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Abstract:
This document presents onsite radiological, onsite toxicological, and offsite toxicological consequences, risk binning, and control decision results for the mixing of incompatible materials in waste tanks representative accident.

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

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Contractor for the U.S. Department of Energy
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LIST OF TERMS

AC	administrative control
ARF	airborne release fraction
DCRT	double-contained receiver tank
DSA	documented safety analysis
DST	double-shell tank
ERPG	emergency response planning guideline
HEPA	high-efficiency particulate air (filter)
PFP	Plutonium Finishing Plant
SMP	safety management program
SOF	sum of fractions
SSC	structures, systems, and components
SST	single-shell tank
TEEL	Temporary Emergency Exposure Limit
TSR	technical safety requirement
TWG	Technical Working Group
ULD	unit-liter dose

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1.0 INTRODUCTION

1.1 PURPOSE

This technical basis document was developed to support the tank farms documented safety analysis (DSA) and describes the risk binning process, the technical basis for assigning risk bins, and the controls selected for the mixing of incompatible materials representative accident and associated represented hazardous conditions. The purpose of the risk binning process is to determine the need for safety-significant structures, systems, and components (SSC) and/or technical safety requirement (TSR)-level controls for a given representative accident or represented hazardous conditions based on an evaluation of the frequency and consequence. Note that the risk binning process is not applied to facility workers, because all facility worker hazardous conditions are considered for safety-significant SSCs and/or TSR-level controls. (See RPP-14286, *Facility Worker Technical Basis Document).* Determination of the need for safety-class SSCs was performed in accordance with DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, as described below.

1.2 BACKGROUND INFORMATION

1.2.1 Representative Accident

Routine tank farm operations include a number of material transfer activities such as waste transfers between tanks, incoming waste transfers from non-tank farm facilities (e.g., Plutonium Finishing Plant [PFP], 222-S Laboratory, T Plant), and bulk chemical additions to double-shell tanks (DST) for corrosion control. When considering the related hazards within tank farms, it was postulated that the mixing of incompatible material in a waste tank could result in a chemical reaction that produces aerosols and enough internal pressure to expel headspace gases, vapors, and aerosolized waste. Incompatible materials that could potentially be transferred to tank farm facilities were studied to determine a bounding case. The scenarios that were considered were:

Scenario 1. Addition of an incompatible material due to a waste transfer from an internal or external source:
- Case A. Misrouting or transfer of incompatible tank waste
- Case B. Incompatible waste addition from external source.

Scenario 2. Inadvertent addition of an incompatible chemical due to a vendor or paperwork error when making a chemical addition to a tank:
- Case A. Addition of excess base to a waste tank
- Case B. Addition of acid to a waste tank waste.

As the tank wastes are similar, reactions due to a transfer from one tank to another will not result in a significant release according to Reynolds (2001), "Potential for Tank Farm Systems to Give Off Toxic Chemicals or Pressurizing Due to Chemical Incompatibility." Reynolds (2001) was

included as an appendix to RPP-9689, *Offsite Radiological Consequence Calculation for the Bounding Mixing of Incompatible Materials Accident*. Therefore, Case A of Scenario 1 was discarded as a potential bounding case.

The majority of waste that is generated externally to tank farms would come from the PFP, the 222-S Laboratory, and T Plant. Each of these facilities utilizes practices that ensure the final facility waste solution is not transferred to incompatible tank waste. In addition, the transfer lines are not compatible with strong acids (the most common incompatible material) and would fail before large volumes could be transferred. Therefore, Scenario 1, Case B was discarded as the bounding case.

Inadvertent addition of chemicals was then examined. The addition of excess base to tank waste was examined for the potential to react and produce ammonia. Substantial amounts of ammonia are dissolved or trapped in some tank wastes. Ammonia is produced by the decomposition of nitrogen-containing compounds that were added to process solutions that eventually ended up as waste. Amine chelating agents such as ethylenediaminetetraacetic acid are among the chief sources. There is some potential for the ammonia in these wastes to be released into the vapor space of tanks and vented to the atmosphere.

The solubility of ammonia increases with decreasing pH due to an increasing fraction of the dissolved ammonia existing as the ammonium ion. As pH is raised, the ammonium ion is converted to the neutral, molecular ammonia solute (aqueous NH_3). The neutral aqueous ammonia desorbs to become gaseous or vapor phase ammonia. The main reactions are as follows:

$$NH_4^+ + OH^- \rightleftharpoons NH_{3(aqueous)} + H_2O$$
$$NH_{3(aqueous)} \rightleftharpoons NH_{3(vapor)}.$$

The potential exists for strong bases to be accidentally added to waste tanks in amounts that may reduce the solubility of ammonia. A series of calculations were performed to predict the solubility of ammonia in a simulated waste and the effect of adding various amounts of 100% sodium hydroxide to the worst-case tank waste. It was found that a large amount of sodium hydroxide (slightly over 4 moles/L of waste) must be added to reach the ammonia saturation point before any ammonia is released by the reaction. An estimate of the bounding ammonia release was calculated in WHC-SD-WM-CN-074, *Chemical Reaction in a DCRT Leading to a Toxic Release*. It was shown that the consequences of an ammonia release are well within conservative guidelines. Therefore, Scenario 2, Case A, was not selected as the representative case.

Since direct chemical additions can be made to the waste tanks, an accident was postulated in which bulk delivery of an unexpected chemical is made to a waste tank (e.g., instead of the caustic addition expected, the delivery truck contains an acid). Since the delivery was assumed to be from a large tanker truck, only common chemicals that are routinely shipped in bulk quantities were considered. Common industrial acids were evaluated for their potential to react with tank waste resulting in gas or vapor generation. The reaction of strong acids with carbonate waste was found to produce large quantities of carbon dioxide. The addition of concentrated sulfuric acid to the tank waste was identified as the bounding case and is presented here.

