport vehicle. F3 is conservatively based on not knowing the capacity of the transfer pump. If the pump were not capable of pumping faster than the vent (creating a vacuum) then this would be an F0
C106-ACID -A-03	A	Speed	Too Fast	Release of hazardous material from the cargo tank to the ground surface due to a ruptured acid cargo tank	Oxalic Acid delivery truck is driven too fast causing it to tip over and rupture the cargo tank while traveling on the Hanford Site	Pool leak of Oxalic Acid	None Identified	Emergency Preparedness (response procedures)	S2	F3	S2 based on conservatism related to inability to predict the exact location of the event. F3 based on anticipated traffic/driving related accidents. This is not a unique condition and is applicable to any activities involving transportation of hazardous material.
C106-ACID -A-04	A	Position	Wrong Location	Release of hazardous material from the tank to the ground surface due to a ruptured acid cargo tank	Oxalic Acid Deliver truck is driven on a steep slope or other driving hazard such as avoiding oncoming traffic causing overturning and rupture of the cargo tank while traveling on the Hanford Site	Pool leak of Oxalic Acid	None Identified	Emergency Preparedness (response procedures)	S2	F3	S2 based on conservatism related to inability to predict the exact location of the event. F3 based on anticipated traffic/driving related accidents. This is not a unique condition and is applicable to any activities involving transportation of hazardous material.
C106-ACID -A-05	A	Special	External Leak	Release of hazardous material from the tank to the ground surface due to a leaking valve on acid cargo tank	Leaking valve on cargo tank during transport	Pool leak of acid on the road	Dual Valves	Emergency Response	S1	F3	S1 based on limited pool size at any one place for moving vehicle F3 based on anticipated worker error in not closing valve or anticipated valve failure