1.2.2 Bounding Offsite Accident

The mixing of incompatible materials accident is the bounding, low-energy atmospheric vapor/gas/aerosol release event, and has been quantitatively analyzed for comparison to the DOE-STD-3009-94, Appendix A, "Evaluation Guideline," of 25 rem. The bounding quantitative analysis for the mixing of incompatible materials accident is documented in RPP-9689, and shows that offsite radiological consequences are less than 1 rem. Therefore, no safety-class equipment or TSR-level controls need to be considered for offsite radiological exposures for any of the low-energy atmospheric vapor/gas/aerosol release events. It is important to note that DOE-STD-3009-94 does not provide any other evaluation guidelines (i.e., evaluation guidelines are not provided for offsite toxicological, onsite radiological, and onsite toxicological exposures). These exposures were evaluated for the representative accident and associated hazardous conditions in accordance with the risk binning process described in Section 1.3.

1.2.3 Associated Hazardous Conditions

In addition to the hazardous condition that defines the representative accident, the current hazard evaluation database lists a number of hazardous conditions that are represented by the mixing of incompatible materials accident. The hazardous conditions typically involve chemical reactions caused by mixing incompatible materials and are postulated to occur in the various tanks (DSTs, single-shell tanks [SST], and double-contained receiver tanks [DCRT]). Also grouped under the mixing of incompatible materials representative accident are various types of conditions that result in the release of ammonia vapors. The ammonia release conditions were assigned to the mixing of incompatible materials accident because they most closely resembled the ammonia releases that were due to the inadvertent addition of excess base. Some type of waste disturbing activity is generally the cause of these ammonia release events.

1.3 RISK BINNING METHODOLOGY

Direction on risk binning was provided by the U.S. Department of Energy, Office of River Protection (Klein and Schepens, 2003, "Replacement of Previous Guidance Provided by RL and ORP"). Risk binning begins with a qualitative evaluation of the frequency and consequence of the representative accident. Consequences are evaluated for the following receptors and exposures: offsite toxicological, onsite radiological, and onsite toxicological. These consequences are assigned to one of three categories: high, moderate, or low. Based on the frequency and consequence, risk bins (ranging from I to IV) are assigned. The approach applied during DSA development was that safety SSCs and/or TSR-level controls are required for accidents or hazardous conditions that are assigned to Risk Bins I or II, and are considered for accidents or hazardous conditions that are assigned to Risk Bin III. For accidents or hazardous conditions assigned to Risk Bin IV, safety SSCs and TSR-level controls are not expected. Safety management programs (SMP) are acceptable for addressing the residual risk posed by Risk Bin IV conditions. Tables 1 and 2 show the criteria that were applied during DSA development for assigning the frequency and consequence categories, and the risk bins, which are assigned to the various combinations of frequency and consequence. After the risk binning process is completed for the representative accident, the process is then repeated for the represented hazardous conditions associated with the representative accident.

Table 1. Offsite (Toxicological Only) Risk Bins.

Consequence category (toxicological only[1])	Event frequency			
	$<10^{-6}$/yr Beyond extremely unlikely	**10^{-4} to 10^{-6}/yr Extremely unlikely**	**10^{-2} to 10^{-4}/yr Unlikely**	**$>10^{-2}$/yr Anticipated**
>ERPG-2 / TEEL-2 (High)	III	II	I	I
>ERPG-1 / TEEL-1 <ERPG-2 / TEEL-2 (Moderate)	IV	III	II	I
< ERPG-1 / TEEL-1 (Low)	IV	IV	III	III

safety SSCs and/or TSR-level controls required.

safety SSCs and/or TSR-level controls considered.

[1] Radiological consequences for the offsite receptor are evaluated in accordance with DOE-STD-3009-94, 2002, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, Change Notice No. 2, Appendix A, U.S. Department of Energy, Washington D.C.

ERPG = emergency response planning guideline. TEEL = Temporary Emergency Exposure Limit.
SSC = structures, systems, and components. TSR = technical safety requirement.

Table 2. Onsite (100 m) Risk Bins.

Consequence category (radiological/ toxicological)	Event frequency			
	$<10^{-6}$/yr Beyond extremely unlikely	**10^{-4} to 10^{-6}/yr Extremely unlikely**	**10^{-2} to 10^{-4}/yr Unlikely**	**$>10^{-2}$/yr Anticipated**
>100 rem >ERPG-3 / TEEL-3 (High)	III	II	I	I
25 to 100 rem >ERPG-2 / TEEL-2 <ERPG-3 / TEEL-3 (Moderate)	IV	III	II	I
<25 rem <ERPG-2 / TEEL-2 (Low)	IV	IV	III	III

safety SSCs and/or TSR-level controls required.

safety SSCs and/or TSR-level controls considered.

ERPG = emergency response planning guideline. TEEL = Temporary Emergency Exposure Limit.
SSC = structures, systems, and components. TSR = technical safety requirement.

Environmental consequences are also assigned during the risk binning process. There are four categories of environmental consequences (E0, E1, E2, and E3, in order of increasing severity); these categories are defined in Table 3.

Table 3. Environmental Consequence Categories.

Category	Definition
E3	Offsite discharge or discharge to groundwater
E2	Significant discharge onsite
E1	Localized discharge of hazardous material
E0	No significant environmental consequence

2.0 RISK BINNING RESULTS

A risk binning team meeting was conducted on July 17, 2002, to obtain consensus on the assignment of frequencies, consequences, and risk bins. The attendees represented a wide range of expertise in the areas of engineering, licensing, and operations, and included representatives from the U.S. Department of Energy, Office of River Protection. Appendix A lists the attendees and the organization each attendee represents. After the meeting, the risk binning results were distributed to the Technical Working Group (TWG) for review and concurrence. The final risk bin results, after comment resolution, are summarized in Tables 4 and 8. See RPP-15116, *Proceedings of the Nuclear Working Group and the Technical Working Group*.

2.1 MIXING OF INCOMPATIBLE MATERIALS REPRESENTATIVE ACCIDENT WITHOUT CONTROLS

2.1.1 Accident Scenario

Large quantities of sodium hydroxide or sodium nitrite are added to DSTs, as necessary, to maintain the waste chemistry within the limits specified in the corrosion control program. These chemicals are delivered in tanker trucks and typically are added directly to the DST that requires chemical adjustment.