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node B: Acid Pumping/Delivery System (Cargo Tank to SST)											
C106-ACID -B-01	B	Pressure	High Pressure	Release of hazardous material from a ruptured acid transfer hose to the atmosphere due to ruptured caustic transfer hose	High pump pressure causes rupture of hose connecting pump to the 241-C-106 delivery hose	Spray leak of hazardous material (0.5M-1.0M Oxalic Acid solution)	Pressure relief or reducing valve Sleeved transfer hoses	Safety Management Program (Hazardous Material Protection Program	S2	F3	S2 conservatively established by HAZOP Team F3 based on anticipated hose failures Hose connection potential of failure due to misassemble or by being bumped.
C106-ACID -B-02	B	Flow	No Flow	Release of hazardous material from a damaged acid transfer pump to the atmosphere due to ruptured Oxalic Acid transfer pump seals	Blocked flow condition causes pump to continuously re-circulate Oxalic Acid Solution resulting in high temperatures and rupture of pump seals	Spray leak of hazardous material (0.5M-1.0M Oxalic Acid solution)	Flow measurement instrumentation Sleeving on pressurized hoses and components	Safety Management Program (Hazardous Material Protection Program)	S2	F3	S2 conservatively established by HAZOP Team F3 based on high probability of blocked flow (misaligned valve, kinked hose)
C106-ACID -B-03	B	Special	External Leak	Release of hazardous material from leaking transfer piping to the atmosphere due to bad connection in piping during Oxalic Acid addition to SST 241-C-106	Improperly connected Oxalic Acid transfer piping leaks	Spray leak of hazardous material	Sleeving of pressurized components	Safety Management Program (Hazardous Material Protection Program)	S2	F3	S2 conservatively established by HAZOP Team F3 based on anticipated worker error in assembling piping
C106-ACID -B-04	B	Reaction	Side Reaction	Release of hazardous material from a ruptured transfer pipe to the atmosphere due to acid degrading the strength of the piping	Oxalic Acid reacts with transfer piping resulting in degraded strength and rupture or leak	Spray leak of hazardous material (0.5M-1.0M Oxalic Acid solution)	Sleeving of pressurized components	Safety Management Program (Hazardous Material Protection Program)	S2	F2	S2 conservatively established by HAZOP Team F2 based on conclusion of HAZOP team that Oxalic Acid would not react with normally available flexible hoses or mild steel primary transfer lines.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-B-05	B	Temperature	Low	Release of hazardous material from acid transfer hose to the ground due to ruptured hose	Freezing cause rupture of acid transfer hose	Leak of hazardous material (0.5M-1.0M Oxalic Acid solution) to soil	Sleeving of hose	Safety Management Program (Hazardous Material Protection Program)	S2	F3	S2 conservatively established by HAZOP Team F3 based on anticipated low temperature conditions
C106-ACID-B-06	B	Special	External Leak	Release of hazardous material from the acid transfer hose to the ground due to drips for quick disconnect fittings	Leakage from quick disconnect fittings causes small drips or leaks when making or breaking connections	Worker exposure to small amounts of 0.5M-1.0M Oxalic Acid solution	Sleeving	Safety Management Program (Hazardous Material Protection Program)	S1	F3	S1 based on small amount of spilled liquid affecting only the facility worker handling the hose F3 based on anticipated small leaks when making or breaking quick disconnect fittings.
C106-ACID-B-07	B	Structural Strength	Low Strength	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid surface spill above SST during initial addition damages concrete tank dome resulting in dome collapse	Release of tank waste	Sleeving	Safety Management Program (Emergency Response)	S3	F1	S3 is based on analyzed accident, Tank Failure due to Excessive Loads F1 is based on consensus of HAZOP team that soil would neutralize acid prior to reaching concrete dome and this would be an extremely unlikely event for this much damage.
C106-ACID-B-08	B	Structural Strength	Low Strength	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid surface spill during initial addition damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	Sleeving	Safety Management Program (Radiation Protection Program)	S1	F2	S1 is based on limited release from damaged dome through soil cover F2 is based on consensus of HAZOP team that soil would neutralize acid prior to reaching concrete dome making damage enough to create an unfiltered leak path would be unlikely.
C106-ACID-B-09	B	Reaction	Wrong Reaction	Worker exposure to hazardous material (CO^2 asphyxiant) due to acid reaction with soil or tank structures causes serious injury	Oxalic acid spill during initial addition reacts with soil or concrete structures releasing CO^2 gas	Release of CO^2 gas which replaces air reducing oxygen content	None Identified	Safety Management Program (Hazardous Material Protection Program)	S1	F2	S1 is based on limited exposure to facility workers only. F2 is based on consensus of HAZOP team that CO^2 buildup would be unlikely in the open areas above a tank.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node C: SST 241-C-106											
C106-ACID-C-01	C	Reaction	Wrong Reaction	Release of radioactive or hazardous material to the atmosphere due to incompatible chemical reacting with the waste in 241-C-106 causing overpressure and subsequent failure of the ventilation system	Acid cargo tank is filled with the wrong chemical resulting in a reaction in 241-C-106	Release of radioactive and hazardous materials from damaged ventilation system	None Identified	Safety Management Program (Hazardous Material Protection Program) Emergency Preparedness (Emergency Response)	S3	F3	S3 is conservatively based on unknown type of chemicals released in the event F3 is based on anticipated worker error at chemical supply depot Procurement specifications require supplier QA documentation that Chemical specified is what was ordered. Most of the waste will have been removed as the result of initial liquid transfers.
C106-ACID-C-02	C	Reaction	Wrong Reaction	Release of radioactive or hazardous material to the atmosphere due to heat of dilution of caustic in 241-C-106 causing overpressure and subsequent failure of the ventilation system	Acid cargo tank is filled with Caustic resulting in a reaction in 241-C-106	Release of radioactive and hazardous materials from damaged ventilation system	None Identified	Safety Management Program (Hazardous Material Protection Program) Emergency Preparedness (Emergency Response)	S1	F3	S1 is based on consensus of HAZOP team that caustic would not react with waste in 241-C-106 to the extent that it would affect more than the facility worker. F3 is based on worker error at chemical supply depot Procurement specifications require supplier QA documentation that Chemical specified is what was ordered. Analysis is required to see if caustic will react with either residual waste or with oxalic acid.
C106-ACID-C-03	C	Reaction	Wrong Reaction	Release of hazardous material to the atmosphere due to incompatible chemical reacting with the waste in SST 241-C-106 causing generation of toxic gas or fumes	Acid cargo tank is filled with the wrong chemical resulting in a reaction in 241-C-106	Release of hazardous materials from SST ventilation system	None Identified	Safety Management Program (Hazardous Material Protection Program) Emergency Preparedness (Emergency Response)	S3	F3	S3 is conservatively based on unknown type of chemicals released in the event F3 is based on anticipated worker error at chemical supply depot Procurement specifications require supplier QA documentation that Chemical specified is what was ordered. Most of the waste will have been removed as the result of initial liquid transfers.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID -C-04	C	Reaction	Wrong Reaction	Release of hazardous material to the atmosphere due to caustic reacting with the waste in SST 241-C-106 causing generation of toxic gas or fumes	Acid cargo tank is filled with caustic solution resulting in a reaction in 241-C-106	Release of hazardous materials from SST ventilation system	None Identified	Safety Management Program (Hazardous Material Protection Program) Emergency Preparedness (Emergency Response)	S1	F3	S1 is based on consensus of HAZOP team that caustic would not react with tank waste or oxalic acid solutions to the extent where the co-located worker would be affected. F3 is based on anticipated worker error at chemical supply depot
C106-ACID -C-05	C	Reaction	Wrong Reaction	Release of dissolved ammonia to the atmosphere due to Oxalic Acid changing the solubility	Oxalic Acid addition changes Ammonia solubility releasing ammonia through ventilation system	Release of hazardous materials (ammonia) from SST ventilation system	None Identified	Safety Management Program (Hazardous Material Protection Program) Emergency Preparedness (Emergency Response)	S2	F0	S2 is based conservatively by HAZOP team that a large generation of ammonia could affect co-located worker. F0 is based on consensus of HAZOP team that this type of reaction will not generate large amounts of ammonia vapors.
C106-ACID -C-06	C	Concentrati on	High	Release of radioactive or hazardous material from the 241-C-106 ventilation system to the atmosphere due to a flammable gas deflagration	Oxalic Acid addition causes a release of flammable gas with ignition and overpressure resulting in damage to the ventilation system and minor dome damage	Release of radioactive or hazardous material from damaged ventilation system	SST ventilation system	Ignition source controls Flammable gas monitoring	S2	F2	S2 based on analyzed accident, Flammable Gas Deflagration. F2 based on the analysis documented in RPP-13547, Rev. 0, *Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere* that concluded that the waste volume in 241-C-106 is insufficient to generate sufficient gas to reach lower flammability limit with barometric breathing. Passive ventilation will be used during this activity.
C106-ACID -C-07	C	Criticality	Inadvertent	Release of radioactive or hazardous material from 241-C-106 to the atmosphere due to inadvertent criticality	Addition of Oxalic Acid to 241-C-106 selectively removes poisons from solids or concentrates fissile material resulting in inadvertent criticality	Criticality produces steam bump causing over pressurization of ventilation system and subsequent release	None Identified	Criticality Controls	S2	F3	S2 is based on analyzed accident, Nuclear Criticality. F3 was conservatively established by the HAZOP team in the absence of a criticality analysis covering acid dissolution.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-C-08	C	Reaction	Side Reaction	Release of radioactive or hazardous material to ground from leaking SST due to acid reaction with tank liner and resulting leak	Addition of Oxalic Acid to 241-C-106 causes reaction with tank liner or dissolution of rust or tank waste plug in an existing leak path with resultant waste release to the soil column	Leak of tank waste to ground subsurface	None Identified	Environmental Programs	S0/E3	F3	S0 is based on direct worker exposure E3 is based on waste release to soil column F3 is conservatively based by the HAZOP team on unknown existence of small, sealed leak paths in liner.
C106-ACID-C-09	C	Reaction	Side Reaction	Release of hazardous material from SST ventilation system to atmosphere due to Oxalic acid reacting with tank waste creating NOx	Addition of Oxalic Acid to 241-C-106 reacts with nitrites in tank waste creating NOx.	Release of NOx through SST ventilation system	HEGA Filter	Safety Management Program (Hazardous Material Protection Program)	S1	F3	S1 is based on consensus of HAZOP team that liquid retrieval prior to acid dissolution in tank will leave insufficient nitrites to affect more than the facility worker. F3 is based on HAZOP team knowledge that this reaction will occur.
C106-ACID-C-10	C	Reaction	Side Reaction	Worker is exposed to high concentrations of CO^2 resulting in severe injury or death due to asphyxiation	Oxalic Acid reacts with sodium carbonate in 241-C-106 producing CO^2 gas that is released through risers	Worker exposure to high concentrations of CO^2	Active Ventilation system	Safety Management Program (Hazardous Material Protection Program)	S1	F1	S1 is based on HAZOP team consensus that CO^2 buildup will not affect co-located workers F1 is based on consensus of HAZOP team that limited amount of CO^2 generation plus there are no normally accessible enclosed spaces during acid dissolution and transfers
C106-ACID-C-11	C	Reaction	Wrong Reaction	Release of radioactive or hazardous material from SST to atmosphere due to a flammable gas deflagration	A stronger acid instead of Oxalic Acid is shipped causing a generation of hydrogen gas (with ignition source) which ignites, damaging ventilation system with minor dome damage	Release of tank aerosols and HEPA loading	SST Ventilation system	Ignition source controls	S2	F2	S2 based on analyzed accident, Flammable Gas Deflagration. F2 based on the analysis documented in RPP-13547, Rev. 0, *Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere* that concluded that the waste volume in 241-C-106 is insufficient to generate sufficient gas to reach lower flammability limit with barometric breathing. Passive ventilation will be used during this activity.
C106-ACID-C-12	C	Structural Strength	Low Strength	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid aerosol from splash and spatter during initial acid addition damages concrete tank dome resulting in dome collapse	Release of tank waste	None Identified	Safety Management Program (Emergency Response)	S3	F1	S3 is based on analyzed accident, Tank Failure due to Excessive Loads. F1 is based on consensus of HAZOP team that damage to tank dome from oxalic acid aerosols sufficient to cause dome collapse is extremely unlikely.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID -C-13	C	Structural Strength	Low Strength	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid aerosol from splash and splatter during initial acid addition damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	None Identified	Safety Management Program (Radiation Protection Program)	S1	F2	S1 is based on analyzed accident, Unfiltered Release. F2 is based on consensus of HAZOP team that damage to tank dome from oxalic acid aerosols sufficient to cause unfiltered release paths is unlikely.
C106-ACID -C-14	C	Structural Strength	Low Strength	Worker exposure to ionizing radiation during replacement of equipment damaged by Oxalic acid	Oxalic acid leak in pit damages equipment resulting in additional worker exposure during repair activities	Worker exposure to ionizing radiation	None Identified	Safety Management Program (Radiation Protection Program)	S1	F3	S1 is based on facility worker exposure only. F3 is based on anticipated damage to pit equipment from oxalic acid exposure.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node D: Ventilation System, 241-C-106											
C106-ACID - D-01	D	Flow	High Rate	Worker exposure to ionizing radiation when changing HEPA filters in 241-C-104 and 241-C-105	Active ventilation system in 241-C-106 draws additional air through the cascade lines to 241-C-104 and 241-C-105 HEPAs causing additional filter changes and unplanned exposure	Worker exposure to ionizing radiation	None Identified	Radiation protection program	S1	F2	S1 based on facility worker exposure only. F2 based on operational history from past practice sluicing (Project W-320) showing only minimal pressure changes in cascaded tanks when active ventilation in 241-C-106 was operating.
C106-ACID - D-02	D	Procedure	Extra Action	Release of radioactive or hazardous materials from tank 241-C-106 to atmosphere through failed filters due to moisture buildup	Moisture buildup on filters from acid recirculation causes excessive back pressure and failure	Waste release to atmosphere	Ventilation Stack CAM Interlock System HEPA Filter dP Interlock System HEPA Filters	LCO Ventilation Stack CAM Interlock System LCO HEPA Filter dP Interlock System HEPA Filter Controls HEPA Filter Efficiency Process Instrumentation and Measuring and Test Equipment	S2	F2	S2 is based on analyzed accident, HEPA Filter Failure—Exposure to High Pressure or Temperature. F2 is based on experience with past practice sluicing Project W-320 with similar vent flow rates. Active vent system contains a de-mister
C106-ACID -D-03	D	Structural Strength	Structural Failure	Release of radioactive or hazardous materials from tank 241-C-106 to soil column due to vacuum induced tank damage	Ventilation system fan on with tank level too low and or inlet damper closed results in vacuum uplift of tank bottom and leak to soil column	Waste release to ground	Inlet damper Seal Loops	Safety Management Programs Emergency Preparedness Maintain certain liquid level	S0/E3	F3	S0 based on no exposure to workers. E3 based on waste leak to soil column. F3 based on active ventilation system capable of uplifting tank bottom.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID -D-04	D	Structural Strength	Structural Failure	Release of radioactive or hazardous materials from tanks connected 241-C-106 via cascade lines to the soil column due to vacuum induced tank damage	Ventilation system fan on with tank level too low and or inlet damper closed results in vacuum uplift of tank bottom of interconnected tanks and leak to soil column	Waste release to ground	Inlet damper Seal Loops	Safety Management Programs Emergency Preparedness Maintain certain liquid level	S0/E3	F1	S0 based on no exposure to workers. E3 based on waste leak to soil column. F1 based on flow restriction of cascade line coupled with anticipated leak paths around a closed ventilation damper plus having to have all in leakage to all cascaded tanks blocked off makes this an extremely unlikely condition.
C106-ACID -D-05	D	Structural Strength	Structural Failure	Release of radioactive or hazardous materials from tank 241-C-106 to atmosphere due to vacuum induced tank damage	Fan controller failure resulting in excessive vacuum in tank, loop seal actuation and tank damage (dome damage)	Waste release to atmosphere	None Identified	Safety Management Programs Emergency Preparedness	S2	F0	S2 based on analyzed accident, Tank Failure Due to Excessive Loads F0 based on ventilation system having insufficient vacuum to damage dome with no restriction or limitations on inlet damper.
C106-ACID -D-06	D	Structural Strength	Structural Failure	Release of radioactive or hazardous materials to the atmosphere due to seismically induced structural failure of the ventilation system	Seismic event causes failure of ventilation system	Tank dome space aerosols and HEPA loading release to atmosphere	None Identified	Safety Management Programs Emergency Preparedness	S2	F1	S2 based on analyzed accident, Unfiltered Release. F1 based on seismic event of sufficient magnitude to seriously damage portable ventilation system such that releases would reach the 100meter receptor considered extremely unlikely.
C106-ACID -D-07	D	Velocity	High Velocity	Release of radioactive or hazardous materials from ventilation ducting due to high winds or tornado	High winds or tornado resulting in failed ventilation ducting and unfiltered release	Waste release to atmosphere	Ventilation Stack CAM Interlock System HEPA Filter dP Interlock System HEPA Filters	LCO Ventilation Stack CAM Interlock System LCO HEPA Filter dP Interlock System HEPA Filter Controls HEPA Filter Efficiency Process Instrumentation and Measuring and Test Equipment	S1	F3	S1 based on limited release from damaged ventilation system. F3 based on anticipated high wind.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-D-08	D	Reaction	Side Reaction	Release of radioactive or hazardous materials from tank 241-C-106 ventilation system to atmosphere due to ventilation system leak	Ducting corrosion, instrumentation damage or seal deterioration caused by oxalic acid aerosols	Waste release to atmosphere	Ventilation Stack CAM Interlock System HEPA Filter dP Interlock System HEPA Filters	LCO Ventilation Stack CAM Interlock System System HEPA Filter Controls HEPA Filter Efficiency Process Instrumentation and Measuring and Test Equipment	S1	F3	S1 based on limited release from small leaks in ventilation system. F3 based on anticipated corrosion or deterioration of HEPA seals in ventilation system with a small release affecting facility worker only.
C106-ACID-D-09	D	Reaction	Side Reaction	Release of radioactive or hazardous materials from tank 241-C-106 ventilation system to atmosphere due to failed HEPA filter	Oxalic acid aerosols damage HEPA filter with subsequent unfiltered release	Waste release to atmosphere	Ventilation Stack CAM Interlock System HEPA Filter dP Interlock System HEPA Filters	LCO Ventilation Stack CAM Interlock System LCO HEPA Filter dP Interlock System HEPA Filter Controls HEPA Filter Efficiency Process Instrumentation and Measuring and Test Equipment	S1	F3	S1 is based on consensus of HAZOP team that damage to HEPA filter from oxalic acid attack would be limited in nature and would affect only the facility worker F3 is based on unknown compatibility of HEPA filter and oxalic acid. De-entrainer will limit exposure of HEPAs to acid.
C106-ACID-D-10	D	Pressure	High Vacuum	Release of radioactive or hazardous materials from tank 241-C-106 to atmosphere due to excessive vacuum	Excessive vacuum caused by human error (closing off inlet damper) in tank from ventilation system resulting in loop seal failure and unfiltered release	Waste release to atmosphere	Transfer Leak Detection System	Encasement Seal Loop Controls	S1	F2	S1 is based on limited exposure path for seal loop failure F2 is based on limited mechanism to release material through seal loop.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-D-11	D	Material	Wrong Ingredient	Release of radioactive or hazardous material to the atmosphere from damaged ventilation system due to temperature induced overpressure	Caustic flush of tank following last acid addition is wrong concentration causing heat generation and over pressurization of ventilation system and HEPA failure	Release of vapor space aerosols and HEPA filter loading	CAM interlock CAM	HEPA filter source term controls Material procurement controls	S2	F1	S2 is based on analyzed accident, HEPA Filter Failure—Exposure to High Temperature or Pressure F1 is based on insufficient heat generation to pressurize headspace of empty tank.
C106-ACID-D-12	D	Flow	High Flow	Release of radioactive or hazardous material from damaged ventilation system due to excess CO_2 generation	Initial addition of oxalic acid causes large release of CO^2 resulting in overpressure and HEPA filter failure				S2	F1	S2 is based on analyzed accident, HEPA Filter Failure—Exposure to High Temperature or Pressure F1 is based on limited material to react and pressurize an essentially empty tank