In the accident scenario without controls, the wrong chemical is delivered and 5,000 gal of concentrated sulfuric acid is added to a DST. The receiving tank is assumed to contain sufficient carbonate waste to completely react with the incoming acid. The carbon dioxide formed is released into the tank headspace carrying with it a fraction of tank waste. It is assumed that the high-efficiency particulate air (HEPA) filters fail, contributing to the consequences. Condensation of the aerosol on the walls of the tank was assumed to be insignificant. The reaction was conservatively considered to be instantaneous. Aerosolized waste is released as a result of the tank pressurization.

2.1.2 Frequency Determination

A frequency of "unlikely" was qualitatively assigned to the mixing of incompatible materials representative accident. The scenario requires that the chemical vendor also produce bulk quantities of sulfuric acid, mistakenly fills the delivery truck with the wrong chemical, places incorrect placarding on the vehicle, and includes incorrect delivery paperwork. The highly corrosive substance would have to be shipped to the receiving facility without being noticed by delivery personnel or shipping and receiving personnel. The vehicle would have to be connected and the corrosive material delivered without notice by participating personnel. In addition the receiving tank would have to contain high concentrations of carbonate waste.

2.1.3 Consequence Determination

This scenario of a bulk addition of acid to a DST or DCRT has not been previously analyzed. To provide an estimate of the radiological and toxicological consequences, calculations were performed and are documented in Appendix B. The accident scenario, without controls, assumes that a cargo tanker filled with 5,000 gal of 98% sulfuric acid (18.7 M) is emptied into a waste tank instead of the chemical expected (e.g., caustic or sodium nitrite). The 5,000 gal assumption is conservative because the sulfuric acid would significantly exceed the weight that tanker trucks can transport. (While tanker trucks contain a nominal volume as large as 7,000 gal, they are limited by total weight of the filled tanker. Generally, the maximum weight that can be transported is 45,000 lb, which is the equivalent weight of 3,000 gal of sulfuric acid. The analysis conservatively assumes the tanker contains significantly more than the full weight capacity of sulfuric acid.) The rate of addition is conservatively assumed to be 175 gal/min (typical addition rates seen in the field range from 75 to 100 gal/min). The receiving tank is assumed to contain sufficient carbonate waste to completely react with the incoming acid. The carbon dioxide formed is released into the tank headspace carrying with it a fraction of tank waste. It is assumed that the HEPA filters fail, contributing to the consequences. Condensation of the aerosol on the walls of the tank was assumed to be insignificant. The reaction was conservatively considered to be instantaneous. The contributors to the toxicological consequences are the HEPA filter release, the aerosolized waste, and sulfuric acid fumes.

The source term used for the aerosol is 10% DST solids and 90% DST liquids. DST waste is assumed since the bounding radiological unit-liter dose (ULD) is found in DST waste. While the reaction will occur in the liquid phase, agitation will occur in the vicinity of the incoming acid stream. The agitation will cause some fine solids to be suspended in liquid. Solids that are dense or have large particle sizes will not be suspended by the bubbles. As the bubbles rise/collide/consolidate and collapse much of the solids will be released. The inclusion of 10% solids in the aerosol is considered a conservative assumption. The radiological ULDs were taken from RPP-5924, *Radiological Source Terms for Tank Farms Safety Analysis*, and the toxicological sums of fractions (SOF) were taken from RPP-8369, *Chemical Source Terms for Tank Farms Safety Analyses*. The atmospheric dispersion factors are from RPP-13482, *Atmospheric Dispersion Coefficients and Radiological/Toxicological Exposure Methodology for Use in Tank Farms.*

Analysis assumptions and inputs are described below:

- 5,000 gal addition (conservative as this volume would exceed the weight that tanker trucks can transport)
- 175 gal/min rate of addition
- The acid is 98% sulfuric acid
- All the aerosol released is assumed to be respirable
- The source term used for the aerosol in the analysis is 10% DST sludge and 90% DST liquids
- The receiving tank is assumed to contain sufficient carbonate waste to completely react with the incoming acid
- The pressurization resulting from the accident fails the HEPA filters
- The inventory on the HEPA filters is equivalent to that which would produce a contact dose rate of 200 mrem/h
- Condensation of the aerosol on the walls of the tank was assumed to be insignificant
- Instantaneous reaction (conservative; would require instantaneous mixing).

It is important to note that the key assumptions listed above were selected to maximize the calculated consequences of the inadvertent acid addition, and that it is the combination of conservative assumptions that drive the accident consequences. Each of the assumptions, the potential effect of changes in the assumption on the frequency or consequence bin (qualitatively judged), and the need to evaluate or protect the assumptions are detailed in Table 5.

2.1.3.1 Assignment of Consequence Bins for the Onsite Radiological Receptor.

Although the evaluation of consequences was intended to be qualitative, there were no previous analyses of an inadvertent large acid addition that could provide an additional frame of reference for the qualitative judgment. Therefore, the radiological consequences were estimated as shown in Appendix B. Also, while determining the offsite toxicological, onsite radiological, and onsite toxicological consequence bins, the meeting participants considered an actual operational experience where a transfer of unneutralized PUREX waste occurred. While the line between the valve pit and the distributor was damaged, there was no noticeable reaction with the tank waste (Occurrence #85-34 [RPP-13121, *Historical Summary of Occurrences from the Tank Farms Final Safety Analysis Report*]). Table 6 compares the onsite radiological consequences of the bounding representative accident to the radiological risk evaluation guidelines. Since the bounding condition resulted in consequences that exceeded the moderate guideline to the onsite radiological receptor, the hazardous condition was assigned a consequence bin of "moderate" for the onsite radiological receptor.