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node E: Transfer Pump											
C106-ACID-E-01	E	Structural Strength	Structural Failure	Worker exposed to ionizing radiation when replacing a damaged transfer pump	Oxalic acid damages transfer pump which must be replaced causing unplanned dose to workers	Worker exposure to ionizing radiation	None Identified	Radiation Protection Programs	S1	F3	S1 is based on worker exposure to ionizing radiation only F3 is based on anticipated reaction of transfer pump to oxalic acid
C106-ACID-E-02	E	Procedure	Wrong Action	Worker exposed to ionizing radiation when replacing a damaged transfer pump	Electric motor hooked up backwards driving pump in reverse damages pump which must be replaced causing unplanned dose to workers	Worker exposure to ionizing radiation	Shielding Reverse rotation preventer Special fittings on pump	Radiation Protection Program	S1	F3	S1 is based on worker exposure to ionizing radiation only F3 is based on anticipated worker error in hooking up pump
C106-ACID-E-03	E	Temperature	High Temperature	Release of radioactive or hazardous material from tank 241-C-106 to the atmosphere due to flammable gas deflagration	A hot spot or spark from transfer pump ignites flammable gas released during sluicing causing failure of the ventilation system and continued unfiltered release	Release of tank waste to atmosphere	SST Active Vent. System	LCO Vent Stack Cam Interlock System LCO Vent system Ignition Controls Flam Gas Monitoring Controls HEPA Filter Controls Emergency Preparedness Process Instrumentation and Measuring and Test Equipment	S2	F2	S2 is based on analyzed accident, Flammable Gas Deflagration. F2 based on the analysis documented in RPP-13547, Rev. 0, *Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere* that concluded that the waste volume in 241-C-106 is insufficient to generate sufficient gas to reach lower flammability limit with barometric breathing. Passive ventilation will be used during this activity.
C106-ACID-E-04	E	Structural Strength	Low Strength	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid spray/aerosol from failed transfer pump damages concrete tank dome resulting in dome collapse	Release of tank waste	None Identified	Safety Management Program (Emergency Response)	S3	F1	S3 is based on analyzed accident, Tank Failure due to Excessive Loads F1 is based on consensus of HAZOP team that soil would neutralize acid prior to reaching concrete dome and this would be an extremely unlikely event for this much damage to cause dome collapse.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-E-05	E	Structural Strength	Low Strength	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid spray/aerosol from failed transfer pump component damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	None Identified	Safety Management Program (Radiation Protection Program)	S1	F2	S1 is based on limited release from unfiltered pathway through soil cover over tank. F2 is based on consensus of HAZOP team that soil would neutralize acid prior to reaching concrete dome and this would be an unlikely event for acid leaks to create cracks or other unfiltered pathways.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node F: Acid Recirculation System											
C106-ACID-F-01	F	Structural Strength	Low Strength	Release of radioactive or hazardous materials from SST to atmosphere due to tank dome failure	Oxalic acid aerosol from re-circulation of acid during dissolution damages concrete tank dome resulting in dome collapse	Release of tank waste	None Identified	Safety Management Program (Emergency Response)	S3	F1	S3 is based on analyzed accident, Tank Failure due to Excessive Loads F1 is based on consensus of HAZOP team that soil would neutralize acid prior to reaching concrete dome and this would be an extremely unlikely event for this much damage to cause dome collapse.
C106-ACID-F-02	F	Structural Strength	Low Strength	Release of radioactive or hazardous materials from the SST to atmosphere due to dome damage causing unfiltered pathways	Oxalic acid aerosol from re-circulation of acid during dissolution damages concrete tank dome resulting in dome damage creating unfiltered pathways	Release of tank headspace aerosols	None Identified	Safety Management Program (Radiation Protection Program)	S1	F2	S1 is based on limited release from unfiltered pathway through soil cover over tank. F2 is based on consensus of HAZOP team that soil would neutralize acid prior to reaching concrete dome and this would be an unlikely event for acid leaks to create cracks or other unfiltered pathways.
C106-ACID-F-03	F	Reaction	Wrong Reaction	Worker exposure to hazardous material (CO^2 asphyxiant) due to acid reaction with soil or tank structures causes serious injury	Oxalic acid spill from damaged aboveground recirculation line reacts with soil or concrete structures releasing CO^2 gas	Release of CO^2 gas which replaces air reducing oxygen content	None Identified	Safety Management Program (Hazardous Material Protection Program)	S1/E2	F1	S1 is based on HAZOP team consensus that CO^2 buildup will not affect co-located workers E2 is based on HAZOP team consensus that oxalic acid spill could be a serious environmental problem.- F1 is based on consensus of HAZOP team that limited amount of CO^2 generation plus there are no normally accessible enclosed spaces during acid dissolution and transfers
C106-ACID-F-04	F	Structural Strength	Structural Failure	Worker exposure to radioactive or hazardous material due to ruptured above ground transfer line	Oxalic acid recirculation line ruptures (improper assembly or other failure) with pool leak of oxalic acid with dissolved tank waste	Release of oxalic acid and dissolved tank waste	Sleeving	Safety Management Program (Hazardous Material Protection Program)	S1	F3	S1 based on HAZOP team consensus that pool leak of oxalic acid with the limited amount of waste available in 241-C-106 would affect only the facility worker. F3 based on anticipated misassembly of transfer line
C106-ACID-F-05	F	Position	Misdirected	Release of radioactive or hazardous material to soil column from waste tank due to misdirected spray of oxalic acid	Recirculation spray hits above tank liner causing a release to ground of contamination through concrete cold joints	Release of radioactive or hazardous material to soil	Mechanical limiter on spray direction	Environmental Programs	S0/E2	F3	S0 based on no worker exposure. E2 based on possibility for significant release of contamination to soil column. F3 based on ability to spray above liner with no mechanical or administrative restrictions on recirculation spray nozzle.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-F-06	F	Criticality	Inadvertent	Release of radioactive or hazardous material from ventilation system in 241-AN-106 due to criticality	Misroute into overground transfer line during recirculation transfers 1 M oxalic acid to receiver tank causing criticality	Criticality produces steam bump causing over pressurization of ventilation system and subsequent release	None Identified	Criticality Controls Transfer Controls (configuration management)	S2	F3	S2 is based on analyzed accident, Nuclear Criticality. F3 was conservatively established by the HAZOP team in the absence of a criticality analysis covering acid dissolution.
C106-ACID-F-07	F	Procedure	Wrong Action	Release of radioactive or hazardous material from ventilation system in 241-AN-106 to the atmosphere due to overpressure and failed HEPA filter	Misroute into overground transfer line during recirculation transfers 1 M Oxalic acid to receiver tank causing chemical reaction and overpressurization of ventilation system	Release of vapor space aerosols and HEPA filter loading	None Identified	Transfer Controls (configuration management)	S2	F3	S2 is based on analyzed accident, HEPA Filter Failure—Exposure to High Temperature or Pressure. F3 based on anticipated worker error.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node G: Transfer Line, 241-C-106 to DST 241-AN-106											
C106-ACID-G-01	G	Reaction	Side Reaction	Release of radioactive or hazardous material from pit due to ruptured transfer line and drain to pit with subsequent overflow	Waste containing excess Oxalic Acid reacts with transfer line causing rupture and leak to containment	Waste transfer leak	Leak Detection System Pit covers	Transfer controls	S2	F1	S2 is based on analyzed accident, Waste Transfer Leak. F1 is based on consensus of the HAZOP team that oxalic acid will not react with transfer line such that it would cause a line rupture.
C106-ACID-G-02	G	Pressure	High	Release of radioactive or hazardous material from pit to ground surface due to waste transfer leak	High pressure results in rupture of hose-in-hose that drains back through the encasement hose to a pit which overflows	Waste Transfer Leak	Transfer leak detection system Pit covers Pipe encasement	Transfer controls	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on no limitations for replacement of existing transfer pump.
C106-ACID-G-03	G	Flow	Reverse	Release of radioactive or hazardous material from 241-C-106 to the ground surface due to siphon of waste from the AN farm receiver tank	Waste transfer pump shuts down resulting in a siphon of waste from the receiver tank to 241-C-106	Waste Transfer Leak	Transfer Leak Detection System Vacuum Breaker	Transfer controls	S2	F0	S2 is based on analyzed accident, Waste Transfer Leak. F0 is based on drop leg provides vacuum break.
C106-ACID-G-04	G	Temperatur e	Low	Release of radioactive or hazardous materials from a pit to the ground surface due to a ruptured waste transfer line	Line freezing causes rupture in line with leak to a pit via the encasement with subsequent pit overflow	Waste Transfer leak	Transfer leak detection system Encasement Heat Trace	Waste Transfer controls	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated low temperatures.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-05	G	Reaction	Wrong Reaction	Worker exposure to hazardous material (CO^2 asphyxiant) due to acid reaction with soil or tank structures causes serious injury	Oxalic acid spill from ruptured transfer line reacts with soil or concrete structures releasing CO^2 gas	Release of CO^2 gas which replaces air reducing oxygen content	None Identified	Safety Management Program (Hazardous Material Protection Program)	S1/E2	F1	S1 is based on HAZOP team consensus that CO^2 buildup will not affect co-located workers E2 is based on HAZOP team consensus that oxalic acid spill could be a serious environmental problem.- F1 is based on consensus of HAZOP team that limited amount of CO^2 generation plus no normally accessible enclosed spaces during acid dissolution and transfers make this an extremely unlikely event
C106-ACID-G-06	G	Procedure	Wrong Action	Release of radioactive or hazardous materials or hazardous waste from transfer line in tank 241-C-106 pit to atmosphere due to leak in line flush connection	Blank flange or hose connection left off flushing connection outside pit after flushing and transfer initiated.	Surface waste leak	Trans Leak Detect Systems Above grade Portions - Process Pits (Integrity) Trans Leak Detect Systems Tank Level Detect Systems Trans Sys Covers Above grade Portions - Process Pits (Splash and Splatter)	LCO Trans. Leak Detection System Transfer Controls (Material Balance) Transfer Controls (Tank Levels) Transfer Controls (Ground Radiation Survey) Emergency Preparedness Process Instrumentation and Measuring and Test Equipment Safety Management Programs	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-07	G	Procedure	Wrong Action	Release of radioactive or hazardous materials or hazardous waste from line in pit to the surface due to leak caused by mispositioned valve, cover plug in place	Air blow down valves left in flush configuration after flushing, cover plug remains in place on initiation of sluicing process, high capacity drain cover left on and pit overflows.	Radioactive liquid and hazardous liquid release to surface	Trans Leak Detect Systems Above grade Portions - Process Pits (Integrity) Trans Leak Detect Systems Tank Level Detect Systems Trans Sys Covers Above grade Portions - Process Pits (Splash and Splatter)	LCO Trans. Leak Detection System Transfer Controls (Material Balance) Transfer Controls (Tank Levels) Transfer Controls (Ground Radiation Survey) Emergency Preparedness Process Instrumentation and Measuring and Test Equipment Safety Management Programs	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-08	G	Temperature	High Temperature	Release of radioactive or hazardous material from overground transfer hose to the ground due to a leaking connection	High temperature water flush degrades seal at hose joint connection causing leak to ground surface	Surface leak of tank waste	OTS Encasements and Connections OTS Vehicle Impact Barriers Transfer Leak Detection System Master Pump Shutdown System	LCO Trans. Leak Detection System Transfer Controls (Material Balance) Transfer Controls (Tank Levels) Transfer Controls (Ground Radiation Survey) Emergency Preparedness (Response Procedures) Process Instrumentation and Measuring and Test Equipment Safety Management Programs	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on process knowledge from documented damage to hose in hose connections caused by high temperature flush water.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-09	G	Structural Strength	Structural Failure	Release of radioactive liquid from overflow of pit on receiver DST to soil surface due to transfer line leak	Jumper break or improper installation in pit with the high capacity drain cover on or drain plugged resulting in overflow of pit	Radioactive liquid and hazardous liquid release to surface	Transfer Leak Detection System Master Pump Shutdown System	LCO Trans. Leak Detection System Transfer Controls (Material Balance) Transfer Controls (Ground Radiation Survey) Emergency Preparedness Process Instrumentation and Measuring and Test Equipment Transfer System Cover Removal Program Safety Management Programs	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error. Includes pit in C-103.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-10	G	Structural Strength	Structural Failure	Release of radioactive liquid from overflow of pit on receiver DST to soil surface due to transfer line leak	Jumper break or improper installation in pit with the high capacity drain cover open and pit cover off	Radioactive liquid and hazardous liquid release to surface	Transfer Leak Detection System Master Pump Shutdown System	LCO Trans. Leak Detection System Transfer Controls (Material Balance) Transfer Controls (Ground Radiation Survey) Emergency Preparedness Process Instrumentation and Measuring and Test Equipment Transfer System Cover Removal Program Safety Management Programs	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error.
C106-ACID-G-11	G	Structural Strength	Structural Failure	Release of radioactive or hazardous materials from pit to atmosphere due to spray leak from jumper	Seismic event damages jumper and breaches cover block by ground motion resulting in spray release	Aerosolized radioactive waste release to atmosphere	Seismic Switch or Alarm Transfer Leak Detection System Pipe Encasements Master Pump Shutdown System	LCO Trans. Leak Detection System Transfer Controls (Material Balance) Transfer Controls (Ground Radiation Survey) Emergency Preparedness Safety Management Program	S2	F2	S2 is based on analyzed accident, Waste Transfer Leak F2 is based on seismic event of sufficient magnitude to damage a jumper is considered unlikely.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-12	G	Structural Strength	Structural Failure	Release of radioactive or hazardous waste due to seismic induced damaged to a transfer line	Seismic event damages overground transfer line by ground motion resulting in spray release	Surface Waste Leak	Pipe Encasements Seismic Switch or Alarm Master Pump Shutdown System	Transfer Controls (Material Balance) Transfer Controls (Ground Radiation Survey) Emergency Preparedness Safety Management Program	S2	F1	S2 based on analyzed accident, Waste Transfer Leak F1 based on seismic event of sufficient magnitude to damage hose-in-hose transfer line considered extremely unlikely.
C106-ACID-G-13	G	Structural Strength	Structural Failure	Release of radioactive or hazardous material to the ground surface or atmosphere from a damaged overground transfer line due to wind blown missile	Missile caused by high wind or tornado penetrates overground transfer line causing surface or spray leak	Surface leak of radioactive waste	OTS Encasements and Connections Transfer Leak Detection System Shielding	LCO Trans. Leak Detection System Transfer Controls (Material Balance) Transfer Controls (Tank Levels) Transfer Controls (Ground Radiation Survey) Emergency Preparedness (Response) Process Instrumentation and Measuring and Test Equipment Safety Management Programs	S2	F2	S2 is based on analyzed accident, Waste Transfer Leak. F2 is based on consensus of HAZOP team that high winds it is unlikely that high winds could cause penetration of a hose-in-hose system.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID -G-14	G	Procedure	Wrong Action	Personnel exposure to ionizing radiation due to excavation or construction activities uncovering shielding on hose-in-hose transfer lines	Error causes removal of shielding above hose-in-hose transfer line resulting in worker exposure to ionizing radiation	Unplanned exposure to ionizing radiation	None Identified	Job hazard analysis Engineering procedures	S1	F3	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated worker error.
C106-ACID -G-15	G	Flow	High Flow	Release of radioactive or hazardous material from a ruptured transfer hose to the atmosphere due to high compressed air pressure	Compressed air blowdown ruptures transfer line with release to atmosphere	Release of tank waste to the atmosphere	Hose-in-hose encasement Transfer Leak detection System Over-pressure relief valve	LCO Trans. Leak Detection System Emergency Preparedness (Response Procedures) Safety Management Program	S2	F2	S2 is based analyzed accident, Waste Transfer Leak. F2 is based on consensus of HAZOP team that using a portable compressor with large enough capacity to damage a hose-in-hose transfer line is unlikely.
C106-ACID -G-16	G	Flow	Reverse Flow	Worker exposure to ionizing radiation due to back flow of waste into compressed air system	Radioactive liquid gravity flows into compressed air system during line blowdown activities	Worker exposure to ionizing radiation	Air check valve Shielding	Radiation Protection Program	S1	F3	S1 is based on worker exposure to ionizing radiation only. F3 is based on relative elevations that would facilitate a backflow condition.
C106-ACID -G-17	G	Concentrati on	High Concentratio n	Worker exposure to ionizing radiation due to unplugging transfer line	Excess solids causes line plug, worker exposure clearing plug	Worker exposure to ionizing radiation	Solids monitor Flow measurement	Radiation Protection Program	S1	F3	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated pick up of solids by transfer pump.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-18	G	Concentration	High Concentration	Small release of radioactive or hazardous materials from the transfer line to the atmosphere due to flammable gas deflagration in line, transfer started	Buildup of solids and flammable gas in transfer line with ignition resulting in breach of transfer line; pumping is started without knowledge of breach	Surface Waste Leak	None Identified	Ignition Controls Flam Gas Monitoring Controls Emergency Preparedness Transfer Controls (Waste Compatibility) Instrumentation and Measuring and Test Equipment	S2	F2	S2 is based on analyzed accident, Waste Transfer Leak. F2 is based on consensus of HAZOP team that generating enough flammable gas to reach the LFL in the transfer line plus having an ignition source is extremely unlikely.
C106-ACID-G-19	G	Concentration	High Concentration	Release of radioactive or hazardous materials to the atmosphere due to flammable gas deflagration in the waste transfer line	Plugging of transfer line occurs, flammable gas builds up and is ignited resulting in a breach of transfer line; pumping is started (collection in pit)	Surface waste leak	None Identified	Ignition Controls Flam Gas Monitoring Controls Emergency Preparedness Transfer Controls (Waste Compatibility) Instrumentation and Measuring and Test Equipment	S2	F2	S2 is based on analyzed accident, Waste Transfer Leak. F2 is based on consensus of HAZOP team that generating enough flammable gas to reach the LFL in the transfer line plus having an ignition source is extremely unlikely.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-20	G	Flow Rate	High Flow	Release of radioactive or hazardous material from the receiver tank ventilation system to the atmosphere due to HEPA filter failure due to high pressure	Compressed air used to blow down transfer line exceeds the HEPA filter capacity in the receiver tank causing filter failure and release of contaminants	Release of DST headspace aerosols and HEPA filter loading	Ventilation Stack CAM Interlock System HEPA Filter dP Interlock System HEPA Filters (Linked to dP interlock)	LCO Ventilation Stack CAM Interlock System LCO HEPA Filter dP Interlock System HEPA Filter Controls (source term) HEPA Filter Efficiency (part of dP interlock) Process Instrumentation and Measuring and Test Equipment	S2	F2	S2 is based on analyzed accident, HEPA Filter Failure—Exposure to High Temperature or Pressure. F2 is based on consensus of HAZOP team that it is unlikely that a compressor of a size to overpower the ventilation system would be used.
C106-ACID-G-21	G	Velocity	High Velocity	Personnel exposure to ionizing radiation due to high winds	High winds uncover overground transfer lines	Worker exposure to ionizing radiation	Shielding plate	Radiation Protection Program	S1	F3	S1 is based on worker exposure to ionizing radiation only. F3 is based on anticipated high winds. Note, it would be extremely unlikely that wind would move the 2-inch thick steel shielding plates.
C106-ACID-G-22	G			Release of radioactive or hazardous material from ruptured transfer line to ground surface	Compressed air flush done during transfer causes water hammer which ruptures line or damages connection	Release of tank waste	Hose-in-hose encasement Transfer Leak detection System Over-pressure relief valve	LCO Trans. Leak Detection System Emergency Preparedness (Response Procedures) Safety Management Program	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on available energy of compressed air system to cause water hammer.
C106-ACID-G-23	G	Flow	Reverse Flow	Release of radioactive or hazardous material from service water line to atmosphere due to misroute	Back flow of waste into raw water flush line causes leak through open piping to ground surface	Release of tank waste	Back Flow Preventer Isolation Valves Pressure switch and alarm	Transfer Controls	S2	F3	S2 based on analyzed accident, Waste Transfer Leak. F3 is based on worker error in valve configuration.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-G-24	G	Procedure	Wrong Step	Release of radioactive or hazardous material from pit due to inadvertent startup of a transfer pump	Inadvertent start up of existing vertical turbine transfer pump in 241-C-106 causes spray leak in pit	Release of tank waste	Pit Leak Detectors Cover Blocks	Transfer Controls Transfer Pump Admin. Lock Controls	S2	F3	S2 is based on analyzed accident, Waste Transfer Leak. F3 is based on anticipated worker error.
C106-ACID-G-25	G	Flow	Reverse Flow	Release of radioactive or hazardous material from cargo tank due to misroute	Misroute back to water flush or acid cargo tank during waste transfer results in tank overflow	Release of tank waste	Back Flow Preventer Isolation Valves Pressure Switch and alarm	Transfer Controls	S2	F3	S2 based on analyzed accident, Waste Transfer Leak. F3 based on anticipated worker error in valve alignment.
C106-ACID-G-26	G	Material	Reaction	Release of radioactive or hazardous material from a transfer line due to a leaking fitting or instrument	Acid degrades or damages in line pressure/flow transducers causing leak	Side Reaction	Leak Detector	Transfer Controls Emergency Response	S2	F3	S2 based on analyzed accident, Waste Transfer Leak F3 based on anticipated material incompatibility