2.1.3.2 Assignment of Consequence Bins for the Onsite and Offsite Toxicological Receptor.

As noted in the previous section, there were no previous analyses of an inadvertent large acid addition to influence the qualitative assignment of consequences. Thus, the toxicological consequences were also estimated as shown in Appendix B. Consequence bins were assigned based on the analysis presented in Appendix B and the occurrence discussed above. Table 7 compares the toxicological consequences of the bounding representative accident to the risk evaluation guidelines. Reviewing the consequences shows that the offsite toxicological consequences are low, while the moderate onsite toxicological consequences are exceeded for the bounding condition. Since the bounding condition resulted in low consequences to the offsite toxicological receptor, the represented hazardous condition was assigned a consequence bin of "low" for the offsite toxicological receptor. A consequence bin of "moderate" was assigned to the onsite toxicological receptor based on the results of the analysis. It should be noted that "moderate" consequences can only be seen from bulk additions. Smaller drum-sized additions will result in significantly lower consequences. The rate of addition will be much lower than 175 gal/min. As drums are drained and the pump is transferred to other drums the addition rate is expected to average around 10 gal/min. Since toxicological consequences are based on the rate of release, the consequences will be proportionately lower. Also, if off-gassing is initiated it is not credible to assume that the facility workers will continue to replace the empty drums with full drums in the midst of a cloud of gas. Therefore, once off-gassing begins only one to two drums would be added before the facility worker would self-evacuate, thus terminating the addition.

Table 4. Summary of Final Risk Binning Results for Represented Conditions.

Postulated accident/hazardous condition	Frequency	Consequences				Risk bin		
		Onsite radiological	Offsite toxicological	Onsite toxicological	Environmental	Onsite radiological	Offsite toxicological	Onsite toxicological
Inadvertent chemical addition to a DST	U	M	L	M	E2	II	III	II
Inadvertent chemical addition to a DCRT or catch tank	U	M	L	M	E2	II	III	II

Notes:

DCRT = double-contained receiver tank.
DST = double-shell tank.
L = low.
M = moderate.
U = unlikely.

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (6 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (frequency/consequence)	Need to Protect AA	Protection basis
An addition rate of 175 gal of acid per minute is assumed.	Reasonably conservative assumption.	No anticipated effect on consequence bin. Field experience with actual chemical additions show that addition rates are typically 75-100 gal/min. Even if higher flowrates were postulated, the analysis is relatively insensitive to the increase. (Since consequences are linear, evaluation for toxicological offsite consequences would only be required if the addition rate were to exceed 2,500 gal/min.)	No	N/A
Acid is 18.7 M sulfuric acid.	Bounding (physically limiting) assumption.	No anticipated effect on consequence bin. 98% sulfuric acid is 18.7 M. This is a bounding assumption.	No	N/A
A breathing rate of 3.33×10^{-4} m^3/s from RPP-5924 is used.	Reasonably conservative assumption.	No anticipated effect on consequence bin. This is a standard analysis assumption.	No	N/A
An atmospheric dispersion coefficient of 2.22×10^{-5} s/m^3 was used for offsite consequences and an atmospheric dispersion coefficient of 3.28×10^{-2} s/m^3 was used for onsite consequences.	Reasonably conservative assumption.	No anticipated effect on consequence bin. The atmospheric dispersion coefficients are from RPP-13482 and represents the 95th percent overall value for accidents less than 1 hr. No credit is taken for either plume meander or deposition.	No	N/A
The bounding entrainment coefficient for a $CaCO_3$ suspension in water was selected from RPP-9689.	Bounding value for this type of phenomenon.	No anticipated effect on consequence bin. The entrainment coefficient would have to be increased by more than an order of magnitude to challenge the offsite moderate consequence guideline.	No	N/A

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (6 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (frequency/consequence)	Need to Protect AA	Protection basis
The source term used for the aerosol in the analysis is 10% DST solids and 90% DST liquids.	Reasonably conservative estimate of solids in the aerosol.	No anticipated effect on consequence bin. This is a modeling assumption that cannot be verified but is considered to be conservative because gas generation will occur in the vicinity of the incoming acid stream. The agitation will not cause the solid waste to be thoroughly mixed with the liquid. In addition, the solids will settle out as they pass through the liquid phase toward the surface. It should also be noted that the SOFs for DST liquids and solids are similar so there is little sensitivity.	No	N/A
The pressurization resulting from the accident fails the HEPA filters.	Bounding assumption. If the HEPA filters do not fail, then they will filter out much of the release instead of contributing to the release.	No anticipated effect on consequence bin. If the HEPA filters do not fail, then the consequences would be decreased since there would be no contribution from the filter.	No	N/A
The inventory on the HEPA filters is equivalent to that which would produce a contact dose rate of 200 mrem/h. This is a modeling assumption based on current tank farm practices.	Conservative value based on operating experience (filter replacement).	No anticipated effect on consequence bin. The contribution from the HEPA filters is insignificant to the overall consequences. The contribution of the HEPA filters to the toxicological dose is ~0.1% and the contribution of the HEPA filters to the radiological dose is ~0.001%. The contribution of the HEPA filters would have to increase by over two orders of magnitude for offsite toxicological guidelines to be exceeded and over three orders of magnitude for the onsite radiological guidelines to be exceeded, which is not considered credible.	No	N/A

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (6 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (frequency/consequence)	Need to Protect AA	Protection basis
The radiological ULDs used were the bounding DST liquid and sludge values provided in RPP-5924. (Although the use of the saltcake ULD is more suitable based on the accident phenomenology and physical configuration of the DSTs, the bounding sludge ULD was used to ensure conservatism.)	The bounding values reported in RPP-5924 were used.	No anticipated effect on consequence bin. The ULD would have to be increased by a factor of two for the high onsite consequence bin to be challenged.	Yes	Protected by AC: Source Terms Controls
The toxicological SOFs used were the bounding DST liquid and solid values provided in RPP-8369.	The bounding values reported in RPP-8369 were used.	No anticipated effect on consequence bin. The SOF would have to be increased by a factor of 2 to challenge the onsite high consequence and a factor of 20 to challenge the offsite moderate consequence bin.	Yes	Protected by AC: Source Term Controls
An instantaneous reaction rate is assumed. This assumption compresses the release into the minimum time maximizing toxicological consequences.	Bounding (physically limited) assumption. It is expected that the reaction would continue for a period longer than the time required to perform the addition.	No anticipated effect on consequence bin. More realistically, the reaction would be slowed by the diffusion of acid through a region depleted of carbonate as the reaction proceeds, which would reduce the toxicological consequences.	No	N/A
The carbonate concentration is assumed to be sufficient to fully react with the sulfuric acid.	Bounding (physically limiting) assumption. If less is assumed, then less carbon dioxide will be generated, reducing the release.	No effect on consequence bin. Excess carbonate will not increase the consequences and carbonate concentrations that are insufficient to completely react with the sulfuric acid would lower the consequences.	No	N/A