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node H: Waste Receiver Tank (DST 241-AN-106)											
C106-ACID-H-01	H	Reaction	Wrong Reaction	Release of radioactive or hazardous material from waste receiver tank to the atmosphere due to transfer of waste containing excess Oxalic Acid reaction with tank waste causing overpressure of ventilation system and unfiltered release	Waste containing Oxalic Acid reacts with waste in 241-AN-106 generating heat or gasses resulting in over pressurization of the ventilation system	Release of radioactive or hazardous material through damaged HEPA filter	HEPA Filter CAM Interlock System dP Interlock System	Transfer controls	S2	F1	S2 is based on analyzed accident, HEPA Filter Failure—Exposure to High Temperature or Pressure F1 is based on consensus of HAZOP team that oxalic acid containing waste reacting with receiver tank waste containing excess caustic to the extent that the HEPA filter is failed is an extremely unlikely event.
C106-ACID-H-02	H	Reaction	Wrong Reaction	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to a flammable gas deflagration from waste transfer containing Oxalic Acid causing release of flammable gas (with ignition source)	Waste transfer containing Oxalic Acid to 241-AN-106 causes release of flammable gas resulting in flammable gas ignition and damage to the ventilation system with minor dome damage	Release of radioactive or hazardous material from damaged ventilation system	DST ventilation system	Ignition source controls Flammable gas monitoring Caustic Transfer controls	S2	F3	S2 is based on analyzed accident, Flammable Gas Deflagration. F3 based on analyzed accident, Flammable Gas Deflagration.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-H-03	H	Reaction	Wrong Reaction	Release of ammonia from 241-AN-106 to the atmosphere due to transferred waste containing Oxalic acid causing a release of hazardous gas or fumes	Waste containing Oxalic Acid transfer to 241-AN-106 causes release of ammonia through the ventilation system	Release of ammonia from the DST ventilation system	HEGA filter	Transfer controls (Waste Compatibility) Safety Management Program (Hazardous Material Protection Program)	S1	F3	S1 is based on worker exposure to ammonia. F3 based on limited ammonia release from waste transfer is anticipated.
C106-ACID-H-04	H	Criticality	Inadvertent	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to inadvertent criticality	Transfer of waste containing Oxalic Acid to 241-AN-106 selectively removes poisons from solids or concentrates fissile material resulting in inadvertent criticality	Criticality produces steam bump causing over pressurization of ventilation system and subsequent release	None Identified	Criticality Controls	S2	F3	S2 is based on analyzed accident, Nuclear Criticality. F3 was conservatively established by the HAZOP team in the absence of a criticality analysis covering acid dissolution.
C106-ACID-H-05	H	Criticality	Inadvertent	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to inadvertent criticality	Inadvertent transfer of 1 M Oxalic Acid solution to 241-AN-106 selectively removes poisons from solids or concentrates fissile material resulting in inadvertent criticality	Criticality produces steam bump causing over pressurization of ventilation system and subsequent release	None Identified	Criticality Controls	S2	F3	S2 is based on analyzed accident, Nuclear Criticality. F3 was conservatively established by the HAZOP team in the absence of a criticality analysis covering acid dissolution.
C106-ACID-H-06	H	Reaction	Side Reaction	Release of radioactive or hazardous material to DST annulus from leaking DST primary tank due to acid reaction with tank liner and resulting leak	Addition of waste containing Oxalic Acid to 241-AN-106 causes reaction with tank liner and resultant leak to annulus	Leak of tank waste to ground subsurface	None Identified	Tank Chemistry Controls	S0/E0	F0	S0 is based on no worker exposure. E0 is based on no release to environment. F0 is based on consensus of HAZOP team that oxalic acid will not attack mild steel in a tank waste environment that normally contains an excess of caustic.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
C106-ACID-H-07	H	Reaction	Side Reaction	Release of radioactive or hazardous materials from tank 241-AN-106 ventilation system to atmosphere due to ventilation system leak	Ducting corrosion or seal deterioration caused by oxalic acid aerosols caused by splash and splatter during transfer	Waste release to atmosphere	Ventilation Stack CAM Interlock System HEPA Filter dP Interlock System HEPA Filters	LCO Ventilation Stack CAM Interlock System LCO HEPA Filter dP Interlock System HEPA Filter Controls HEPA Filter Efficiency Process Instrumentation and Measuring and Test Equipment	S1	F2	S1 based on limited release from small leaks in ventilation system. F2 based on consensus of HAZOP team that aerosol generation from a drop leg would be unlikely to damage HEPA filters.
C106-ACID-H-08	H	Reaction	Side Reaction	Release of radioactive or hazardous materials from tank 241-AN-106 ventilation system to atmosphere due to failed HEPA filter	Oxalic acid aerosols from splash and splatter during transfer damage HEPA filter with subsequent unfiltered release	Waste release to atmosphere	Ventilation Stack CAM Interlock System HEPA Filter dP Interlock System HEPA Filters	LCO Ventilation Stack CAM Interlock System LCO HEPA Filter dP Interlock System HEPA Filter Controls HEPA Filter Efficiency Process Instrumentation and Measuring and Test Equipment	S2	F2	S2 is based on analyzed accident, Unfiltered Release. F2 based on consensus of HAZOP team that aerosol generation from a drop leg would be unlikely to damage HEPA filters.