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (6 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (frequency/consequence)	Need to Protect AA	Protection basis
No credit is taken for condensation or plate-out of aerosol on the walls of the tank.	Bounding (physically limited) assumption. Aerosol plate-out would occur on the walls of the tank lowering the volume of aerosol released.	No anticipated effect on consequence bin. Any plate-out would cause the consequences to decrease.	No	N/A
The waste tank was assumed to contain 1,000,000 gal of waste for calculation of the aerosol contribution.	Bounding (physically limiting) assumption. No credit was taken for dilution of aerosol in the headspace.	No anticipated effect on consequence bin. Any dilution of the aerosol in the headspace would decrease consequences.	No	N/A
The waste tank was assumed to contain 50,000 gallons of waste for calculation of the sulfuric acid contribution.	Reasonably conservative assumption.	No anticipated effect on the consequence bin. Tank was assumed to have a minimum volume to maximize the sulfuric acid vapors. The analysis is insensitive to the sulfuric acid vapors since the contribution was seven orders of magnitude less than the contribution from the aerosol.	No	N/A

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (6 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (frequency/consequence)	Need to Protect AA	Protection basis
The volume of the acid addition was assumed to be 5,000 gal. Based on the density of sulfuric acid, this exceeds the allowable gross vehicle weight for tanker trucks. (While tanker trucks contain a nominal capacity of as much as 7,000 gal, they are limited by total weight of the filled tanker. Generally, the maximum weight that can be transported is 45,000 lb which is the equivalent weight of 3,000 gal of sulfuric acid. The analysis conservatively assumes the tanker contains significantly more than the full weight capacity of sulfuric acid.)	Reasonably conservative assumption due to weight limitation.	No anticipated effect on consequence bin. Could affect consequence bin if conditions change allowing tanker trucks to transport much larger quantities. If current transportation regulations were changed to make larger shipments credible, the radiological consequences would increase. The allowed quantities would have to be greater than10,000 gal before the consequence bin would need to be reevaluated. Toxicological consequences would not require reevaluation since they are based on the peak release and not the total release.	No	N/A
Qualitative Evaluation of Analysis Assumptions for Other Represented Conditions.				
It is assumed that there will be no chemical additions to SSTs.	Reasonably conservative assumption.	No anticipated effect on consequence bin. If additions are proposed to SSTs, the risk bins would not change. The radiological source terms for SSTs are bound by DSTs and the toxicological SOFs are similar (within a factor of two). The toxicological SOFs would have to be a factor of five larger than the DST SOFs for the consequence bin to be challenged.	No	N/A

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (6 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (frequency/consequence)	Need to Protect AA	Protection basis

Notes:

DOE-HDBK-3010-94, 2000, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Change Notice No. 1, U.S. Department of Energy, Washington, D.C.

RPP-5924, 2003, *Radiological Source Terms for Tank Farms Safety Analysis*, Rev. 3, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-8369, 2003, *Chemical Source Terms for Tank Farms Safety Analyses,* Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13482, 2003, *Atmospheric Dispersion Coefficients and Radiological/Toxicological Exposure Methodology for Use in Tank Farms*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

AA = analysis assumptions.
ARF = airborne release fraction.
DST = double-shell tank.
HEPA = high-efficiency particulate air (filter).
N/A = not applicable.
SOF = sum of fractions.
SST = single-shell tank.
ULD = unit-liter dose.

Table 6. Summary of Onsite Radiological Consequences for the Mixing of Incompatible Materials Without Controls.

Accident	Onsite Radiological Consequences		
	Calculated dose (rem)	Moderate consequence guideline (rem)	High consequence guideline (rem)
Mixing of incompatible materials	4.3×10^{1}	2.5×10^{1}	1.0×10^{2}

Table 7. Summary of Toxicological Consequences for the Mixing of Incompatible Materials Without Controls.

Case	Toxicological Consequences							
	Onsite				Offsite			
	Moderate consequence		High consequence		Moderate consequence		High consequence	
	SOF	Guideline	SOF	Guideline	SOF	Guideline	SOF	Guideline
Mixing of incompatible materials	1.5×10^{1}	1 (ERPG-1)	7.2×10^{-1}	1 (ERPG-2)	6.7×10^{-2}	1 (ERPG-2)	1.0×10^{-2}	1 (ERPG-3)

Notes:
ERPG = emergency response planning guideline.
SOF = sum of fractions.

2.1.3.3 Assignment of Environmental Consequences.

Based on operational experience and the conservative calculations in Appendix B it was concluded that there is potential for material release to either the atmosphere or ground. Therefore, an environmental consequence of E2 was assigned to the mixing of incompatible materials representative accident.

2.1.3.4 Assignment of Risk Bins.

Table 4 summarizes the frequency and risk bin assignments for the mixing of incompatible materials accident scenario without controls. The assignment of risk bins is derived from the consequences and estimated frequency of the accident. The risk bin for the offsite toxicological receptor is III because the consequence is "low" and the frequency is "unlikely." The risk bin for the onsite toxicological receptor and the onsite radiological receptor is II since the consequence is "moderate" and the frequency is "unlikely."

2.2 MIXING OF INCOMPATIBLE MATERIALS ASSOCIATED HAZARDOUS CONDITIONS

There are more than 40 hazardous conditions represented by the mixing of incompatible materials representative accident. (Note that the specific number of hazardous conditions reported in the hazard evaluation database may increase or decrease in the future based on changes in field configurations or operations.) The results of the risk binning process for these hazardous conditions are shown in the hazard evaluation database under the representative accidents 03 and 23. Included in the hazard evaluation database entries is a basis for each consequence and frequency.

Meeting participants considered process knowledge, operational history, and the conservatisms in the analysis when assigning consequence and frequency bins to the other represented hazardous conditions. The results are summarized in Table 8, and are discussed below.

- Small inadvertent addition. Inadvertent additions from small containers, such as 55-gal drums, was assigned a frequency of "unlikely" for reasons similar to the bounding case. The consequences were judged to be low since the total volume of potentially reactive acid is small and the credible rate of addition was much lower than the bounding case.

- Tank waste mixing with tank waste conditions that result in energetic reactions. Tank waste mixing with tank waste conditions were judged to be "extremely unlikely" because process history and knowledge have shown that mixing different tank wastes does not result in an energetic reaction (Reynolds 2001). Even if a reaction were assumed to occur, it was judged that it would be significantly less than the bounding case of 5,000 gal of concentrated sulfuric acid.

- Incompatible waste transfer from external sources (B Plant, T Plant, 222-S Laboratory, and PFP). Waste transfers from B Plant were judged to be "beyond extremely unlikely" since it is physically disconnected from tank farms. Transfers from PFP, T Plant, and 222-S Laboratory were judged to be "unlikely" due to the physical configuration and inventories of acids contained in the facilities. Even if a transfer was assumed to occur, it was judged to be significantly lower than the consequences of the bounding case of 5,000 gal of concentrated sulfuric acid.

- Toxic gas (ammonia) release during intrusive activity. Toxic gas releases due to intrusive activities were assigned a frequency of anticipated based on the history of tank farms. The consequences were shown to be low in WHC-SD-WM-CN-074.

Table 8. Summary of Final Risk Binning Results for Associated Conditions.

Postulated accident/hazardous conditions	Frequency	Consequences				Risk bin		
		Onsite radiological	Offsite toxicological	Onsite toxicological	Environmental	Onsite radiological	Offsite toxicological	Onsite toxicological
Small inadvertent addition (55-gal drum)	U	L	L	L	E1	III	III	III
Tank waste mixing with tank waste conditions that result in energetic reactions	EU	L	L	L	E1	IV	IV	IV
Incompatible waste transfer from B Plant	BEU	M	L	M	E1	IV	IV	IV
Incompatible waste transfers from 222-S Laboratory, T Plant, or the PFP	U	L	L	L	E1	III	III	III
Toxic gas release during intrusive activity	A	L	L	L	E0	III	III	III

Notes:

A = anticipated.
BEU = beyond extremely unlikely.
EU = extremely unlikely.
L = low.
M = moderate.
PFP = Plutonium Finishing Plant.
U = unlikely.

3.0 CONTROL SELECTION

After the allocation of risk bins, a group was empanelled to select controls for the represented hazardous conditions. A multidisciplinary group representing organizations both internal and external to the Tank Farm Contractor performed the selection of controls. The list of control decision makers is listed in Appendix C. Controls were considered and selected to prevent or mitigate consequences of the hazards that were identified as requiring controls.

3.1 PROPOSED CONTROLS FOR THE MIXING OF INCOMPATIBLE MATERIALS REPRESENTATIVE ACCIDENT

A summary of the representative accident, as well as a synopsis of the risk binning results, was presented to the control selection team. The group then proposed and discussed numerous potential mitigative and preventative controls for the representative accident. The possible mitigative controls proposed were:

- Headspace gas/vent gas monitoring
- Self-evacuation training
- Limit the chemical addition rate
- HEPA filter efficiency controls
- Activated carbon filtration of ventilation exhaust
- Scrubbing of ventilation gases with water/caustic solution
- Personal protective equipment
- Limited area access.

Possible preventative controls were also considered:

- Perform a pH analysis to ensure compatibility
- Verify procurement/delivery paperwork prior to additions
- Use an evaluated suppliers list including periodic reviews/audits of chemical vendor quality control and assurance programs
- Control volume of additions
- Eliminate the need for liquid chemical additions

3.2 SELECTED CONTROL FOR THE MIXING OF INCOMPATIBLE MATERIALS REPRESENTATIVE ACCIDENT

3.2.1 Control Selection

The proposed controls were discussed and evaluated by the group. Control decision criteria are established in:

- Title 10, *Code of Federal Regulations,* Part 830, Subpart B, "Nuclear Safety Management" (10 CFR 830)
- DOE-STD-3009-94
- DOE G 421.1-2, *Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830*
- DOE G 423.1-1, *Implementation Guide for Use in Developing Safety Requirements*
- Klein and Schepens (2003).

The control decision preference can be summarized as follows:

- Preventive controls over mitigative
- Passive controls over active control
- Engineering controls over administrative controls
- Controls with the highest reliability
- Controls closest to the hazard
- Controls with the lowest implementation and maintenance costs.

A consensus was reached based on the judgment of the participants to perform a pH analysis to ensure compatibility. This analysis is a reliable and effective preventive control. It is close to the hazard and can be implemented with minimal operational or budgetary impact. The other controls were eliminated because:

- Controlling the volume of the addition was considered unreliable and ineffective as a selected control.
- Monitoring the headspace gas/vent gas or limiting the chemical addition rate are mitigative controls that are considered unreliable.
- HEPA filter efficiency controls are mitigative controls that are only effective for non-bounding conditions as the HEPA filter fails in the analyzed accident.
- Activated carbon filtration of ventilation exhaust or the scrubbing of ventilation gases with water/caustic solution are mitigative controls that would require major plant modifications including additional safety analyses.

- Verification of procurement/delivery paperwork prior to additions and the use of an evaluated suppliers list, including periodic reviews/audits of chemical vendor quality control and assurance programs, were not considered as effective as the selected control.

- Eliminating the need for liquid chemical additions would degrade the safe storage of waste by eliminating the current corrosion control program, and hinder the tank closure effort by eliminating many potential decontamination and decommissioning proposals.

- Self-evacuation training, limited area access, and personal protective equipment are effective controls for facility workers but were considered less effective for the onsite (100 m) worker.

3.2.2 Format of the Selected Control

Once the control was selected, options for how the control would be depicted were evaluated. The possibilities were:

- The control could be documented as a new standalone TSR administrative control (AC)
- The control could be a key element under a TSR AC (i.e., transfer controls)
- The control could be included in the SMPs:
  - Reflected as a bullet point in the SMP AC, specifying the key elements
  - Reflected as a bullet point in the SMP AC, with the details listed in the DSA
  - Listed in the DSA description of the SMP.