Table C-1. Acid Retrieval of 241-C-106 Solids DRAFT HAZOP Results

Item ID	Node	Process Variable	Guideword	Hazardous Condition	Possible Cause of Deviation	Immediate Consequence	Suggested SSCs	Suggested TSRs	Cons Cat NC	Freq Cat NC	Remarks
Node I: Instrumentation and Controls											
C106-ACID -I-01	I	Reaction	Side Reaction	Release of radioactive or hazardous material from 241-C-106 to the atmosphere due to a flammable Gas deflagration	Oxalic acid aerosols causes in-tank instrumentation failure causing a spark and igniting flammable gas causing damage to the ventilation system	Release of tank waste to the atmosphere	SST Active Vent. System	LCO Vent Stack Cam Interlock System LCO Vent system Ignition Controls Flam Gas Monitoring Controls HEPA Filter Controls Emergency Preparedness Process Instrumentation and Measuring and Test Equipment	S2	F2	S2 is based on analyzed accident, Flammable Gas Deflagration. F2 based on the analysis documented in RPP-13547, Rev. 0, *Evaluation of the Potential for Tank 241-C-106 to Achieve a Flammable Gas Atmosphere* that concluded that the waste volume in 241-C-106 is insufficient to generate sufficient gas to reach lower flammability limit with barometric breathing. Passive ventilation will be used during this activity.
C106-ACID -I-02	1	Procedure	Wrong Action	Release of radioactive or hazardous material from 241-AN-106 to the atmosphere due to a flammable Gas deflagration	Inadvertent transfer of 1 M oxalic acid solution caused failure of in-tank instrumentation causing a spark which ignites flammable gas causing damage to the ventilation system	Release of tank waste to the atmosphere	DST/AWF Vent. System	LCO Vent Stack Cam Interlock System LCO Vent system Ignition Controls Flam Gas Monitoring Controls HEPA Filter Controls Emergency Preparedness Process Instrumentation and Measuring and Test Equipment	S2	F1	S2 is based on analyzed accident, Flammable Gas Deflagration. F1 is based on a consensus of the HAZOP team that aerosol generation from a transfer of oxalic containing waste into a tank containing excess caustic would be extremely unlikely to degrade in tank instrumentation to the extent that that a spark source would be created.

APPENDIX D

CONTROL DECISION ROSTER

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CONTROL DECISION MEETING ATTENDANCE

Meeting Subject: Acid Dissolution of SST 241-C-106 Residual Waste

Meeting Date: May 15, 2003

Name	Knowledge Areas(s) Represented (use codes below)	Organization	Telephone/msin
J.M. GRIGSBY	1,2,3,6,7,9	R/C NS&L	372-1907
Shelly Doss	14	Environmental	373-6048
ERIC SHEN	4,22,23	ARES CORP	946-3300
Leela M Sasaki	22	Closure Proj Engr. Support	373 1027/R2-12
John Schofield	4,5,22	R/C P	3-2245/S7-12
John Bores	15	QA	376-8131/R2-87
Blaine Barton	22	Closure Project Eng Support	376-5118/R2-11
Dan Reynolds	22	Proc. Eng.	373-3115/R2-11
Kevin Sandorn	1,2,6,7,9,10		
MILTON SHULTZ	2,3,6,7,9,10	R/C NS&L	372-3740
John Propson	4,18	CHG	372-0455
Ralph Rutter	17	CH2M HILL	376-6503
Bob Brown			

Knowledge Areas:

1. Licensing
2. Safety Analysis
3. Hazard Analysis
4. Engineering
5. Operations
6. Accident Analysis
7. Nuclear Safety
8. Design Authority
9. Technical Safety Requirements
10. Safety Structures, Systems, and Components
11. Emergency Preparedness
12. Radiological Control
13. Regulatory Compliance
14. Environmental Protection
15. Quality Assurance
16. Other - specify
17. Industrial Safety
18. Project Management
19. Industrial Hygiene
20. Maintenance Engineering
21. Reliability Engineering
22. Process Engineering
23. Equipment Engineering

CONTROL DECISION MEETING ATTENDANCE

Meeting Subject: Acid Dissolution of SST 241-C-106 Residual Waste

Meeting Date: May 15, 2003

Name	Knowledge Areas(s) Represented (use codes below)	Organization	Telephone/msin
Ryan D. Smith	1,7,9,10	CHG NS+L	372-1283/R1-49
CHRIS SORENSEN		ORP	372-3294
BOB GUSTAVSON	4,8,9,10,23	CHG	373-5090
Jim Thompson		ORP	373-9757
Chris Burke	4,18		
D. SAUERESSIG	5,11,18	CHG	373-0183

Knowledge Areas:

1. Licensing
2. Safety Analysis
3. Hazard Analysis
4. Engineering
5. Operations
6. Accident Analysis
7. Nuclear Safety
8. Design Authority
9. Technical Safety Requirements
10. Safety Structures, Systems, and Components
11. Emergency Preparedness
12. Radiological Control
13. Regulatory Compliance
14. Environmental Protection
15. Quality Assurance
16. Other - specify
17. Industrial Safety
18. Project Management
19. Industrial Hygiene
20. Maintenance Engineering
21. Reliability Engineering
22. Process Engineering
23. Equipment Engineering

CONTROL DECISION MEETING ATTENDANCE

Meeting Subject: Followup Control Decision For Oxalic Acid Waste Recovery in SST 241-C-106.

Meeting Date: June 5, 2003

Name	Knowledge Areas(s) Represented (use codes below)	Organization	Telephone/msin
Lawrence T. Kripps	1,2,3,6,7,9,10,17	NSL	376-1661
J.M. Grigsby	NS&L	NS&L	372-1907
Leela M. Sasaki	22	Process Engr.	373-1027
M.P. Flasch	Startup + Testing	S+T	373-4473
Dan Reynolds	22	Proc. Eng	373-3115
Sheldon Stahl	1,2,3,6,7,9,10		
John Schofield	4,5,22	Battelle/PSW	373-2245
Ralph Butler	17, 19	CP Safety	376-6503
Milton Shultz	1,2,3,6,7,9,10	NS&L	372-3740

Knowledge Areas:

1. Licensing
2. Safety Analysis
3. Hazard Analysis
4. Engineering
5. Operations
6. Accident Analysis
7. Nuclear Safety
8. Design Authority
9. Technical Safety Requirements
10. Safety Structures, Systems, and Components
11. Emergency Preparedness
12. Radiological Control
13. Regulatory Compliance
14. Environmental Protection
15. Quality Assurance
16. Other - specify
17. Industrial Safety
18. Project Management
19. Industrial Hygiene
20. Maintenance Engineering
21. Reliability Engineering
22. Process Engineering
23. Equipment Engineering

CONTROL DECISION MEETING ATTENDANCE

Meeting Subject: Followup Control Decision For Oxalic Acid Waste Recovery in SST 241-C-106.

Meeting Date: June 5, 2003

Name	Knowledge Areas(s) Represented (use codes below)	Organization	Telephone/msin
Kevin Sundgren	1, 2, 3, 6, 7, 9, 10	Nuc. Safety	372-0374
John Bores	15	QA	376-8131
RON FENIC	5	WFO SUPPORT	373-0778
[illegible]	4, 18	[illegible]	[illegible]
WARREN THOMPSON	4, 22, 18	ENGINEERING	372-8053
Blaine Barton	22	"	376-5118
John Prospoon	4, 18	Engineering	372-0455
JIM BELLOMY	4, 5, 20, 21, 23, 18	ENGINEERING	372-1673
Ryan Smith			
Evelyn Wiesl			
John Prospon			
Jim Bellomy			
~~Mike Flyt~~			
~~Dee Reynolds~~			
~~John Schofield~~			
Ralph Butler			
~~Larry Knapp~~			
~~Matt Shultz~~			

Leela

Knowledge Areas:

1. Licensing
2. Safety Analysis
3. Hazard Analysis
4. Engineering
5. Operations
6. Accident Analysis
7. Nuclear Safety
8. Design Authority
9. Technical Safety Requirements
10. Safety Structures, Systems, and Components
11. Emergency Preparedness
12. Radiological Control
13. Regulatory Compliance
14. Environmental Protection
15. Quality Assurance
16. Other - specify
17. Industrial Safety
18. Project Management
19. Industrial Hygiene
20. Maintenance Engineering
21. Reliability Engineering
22. Process Engineering
23. Equipment Engineering

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APPENDIX E

MEMO: OXALIC ACID DISSOLUTION IN TANK 241-C-106 EFFECT ON CONCRETE AND GAS GENERATION

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INTEROFFICE MEMO

CH2MHILL
Hanford Group, Inc.

From:	Closure Project Engineering Support	7G330-DAR-03-002
Phone:	373-3115	
Date:	May 27, 2003	
Subject:	OXALIC ACID DISSOLUTION IN TANK 241-C-106 EFFECT ON CONCRETE AND GAS GENERATION	
To:	R. D. Smith	R1-49
Copies:	W. B. Barton	S7-70
	K. E. Carpenter	S7-65
	T. H. May	S7-70
	J. G. Propson	S7-65
	K. R. Sandgren	R1-49
	L. M. Sasaki	S7-70
	W. T. Thompson	S7-70
	DAR File/LB	S7-70

A recent Hazard and Operability Study study of dissolving sludge using oxalic acid in Tank 241-C-106 identified potential safety issues. This memo will address two of those issues. The two issues are: 1) the effect of oxalic acid on the concrete in the tank dome and 2) the gas generation rate caused by the reaction of acid with carbonates in the sludge. Discussions of these two issues are contained in the two attachments.

The oxalic acid can only get to the concrete dome of the tank by aerosol deposition. This mechanism will prevent large quantities of acid from reaching the dome. The small amount that may reach there cannot react with enough concrete to affect the strength of the concrete.

The release of carbon dioxide will be controlled by the addition rate of the oxalic acid into the tank. The controlled addition rate will control the reaction rate by limiting the acid available at any given time to react with the carbonates in the sludge. The limiting acid addition rate will be 40 gallons per minute with a wait of several hours between truckloads to allow for the gas generation rate to decrease before more oxalic acid is added.

For further details, please contact the authors of the attachments, W. Blaine Barton, on 376-5118 and Leela Sasaski, on 373-1027.

D. A. Reynolds
Principal Engineer

dmn

Attachments 2

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7G330-DAR-03-002

Attachment 1

POTENTIAL FOR AND EFFECTS OF OXALIC ACID ATTACK ON TANK 241-C-106 DOME

Consisting of 3 pages,
including coversheet

Potential for and effects of Oxalic Acid attack on Tank 241-C-106 Dome

Oxalic acid is generally considered a weak acid. Although it does react with concrete in a manner that weakens the point of attack, it is commonly used as a cleaning agent to remove stains from concrete surfaces. This is because it can only be made-up in comparatively weak solutions. At room temperatures oxalic acid solutions saturate at around one molar concentration or about eight % by weight. At these concentrations it take a large volume of solution to react with a small quantity of solids. For example one liter of oxalic acid will react with at most 40 grams of calcium (Ca), the active ingredient in cement if there are no other competing reactions.

In the tank the structural concrete is protected from attack by oxalic acid by the carbon steel liner of the tank. The liner covers all surfaces except the dome of the tank. In order to attack the concrete of the tank dome the oxalic acid must be brought into contact with the dome. An examination of the tank physical conditions will show that it is very difficult for significant quantities of oxalic acid to reach the tank dome. We will consider the potential for aerosol formation and the entrainment velocity available to carry the aerosol to the dome.

There are three mechanisms for aerosol generation, droplet formation from the introduction of the acid into the tank, droplet formation from the recirculation mixing flow, and droplet formation from the release of carbon dioxide gas from the waste carbonates (This will be similar to the fizzing of an open pop bottle). The fresh acid can be introduced into the tank either through a drop leg on the pump column which terminates within 3 inches of the bottom of the tank or thru the recirculation loop. With the very short free falling distance there is very little aerosol formation at the start of the acid addition and within 1000 gallons added to the tank the dropleg is submerged further limiting the already low aerosol formation. The recirculation loop is similar to the pump dropleg in that it is designed to be submerged during recirculation of the acid. In addition, it uses a horizontal jet ejector to mix the recirculated fluid with the bulk liquids in the tank. The submerged and horizontal nature of the discharge of the recirculating system along with the loss of velocity associated with the ejector induced mixing are all designed to minimize the generation of aerosols from the recirculation loop. This system will not result in significant aerosol formation either during adding fresh acid into the tank or recirculating the acid during digest periods. Finally, aerosols may be formed by the collapse of gas bubbles as they exit the liquid surface. This is similar to the effervescence of pop when it is vigorously stirred. The bubble collapse result in the formation of comparatively large droplets which settle rapidly under the influence of gravity. Without a significant vertical velocity to carry these droplets to the tank dome they will settle back to the waste liquid surface.

The acid will be added to the tank in such a way as to insure that the gas generation rate will be less than 1000 cubic feet per minute. Assuming that all the generated gas is discharged through the exhauster at a rate of 1000 cubic feet per minute, this will result in a vertical velocity of less than one foot per second in the tank (1000 ft^3/minute / 4415 ft^2 area of the tank = 0.226 linear feet per minute vertical velocity). Assuming Stoke's law for settling of the droplets and a vertical velocity of one ft per minute, all particles larger than 0.0005 inches will settle back to the waste surface. For all practical purposes this means that all the aerosol generated will fall back into the pool. In addition, the height of the tank walls is 18 feet. In this distance any initial velocity imparted to the droplet will be lost and the droplet will fall back to the pool. There will be very little aerosol which can rise to the tank dome.

Assuming that the oxalic acid can wet the dome to a depth of 1/16 inch, what effect would this have on the dome? Because of the low concentration of the acid and the high concentration of Ca in the concrete matrix less than an equal thickness of concrete would be attacked and loose its structural strength. Since the concrete of the tank dome is 15 inches thick there would be no appreciable loss of strength in the tank dome.

The use of oxalic acid in the tank presents no significant hazard of collapse to the tank dome.

Maximum Droplet Size that will be suspended

Problem: What is the maximum droplet size of oxalic acid solution that will be suspended by a vertical airflow of one foot per minute?

Reference: R. B. Bird, W. E. Stewart, E. N. Lightfoot, ***Transport Phenomena***, John Wiley & Sons, New York, 1960

Approach: We will use Stoke's law to balance the drag forces which would suspend the droplet with the gravitational forces which will cause the particle to settle. We will neglect the buoyancy imparted by the gas to the droplet. This is a conservative assumption since although the buoyancy term is small; it is in the direction of increased lift and thus underestimates the maximum droplet size.

Equation: $4/3\pi R^3(\rho_s)g = 6\pi\mu v_t R$ From Reference Eqn 2.6-15 page 60

Where ρ = density of the droplet = 1.04(specific gravity of acid)*62.4 lbs/ft^3 = 64.9 lbs/ft^3
g = universal gravitational constant = 32.2 ft/sec^2
π = 3.14
μ = viscosity of air = 1.2 *10^{-5} lbm/ft sec
v_t = Vertical velocity component = 1 ft/min = 0.1667 ft/sec
R = Radius of the droplet

Solving for R gives
R = 0.00002075 ft = 0.000249 in.

Thus any particle larger than 0.0005 inches in diameter will fall back to the pool.

Wm. Blaine Barton
W. B. Barton
Closure Projects Engineering Support

Checker: DA Reynolds Daniel A. Reynolds
Date: 5/27/03

7G330-DAR-03-002

Attachment 2

LIMITING CARBON DIOXIDE GENERATION DURING ADDITION OF OXALIC ACID TO TANK 241-C-106

Consisting of 4 pages, including coversheet

Limiting Carbon Dioxide Generation During Addition of Oxalic Acid to Tank 241-C-106

The retrieval of Tank 241-C-106 involves the treatment of the sludge with oxalic acid to dissolve most of the solids. Current plans are for the oxalic acid to be added to the tank in six batches of 30,000 gallons (gal), for a total of 180,000 gal. The acid will be delivered in truckloads of 5,000 gal each and the concentration of the oxalic acid will be 0.9 molar (Reynolds 2003).

The addition of oxalic acid to Tank 241-C-106 will result in the generation of gas as the acid reacts with carbonate in the sludge to create carbon dioxide:

$$H_2C_2O_4 + CO_3^{-2} \rightarrow CO_2\,(gas) + H_2O + C_2O_4^{-2} \qquad (1)$$

There are two issues associated with the generation of carbon dioxide in the tank:

1. The gas generation rate may exceed the capacity of the exhauster and result of a loss of the headspace vacuum and releases to the environment.
2. The gas generation can result in the tank waste being carried into the tank headspace as aerosols resulting in the headspace vapors which would exceed onsite radiological and toxicological guidelines if released to the environment.

Tank 241-C-106 exhauster will draw approximately 950 cubic feet per minute (ft^3/minute) from the tank and must maintain at least 0.3 inches water gauge vacuum in the tank. To maintain this vacuum in the tank, the maximum allowable gas generation rate will be slightly less than 950 ft^3/min, depending on air inleakage paths (Minteer 2003).

To maintain tank headspace vapor compositions below the radiological and toxicological guidelines, the gas generation rate must be below 0.225 cubic meters per second (477 ft^3/minute) (Sandgren 2003).

Based on sludge dissolution studies with Tank 241-C-106 sludges, the rate of gas generation reached a maximum of 4.2 millimoles per hour per gram within a few minutes of oxalic acid addition and decreased to essentially zero within several hours (Herting 2003). If this maximum rate is applicable to the sludge in Tank 241-C-106 (9,000 gal sludge with an estimated density of 1.7 grams per milliliter), a gas generation rate of 3,500 ft^3/min at normal temperature and pressure would result. Therefore, controlling the gas generation rate by controlling the rate of addition of oxalic acid was considered.

In a well mixed, liquid phase reaction, the reaction

$$H_2C_2O_4 + CO_3^{-2} \rightarrow CO_2\,(gas) + H_2O + C_2O_4^{-2} \qquad (1)$$

would proceed first by the conversion of carbonate to bicarbonate:

$$H_2C_2O_4 + 2\,CO_3^{-2} \leftrightarrow 2\,HCO_3^{-} + C_2O_4^{-2} \qquad (2)$$

then to carbonic acid and the release of carbon dioxide:

$$H_2C_2O_4 + 2\,HCO_3^{-} \leftrightarrow 2\,H_2CO_3 + C_2O_4^{-2} \rightarrow 2\,CO_2\,(g) + 2\,H_2O + C_2O_4^{-2} \qquad (3)$$

For carbonic acid (Dean 1973):

$$pK_{a1} = 6.35 \quad ([H+][HCO_3^-]/[H_2CO_3])$$
$$pK_{a2} = 10.33 \quad ([H+][CO_3^{-2}]/[HCO_3^-])$$

Therefore, the initial amounts of oxalic acid added would serve primarily to convert carbonate to bicarbonate. Further addition of oxalic acid would react with the bicarbonate to generate carbon dioxide. Although one mole of oxalic acid generates one mole of carbon dioxide in the overall reaction, the initial addition of oxalic acid to Tank 241-C-106 may generate little carbon dioxide while further addition can result in the generation of carbon dioxide at a rate of as much as two moles of carbon dioxide per mole of oxalic acid added.

Assumptions for calculation of oxalic acid addition rate:

- The gas generation rate should be limited to 50 percent of the lower of the two maximum allowable generation rates above (i.e., 477 ft^3/min x 50% = 238 ft^3/min).
- Normal temperature and pressure (1 atmosphere and 25 °C) were used to calculate gas volumes. The highest temperature observed in Tank 241-C-106 during the past year (May 20, 2002 through May 20, 2003) was 93.2 °F (34 °C), which would result in only a 3 percent difference in volume.
- One mole of oxalic acid generates two moles of carbon dioxide (Reaction 3 above).

To limit the gas generation rate to 238 ft^3/min, the acid addition rate should be limited to approximately 40 gallons per minute and several hours should be allowed between truckloads to allow the gas generation reaction rate to decrease before more oxalic acid is added. This process should be performed for the first three batches (90,000 gal) of oxalic acid added to the tank. Based on the laboratory studies, Reynolds (2003) estimates that the pH of the liquid in the tank should be about 2 after 3 batches. At this pH, it is expected that the most of the carbon dioxide would have been released. Additionally, the laboratory studies indicate that over 90 percent of the carbonate will have been released from the sludge as carbon dioxide and the reaction rate would have fallen to within allowable levels by the end of the third batch.