After discussion, it was agreed to represent the preventative control as a standalone AC in the TSRs. A standalone AC most strongly links the basis and applicability of the control with the final disposition of the control.

The precise wording of the control was then considered. The key areas of discussion were on the use of "field testing," whether a specific pH should be defined, and whether SSTs, DCRTs, and catch tanks should be included in the applicability. The consensus resulted in Table 9.

Table 9. Summary of Technical Safety Requirement Controls for Mixing of Incompatible Material.

Control	Safety function	Comments
Bulk Chemical Additions • Perform field testing to verify that bulk chemicals shipped in tanker trucks have a pH ≥ 7 before addition to DSTs, DCRTs, and catch tanks.	Prevents inadvertent additions of acids.	—
Safety Management Programs • Measuring and test equipment program	Ensures program is maintained to control tank farm measuring and test equipment used to verify parameters to comply with TSRs.	—

Notes:
DST = double-shell tank.
DCRT = double-contained receiver tank.
TSR = technical safety requirement.

It was noted during the evaluation that:

- The AC bases should address the following:
  - The control does not apply to waste transfers; chemical delivery from drums (e.g., 55-gal drums) that connect to tank farm tanks or to waste transfer systems during chemical additions; or to additions of water or inhibited water. Inhibited water includes dilute concentrations of sodium hydroxide and sodium nitrite.
  - DSTs, DCRTs, and catch tanks are the only tank farm facilities where the addition of bulk chemicals from tank trucks is authorized (i.e., within the scope of the DSA). The addition of bulk chemicals to SSTs to support proposed retrieval methods would require additional safety analysis.
  - Clarification of the intent of "field testing." "Field testing" is intended to mean a test by the Tank Farm Contractor after receipt of the shipment but before addition of the chemical.
- The specific method(s) of testing for pH (e.g., litmus paper) will be identified and controlled by a TSR AC program for instrumentation and measuring and test equipment. Any special requirements for the identified testing method(s) will be developed and documented for program implementation.

3.3 CONTROL ALLOCATION

Of the conditions grouped under the mixing of incompatible materials accident scenario, a few conditions were identified as requiring controls due to onsite toxicological consequences of the

inadvertent addition of acid. For these cases, the standalone AC was allocated. This new AC requires that the pH of bulk chemical additions be verified before transferring, thereby preventing the accident. Also allocated for these cases was a measuring and test equipment program that stipulates that any required instrumentation is properly calibrated or functionally tested. Defense-in-depth features were also identified for some of the represented conditions and are described in RPP-14821, *Technical Basis Document for Defense-In-Depth Features*.

4.0 REFERENCES

10 CFR 830, "Nuclear Safety Management," *Office of the Federal Register* (FR 1810, Vol. 66, No. 7), January 10, 2001.

DOE G 421.1-2, 2001, *Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830*, U.S. Department of Energy, Washington, D.C.

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DOE-HDBK-3010-94, 2000, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Change Notice No. 1, U.S. Department of Energy, Washington, D.C.

DOE-STD-3009-94, 2002, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, Change Notice No. 2, U.S. Department of Energy, Washington, D.C.

Klein, K. A., and R. J. Schepens, 2003, "Replacement of Previous Guidance Provided by RL and ORP" (letter 03-ABD-0047 to E. K. Thomson, Fluor Hanford Inc., and E. S. Aromi, CH2M HILL Hanford Group Inc., February 4), U.S. Department of Energy, and Office of River Protection, Richland, Washington.

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RPP-5924, 2003, *Radiological Source Terms for Tank Farms Safety Analysis*, Rev. 3, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-8369, 2003, *Chemical Source Terms for Tank Farms Safety Analyses*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland Washington.

RPP-9689, 2003, *Offsite Radiological Consequence Calculation for the Bounding Mixing of Incompatible Materials Accident*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13121, 2003, *Historical Summary of Occurrences from the Tank Farms Final Safety Analysis Report*, 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. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-14286, 2003, *Facility Worker Technical Basis Document*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-14821, 2003, *Technical Basis Document for Defense-In-Depth Features*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-15116, 2003, *Proceedings of the Nuclear Working Group and the Technical Working Group*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

WHC-SD-WM-CN-074, 1997, *Chemical Reaction in a DCRT Leading to a Toxic Release*, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

RISK BINNING MEETING ATTENDEES

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APPENDIX A

RISK BINNING MEETING ATTENDEES

DSA Accident Risk Binning Attendance Sheet

Meeting Subject: Criticality (Rep Acc. 0.1) Incompatible material (Rep Acc. 2&23) Date 7/17/02

Name	Organization	Phone	Mail Stop
MILTON V. SHULTZ	CHG-NS&L	372-3740	R1-44
* David M. Carson	FFS SA+VE	372-1717	E1-64
Joseph J. Bevelacqua	ORP	376-8443	H6-60
* Steve Faulk	CHG EP	376-0688	S7-86
Richard Williams	CHG Rad Con	373-2909	S7-75
Robert D Carrell	ORP support	521-6921	H6-60
Kevin Sandgren	CHG - NS&L	372-0374	R1-49
MARK HASTY	CHG-OPS	373-9378	S7-83
Steve Fitzpatrick	ORP Support (HPMC)	528-5007	E1-60
Clifford Hampton	CHG OPS	372-0568	R2-50
Ed Ford	CHG-NS&L	373-1296	R1-44
Robert Shepard	ORP Support (LMA)	521-2680	—
* KENNY FOWLER	CHG-Proc Engr	373-5930	R2-11

* only Criticality

DSA Accident Risk Binning Attendance Sheet

Meeting Subject: Mixing of Incompat Material Date 7/18/02

DAY 2

Name	Organization	Phone	Mail Stop
MILTON V. SHULTZ	CHG - NS&L	372-3740	R1-44
Ed Ford	CHG - NS&L	373-1296	R1-44
CLIFF HAMPTON	CHG OPS	372-0566	R2-50
Phil Miller	CHG ENV	373-1520	R1-57
Joseph Bevelacqua	ORP	376-4443	H6-60
MARK HASTY	CHG-OPS	373-9378	S7-83
Kevin Schwinkendorf	Fluor Federal Services	376-0960	
Robert Shepard	ORP-Support (LNA)	521-2680	
Steve Eischeid	ORP-Support (HPME)	528-5007	
RYK WILLIAMS	CHG	373-4989	S7-75
BRAD SMITH	CHG - NS&L	376-1907	R1-44
Kevin Sandgren	CHG - NS&L	372-0371	R1-49