References:

Dean, J. A., Editor, 2003, *Lange's Handbook of Chemistry*, eleventh edition, McGraw-Hill Book Company, New York, New York.

Herting, D. L., 2003, "Final Report for Tank 241-C-106 Sludge Dissolution, Phase II," (letter FH-0301877 to D. A. Reynolds, CH2M HILL, May 8), Fluor Hanford, Richland, Washington.

Minteer, D. J., 2003, electronic mail message to L. M. Sasaki, May 21, CH2M HILL Hanford Group, Inc., Richland, Washington.

Reynolds, D. A., 2003, "Process Description of the C-106 Oxalic Acid Dissolution," (draft), CH2M HILL Hanford Group, Inc., Richland, Washington.

Sandgren, K. R., 2003, electronic mail message to L. M. Sasaki, May 21, CH2M HILL Hanford Group, Inc., Richland, Washington.

Maximum Acid Addition Rate

Conversion Factors

35.314 ft^3/m^3
1000 liter/m^3
3.785 liter/gallon

Molar Gas Volume

22.4 liter/mole at 273.15 °K
24.5 liter/mole at 298.15 °K

For onsite radiological and toxicological consequences to fall within guidelines, the Carbon Dioxide generation rate must be less than 0.255 m^3/second

0.225 m^3/second * 35.314 ft^3/m^3*60 sec/minute = 477 ft^3/minute
or
0.225 m^3/second*1000 liter/m^3*60 sec/minute = 13,500 liter/minute

Taking a conservative approach and setting process control limit to 50% of that:

477 ft^3/minute*0.5 = 238 ft^3/minute
or
13,500 liter/minute*0.5 = 6750 liter/minute

The allowable gas generation rate is:

6750 liter/minute/24.5 liter/mole = 276 mole/minute

2 moles bicarbonate and 1 mole of oxalic acid react to form 2 moles of carbon dioxide gas. Assume oxalate reacts as soon as it is added.

Oxalate concentration is 0.9 mole/liter

Allowable acid addition rate:

(276 mole gas/minute)(1 mole acid/2 mole gas)(1 liter acid/0.9 mole acid)(1 gallon/3.785 liter)=40.5 gallon/minute

Leela Sasaki
Closure Projects Engineering Support

Checker: Daniel A. Reynolds
Date: 5/27/03

APPENDIX F

MEMO: ADDITIONAL INFORMATION ON GASSING OF SLUDGE IN 241-C-106 ON ADDING OXALIC ACID

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INTEROFFICE MEMO

CH2MHILL
Hanford Group, Inc.

From:	Closure Project Engineering Support	7G330-DAR-03-003
Phone:	373-3115 S7-90	
Date:	June 9, 2003	
Subject:	ADDITIONAL INFORMATION ON GASSING OF SLUDGE IN 241-C-106 ON ADDING OXALIC ACID	

To:	R. D. Smith	S7-90
Copies:	W. B. Barton	S7-90
	K. E. Carpenter	S7-65
	T. H. May	S7-65
	J. G. Propson	S7-65
	K. R. Sandgren	S7-90
	L. M. Sasaki	S7-90
	M. V. Shultz	S7-90
	W. T. Thompson	S7-70
	DAR File/LB	

Reference: Interoffice Memo D. A. Reynolds to R. D. Smith, "Oxalic Acid Dissolution in Tank 241-C-106 Effect on Concrete and Gas Generation," 7G330-DAR-03-002, dated May 27, 2003.

The purpose of this memo is to provide additional information on the gas effervescence when oxalic acid is added to the residual heel in Tank 241-C-106. Several points will be clarified with this memo. The total amount of gas that can be generated per batch, the mixing effect of the effervescence, a more realistic bounding acid addition rate, and when the acid/carbonate reaction will be spent will all be addressed.

The basic reaction of oxalic acid with carbonate is shown in equation 1.

$$H_2C_2O_4 + CO_3^{-2} = CO_{2(gas)} + H_2O + C_2O_4^{-2} \qquad \text{equation 1}$$

This equation shows that 1 mole of oxalic acid ($H_2C_2O_4$) reacts with 1 mole of carbonate (CO_3^{-2}) to produce 1 mole of carbon dioxide gas ($CO_{2(gas)}$).

The total amount of carbon dioxide gas that can be generated per batch of acid can be computed. The batches of acid will be 30,000 gallons of nominally 1 mole/liter oxalic acid. The volume of one lb mole of gas is 359 ft^3/lbmole at 32°F.

(30,000 gal)(3.785 liter/gal)(1 gmole/liter)(1 lbmole/454gmole)(359 ft^3/lbmole) = 90,000 ft^3 at standard conditions.

This amount of gas, which is the maximum that can be produced, is given off over time and not all at once. The length of time is dependent on the rate that the acid is moved into contact with the solids that contain the carbonate. But note that a 1000 cfm exhauster will be on during the acid contact. If that exhauster is throttled back to a nominal 500 cfm, then 196 minutes will be all that is required to remove the 90,000 cubic feet of carbon dioxide. The 30,000 gallons of acid cannot be put into the tank in less than 180 minutes. If the exhauster is not throttled back, then about 100 minutes will be required.

The one control that can be used to control the gas effervescence is the rate that acid is added to the tank. The attachment to this memo shows that 80 gpm is a conservative rate that will keep the effervescence below 477 cfm if all of the acid reacts by equation 1. Operationally, the oxalic acid will be introduced at about 40 gpm to give some additional margin.

One scenario that has been raised is the possibility of a large pool of acid that does not contact the solids that is rapidly stirred to contact the solids. This large reservoir may react at that time and give a spike of gas. This scenario is not possible with the acid addition system that is designed.

The acid will be added to Tank 241-C-106 by going through the mixing eductor. This puts the acid near the bottom of the tank where it can contact the solids rapidly. The gas evolution will begin when the acid reaches the solids and the carbon dioxide starts to effervesce. The gas bubbles will act similar to air lift mixers to stir the liquid above the solids. More effervescence will cause greater stirring. As the reaction moves to completion and the effervescence is lower, the stirring will decrease. This gas effervescence will provide better agitation than the mixing eductor. Meanwhile, the fresh acid being added through the mixing eductor will be causing mixing. These two mixing phenomena will produce a nearly homogeneous liquid pool and will certainly prevent a large reservoir of unreacted acid from accumulating. The only way a large reservoir of unreacted acid can accumulate is for the carbonate in the solids to be depleted. Once that happens, then the carbon dioxide gassing ceases to be a problem.

Adding acid at about 40 gpm is a prudent method of controlling the gassing of the sludge. However, the laboratory work shows that eventually the bulk of the carbonate is consumed and gassing drops way off. There are several ways to tell when the gas effervescence has decayed off. The ventilation system will be recording flow rates and pressures. A change in these will signal when the bulk of the ventilation is coming from air through the breather filter. Industrial hygiene will be monitoring the off gas and oxygen concentration is one of those parameters that they measure. A large oxygen content will signal that air is being vented and not just carbon dioxide. The mixing eductor leg has a pH meter in it. When the pH of the acid remains below 4 at the end of a batch, that is an indication that the carbonate is essentially gone and the acid is now mostly dissolving the sludge. One or more of these methods will be examined to determine when the next batch no longer needs a restriction on the acid addition rate.

D A Reynolds

D. A. Reynolds
Principal Engineer

Computation Checked by: D M Sasaki
Date: 6/9/03

DAR/ad

Attachment

7G330-DAR-03-003

Attachment 1

LIMITING CARBON DIOXIDE GENERATION DURING ADDITION OF OXALIC ACID TO TANK 241-C-106

Consisting of 4 pages, including coversheet

Limiting Carbon Dioxide Generation During Addition of Oxalic Acid to Tank 241-C-106

The retrieval of Tank 241-C-106 involves the treatment of the sludge with oxalic acid to dissolve most of the solids. Current plans are for the oxalic acid to be added to the tank in six batches of 30,000 gallons (gal), for a total of 180,000 gal. The acid will be delivered in truckloads of 5,000 gal each and the concentration of the oxalic acid will be 0.9 molar (Reynolds 2003).

The addition of oxalic acid to Tank 241-C-106 will result in the generation of gas as the acid reacts with carbonate in the sludge to create carbon dioxide:

$$H_2C_2O_4 + CO_3^{-2} \rightarrow CO_2\,(gas) + H_2O + C_2O_4^{-2} \qquad (1)$$

There are two issues associated with the generation of carbon dioxide in the tank:

1. The gas generation rate may exceed the capacity of the exhauster and result of a loss of the headspace vacuum and releases to the environment.
2. The gas generation can result in the tank waste being carried into the tank headspace as aerosols resulting in the headspace vapors which would exceed onsite radiological and toxicological guidelines if released to the environment.

Tank 241-C-106 exhauster will draw approximately 950 cubic feet per minute (ft^3/min) from the tank and must maintain at least 0.3 inches water gauge vacuum in the tank. To maintain this vacuum in the tank, the maximum allowable gas generation rate is 550 ft^3/min (Minteer 2003).

To maintain tank headspace vapor compositions below the radiological and toxicological guidelines, the gas generation rate must be below 0.225 cubic meters per second (477 ft^3/min) (Sandgren 2003).

Based on sludge dissolution studies with Tank 241-C-106 sludges, the rate of gas generation reached a maximum of 4.2 millimoles per hour per gram within a few minutes of oxalic acid addition and decreased to essentially zero within several hours (Herting 2003). If this maximum rate is applicable to the sludge in Tank 241-C-106 (9,000 gal sludge with an estimated density of 1.7 grams per milliliter), a gas generation rate of 3,500 ft^3/min at normal temperature and pressure would result. Therefore, controlling the gas generation rate by controlling the rate of addition of oxalic acid was considered.

In a well mixed, liquid phase reaction, the reaction

$$H_2C_2O_4 + CO_3^{-2} \rightarrow CO_2\,(gas) + H_2O + C_2O_4^{-2} \qquad (1)$$

would proceed first by the conversion of carbonate to bicarbonate:

$$H_2C_2O_4 + 2\,CO_3^{-2} \leftrightarrow 2\,HCO_3^{-} + C_2O_4^{-2} \qquad (2)$$

then to carbonic acid and the release of carbon dioxide:

$$H_2C_2O_4 + 2\,HCO_3^{-} \leftrightarrow 2\,H_2CO_3 + C_2O_4^{-2} \rightarrow 2\,CO_2\,(g) + 2\,H_2O + C_2O_4^{-2} \qquad (3)$$

For carbonic acid (Dean 1973):

$$pK_{a1} = 6.35 \quad ([H+][HCO_3^-]/[H_2CO_3])$$
$$pK_{a2} = 10.33 \quad ([H+][CO_3^{-2}]/[HCO_3^-])$$

Therefore, the initial amounts of oxalic acid added would serve primarily to convert carbonate to bicarbonate. Further addition of oxalic acid would react with the bicarbonate to generate carbon dioxide. Although one mole of oxalic acid generates one mole of carbon dioxide in the overall reaction, the initial addition of oxalic acid to Tank 241-C-106 may generate little carbon dioxide while further addition can result in the generation of carbon dioxide at a rate of as much as two moles of carbon dioxide per mole of oxalic acid added. In reality, the reaction rate in Tank 241-C-106 is expected to remain well below 2 moles of carbon dioxide per mole of oxalic acid added because the tank does not represent a well-mixed, liquid phase with all the carbonate in solution.

Assumptions for calculation of oxalic acid addition rate:

- The gas generation rate is limited to the lower of the two maximum allowable generation rates above (i.e., 477 ft^3/min).
- Normal temperature and pressure (1 atmosphere and 25 °C) were used to calculate gas volumes. The highest temperature observed in Tank 241-C-106 during the past year (May 20, 2002 through May 20, 2003) was 93.2 °F (34 °C), which would result in only a 3 percent difference in volume.
- One mole of oxalic acid generates two moles of carbon dioxide (Reaction 3 above).

To limit the gas generation rate to 477 ft^3/min, the acid addition rate should be limited to approximately 80 gallons per minute. Operationally, it is recommended that the acid addition rate be approximately 40 gallons per minute and several hours should be allowed between truckloads to allow the gas generation reaction rate to decrease before more oxalic acid is added. This process should be performed for the first three batches (90,000 gal) of oxalic acid added to the tank. Based on the laboratory studies, Reynolds (2003) estimates that the pH of the liquid in the tank should be about 2 after 3 batches. At this pH, most of the carbon dioxide would have been released. Additionally, the laboratory studies indicate that over 90 percent of the carbonate will have been released from the sludge as carbon dioxide and the reaction rate would have fallen to within allowable levels by the end of the third batch.

References:

Dean, J. A., Editor, 2003, *Lange's Handbook of Chemistry*, eleventh edition, McGraw-Hill Book Company, New York, New York.

Herting, D. L., 2003, "Final Report for Tank 241-C-106 Sludge Dissolution, Phase II," (letter FH-0301877 to D. A. Reynolds, CH2M HILL, May 8), Fluor Hanford, Richland, Washington.

Minteer, D. J., 2003, electronic mail message to L. M. Sasaki, June 3, CH2M HILL Hanford Group, Inc., Richland, Washington.

Reynolds, D. A., 2003, "Process Description of the C-106 Oxalic Acid Dissolution," (draft), CH2M HILL Hanford Group, Inc., Richland, Washington.

Sandgren, K. R., 2003, electronic mail message to L. M. Sasaki, May 21, CH2M HILL Hanford Group, Inc., Richland, Washington.

Maximum Acid Addition Rate

Conversion Factors

35.314 ft^3/m^3
1000 liter/m^3
3.785 liter/gallon

Molar Gas Volume

22.4 liter/mole at 273.15 °K
24.5 liter/mole at 298.15 °K

For onsite radiological and toxicological consequences to fall within guidelines, the carbon dioxide generation rate must be less than 0.255 m^3/second

0.225 m^3/second • 35.314 ft^3/m^3*60 sec/minute = 477 ft^3/minute
or
0.225 m^3/second*1000 liter/m^3*60 sec/minute = 13,500 liter/minute

The allowable gas generation rate is:

13,500 liter/minute/24.5 liter/mole = 551 mole/minute

2 moles bicarbonate and 1 mole of oxalic acid react to form 2 moles of carbon dioxide gas. Assume oxalate reacts as soon as it is added.

Oxalate concentration is 0.9 mole/liter

Allowable acid addition rate:

(551 mole gas/minute)(1 mole acid/2 mole gas)(1 liter acid/0.9 mole acid)(1 gallon/3.785 liter) = 81 gallon/minute

L.M. Sasaki
Leela Sasaki
Closure Projects Engineering Support

Checker: [signature]
Date: 4/10/03

APPENDIX G

PEER REVIEW CHECKLIST

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CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: RPP-16537, *Safety Evaluation of Oxalic Acid Waste Retrieval in Single-Shell Tank 241-C-106*, Rev. 0

Scope of Review (e.g., document section or portion of calculation): Entire document except Section 4.3.4

Yes	No	NA*	
[X]	[ ]	[ ]	1. Previous reviews are complete and cover the analysis, up to the scope of this review, with no gaps.
[X]	[ ]	[ ]	2. Problem is completely defined.
[X]	[ ]	[ ]	3. Accident scenarios are developed in a clear and logical manner.
[X]	[ ]	[ ]	4. Analytical and technical approaches and results are reasonable and appropriate. *(ORP QAPP criterion 2.8)*
[X]	[ ]	[ ]	5. Necessary assumptions are reasonable, explicitly stated, and supported. *(ORP QAPP criterion 2.2)*
[ ]	[ ]	[X]	6. Computer codes and data files are documented.
[X]	[ ]	[ ]	7. Data used in calculations are explicitly stated.
[X]	[ ]	[ ]	8. Bases for calculations, including assumptions and data, are consistent with the supported safety basis document (e.g., the Tank Farms Final Safety Analysis Report).
[X]	[ ]	[ ]	9. Data were checked for consistency with original source information as applicable. *(ORP QAPP criterion 2.9)*
[X]	[ ]	[ ]	10. For both qualitative and quantitative data, uncertainties are recognized and discussed, as appropriate. *(ORP QAPP criterion 2.17)*
[X]	[ ]	[ ]	11. Mathematical derivations were checked including dimensional consistency of results. *(ORP QAPP criterion 2.16)*
[X]	[ ]	[ ]	12. Models are appropriate and were used within their established range of validity or adequate justification was provided for use outside their established range of validity.
[X]	[ ]	[ ]	13. Spreadsheet results and all hand calculations were verified.
[X]	[ ]	[ ]	14. Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring outside information. *(ORP QAPP criterion 2.5)*
[ ]	[ ]	[X]	15. Software input is correct and consistent with the document reviewed.
[ ]	[ ]	[X]	16. Software output is consistent with the input and with the results reported in the document reviewed.
[ ]	[ ]	[X]	17. Software verification and validation are addressed adequately. *(ORP QAPP criterion 2.6)*
[X]	[ ]	[ ]	18. Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references. *(ORP QAPP criterion 2.9)*
[X]	[ ]	[ ]	19. Safety margins are consistent with good engineering practices.
[X]	[ ]	[ ]	20. Conclusions are consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	21. Results and conclusions address all points in the purpose. *(ORP QAPP criterion 2.3)*

[X] [ ] [ ] 22. All references cited in the text, figures, and tables are contained in the reference list.
[X] [ ] [ ] 23. Reference citations (e.g., title and number) are consistent between the text callout and the reference list.
[X] [ ] [ ] 24. Only released (i.e., not draft) references are cited. *(ORP QAPP criterion 2.1)*
[X] [ ] [ ] 25. Referenced documents are retrievable or otherwise available.
[X] [ ] [ ] 26. The most recent version of each reference is cited, as appropriate. *(ORP QAPP criterion 2.1)*
[X] [ ] [ ] 27. There are no duplicate citations in the reference list.
[X] [ ] [ ] 28. Referenced documents are spelled out (title and number) the first time they are cited.
[X] [ ] [ ] 29. All acronyms are spelled out the first time they are used.
[X] [ ] [ ] 30. The Table of Contents is correct.
[X] [ ] [ ] 31. All figure, table, and section callouts are correct.
[X] [ ] [ ] 32. Unit conversions are correct and consistent.
[X] [ ] [ ] 33. The number of significant digits is appropriate and consistent.
[X] [ ] [ ] 34. Chemical reactions are correct and balanced.
[X] [ ] [ ] 35. All tables are formatted consistently and are free of blank cells.
[X] [ ] [ ] 36. The document is complete (pages, attachments, and appendices) and in the proper order.
[X] [ ] [ ] 37. The document is free of typographical errors.
[X] [ ] [ ] 38. The tables are internally consistent.
[X] [ ] [ ] 39. The document was prepared in accordance with HNF-2353, Section 4.3, Attachment B, "Calculation Note Format and Preparation Instructions".
[X] [ ] [ ] **Concurrence**

Kevin Sandgren [signature] 6/11/03
Reviewer (Printed Name and Signature) Date

- If No or NA is chosen, an explanation must be provided on this form.
  - No computer codes were used for the calculations included in the report. All calculations were verified through hand calculations.

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: RPP-16357 section 4.3.4

Scope of Review (e.g., document section or portion of calculation):

Yes	No	NA*	
[]	[]	[✓]	1. Previous reviews are complete and cover the analysis, up to the scope of this review, with no gaps.
[]	[]	[✓]	2. Problem is completely defined.
[]	[]	[✓]	3. Accident scenarios are developed in a clear and logical manner.
[✓]	[]	[]	4. Analytical and technical approaches and results are reasonable and appropriate. *(ORP QAPP criterion 2.8)*
[✓]	[]	[]	5. Necessary assumptions are reasonable, explicitly stated, and supported. *(ORP QAPP criterion 2.2)*
[]	[]	[✓]	6. Computer codes and data files are documented.
[✓]	[]	[]	7. Data used in calculations are explicitly stated.
[]	[]	[✓]	8. Bases for calculations, including assumptions and data, are consistent with the supported safety basis document (e.g., the Tank Farms Final Safety Analysis Report).
[]	[]	[✓]	9. Data were checked for consistency with original source information as applicable. *(ORP QAPP criterion 2.9)*
[]	[]	[✓]	10. For both qualitative and quantitative data, uncertainties are recognized and discussed, as appropriate. *(ORP QAPP criterion 2.17)*
[✓]	[]	[]	11. Mathematical derivations were checked including dimensional consistency of results. *(ORP QAPP criterion 2.16)*
[]	[]	[✓]	12. Models are appropriate and were used within their established range of validity or adequate justification was provided for use outside their established range of validity.
[✓]	[]	[]	13. Spreadsheet results and all hand calculations were verified.
[✓]	[]	[]	14. Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring outside information. *(ORP QAPP criterion 2.5)*
[]	[]	[✓]	15. Software input is correct and consistent with the document reviewed.
[]	[]	[✓]	16. Software output is consistent with the input and with the results reported in the document reviewed.
[]	[]	[✓]	17. Software verification and validation are addressed adequately. *(ORP QAPP criterion 2.6)*
[✓]	[]	[]	18. Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references. *(ORP QAPP criterion 2.9)*
[]	[]	[✓]	19. Safety margins are consistent with good engineering practices.
[✓]	[]	[]	20. Conclusions are consistent with analytical results and applicable limits.
[]	[]	[✓]	21. Results and conclusions address all points in the purpose. *(ORP QAPP criterion 2.3)*
[✓]	[]	[]	22. All references cited in the text, figures, and tables are contained in the reference list.

[✓] [ ] [ ] 23. Reference citations (e.g., title and number) are consistent between the text callout and the reference list.
[✓] [ ] [ ] 24. Only released (i.e., not draft) references are cited. *(ORP QAPP criterion 2.1)*
[✓] [ ] [ ] 25. Referenced documents are retrievable or otherwise available.
[✓] [ ] [ ] 26. The most recent version of each reference is cited, as appropriate. *(ORP QAPP criterion 2.1)*
[✓] [ ] [ ] 27. There are no duplicate citations in the reference list.
[✓] [ ] [✓] 28. Referenced documents are spelled out (title and number) the first time they are cited.
[✓] [ ] [ ] 29. All acronyms are spelled out the first time they are used.
[ ] [ ] [✓] 30. The Table of Contents is correct.
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[ ] [ ] [✓] 35. All tables are formatted consistently and are free of blank cells.
[ ] [ ] [✓] 36. The document is complete (pages, attachments, and appendices) and in the proper order.
[✓] [ ] [ ] 37. The document is free of typographical errors.
[ ] [ ] [✓] 38. The tables are internally consistent.
[ ] [ ] [✓] 39. The document was prepared in accordance with HNF-2353, Section 4.3, Attachment B, "Calculation Note Format and Preparation Instructions".
[✓] [ ] [ ] **Concurrence**

John P. Harris [signature] 6/11/03

Reviewer (Printed Name and Signature) Date

• If No or NA is chosen, an explanation must be provided on this form.