APPENDIX B

CONSEQUENCE CALCULATIONS FOR THE MIXING OF INCOMPATIBLE MATERIALS

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APPENDIX B

CONSEQUENCE CALCULATIONS FOR THE MIXING OF INCOMPATIBLE MATERIALS

B1.0 ONSITE RADIOLOGICAL CONSEQUENCES

The Mixing of Incompatible Materials accident scenario, without controls, assumes that a cargo tanker filled with 5,000 gal of concentrated sulfuric acid (18.7 M) is emptied into a double-shell tank (DST) instead of the chemical expected (e.g., caustic or nitrite). The rate of addition is assumed to be 175 gal/min. The receiving tank is assumed to contain sufficient carbonate waste to completely react with the incoming acid. The carbon dioxide formed is released into the tank headspace carrying with it a fraction of tank waste. It is assumed that the high-efficiency particulate air (HEPA) filters fail, contributing to the consequences. Condensation of the aerosol on the walls of the tank was assumed to be insignificant. The reaction was conservatively considered to be instantaneous. The contributors to the radiological consequences are the HEPA filter release and the aerosolized waste.

B1.1 CONTRIBUTION OF AEROSOLIZED WASTE

Sulfuric acid is a common industrial chemical. It is also typically transported at nearly 100% concentration (18.7 M) to reduce costs and lower its corrosion potential. The reaction of sulfuric acid with sodium carbonate is shown below:

$$H_2SO_4 + Na_2CO_3 \longrightarrow CO_{2\,(gas)} + Na_2SO_4 + H_2O\,.$$

It can be seen that each mole of sulfuric acid would result in the generation of one mole of carbon dioxide.

Calculating the total release of carbon dioxide:

$$(5{,}000\text{ gal})\,(3.785\text{ L/gal})\,(18.7\text{ g moles/L})\,(44\text{ g/g mole}) = 1.56 \times 10^7 \text{ grams carbon dioxide}$$
$$= 1.56 \times 10^4 \text{ kg carbon dioxide}$$

or:

$$(5{,}000\text{ gal})\,(3.785\text{ L/gal})\,(18.7\text{ g moles/L})\,(24.5\text{ L/g mole}) = 8.67 \times 10^6 \text{ L carbon dioxide}$$

where:

5,000 gal	= assumed volume of sulfuric acid addition
3.785 L/gal	= conversion factor (*CRC Handbook of Chemistry and Physics* [Weast 1981])
18.7 g moles/L	= molarity of concentrated 98% sulfuric acid (Weast 1981)
44 g/g mole	= molecular weight of carbon dioxide (Weast 1981)
24.5 L/g mole	= the volume of carbon dioxide gas at 25 °C (298 K) = (22.4 L/g mole at 273K) (298 K/273 K).

The volume of aerosol carried off by the waste can be estimated using an entrainment coefficient E:

E = Volume aerosol/Volume gas through the surface

At low superficial gas velocities discrete bubbles rise through the pool uniformly and steadily. This flow pattern is classified as the bubbly flow regime. When superficial gas velocity exceeds the threshold value ($j_{g,t}$) the flow regime transitions from bubbly flow to churn turbulent flow which is characterized by nonuniform bubbles rising in a more random manner. The transitional superficial velocity can be found in RPP-9689, *Offsite Radiological Consequence Calculation for the Bounding Mixing of Incompatible Materials Accident*:

$$j_{g,t} = 0.3\ [(\sigma g)/(\rho_f)]^{1/4} = 4.8 \times 10^{-2}\ \text{m/s}$$

where:

σ is the liquid surface tension, 0.072 kg/s^2 for water against air at 25 °C (Weast 1981)
g is the gravitational constant, 9.81 m/s^2
ρ_f is the assumed liquid density, 1.1×10^3 kg/m^3.

The superficial velocity (j_g) for carbon dioxide generation can be calculated:

$$j_g = [(9.1\ \text{kg/s}) / (1.8\ \text{kg/m}^3)]\ [(9.2\ \text{m}) / (3.79 \times 10^3\ \text{m}^3)] = 1.2 \times 10^{-2}\ \text{m/s}$$

where:

9.1 kg/s	= the carbon dioxide generation rate
	= (1.56×10^4 kg CO_2) / [{(5000 gal) / (175 gal/min)} (60 s/min)]
9.2 m	= depth of waste in tank [a full tank is assumed]
3.79×10^3 m^3	= waste volume [1,000,000 gal assumed volume]
1.8 kg/m^3	= density of gas at 25 °C [(44.01 kg/kg mole) / (24.5 m^3/kg mole).

Since the superficial velocity is less than the threshold velocity, the applicable flow regime is bubbly flow.

The source term used for the aerosol in this analysis is 10% DST sludge and 90% DST supernatant. Gas generation will occur in the vicinity of the incoming acid stream. The agitation caused by the gas generation will not cause the solid waste to be thoroughly mixed with the liquid. In addition, the solids will settle out as they pass through the liquid phase toward the surface. The inclusion of 10% solids in the aerosol is a conservative assumption. The radiological unit-liter dose (ULD) for the waste is from RPP-5924, *Radiological Source Terms for Tank Farms Safety Analysis*.

The waste aerosolized is calculated as follows:

$$(8.67 \times 10^6\ \text{L})\ (2.3 \times 10^{-7}) = 2.0\ \text{L}$$

where:

2.3×10^{-7} = bounding entrainment coefficient for $CaCO_3$ suspension in water (RPP-9689)

Given

ULD for DST liquids = 1.0×10^3 Sv/L (RPP-5924)
ULD for DST solids = 1.9×10^5 Sv/L (RPP-5924)

ULD for aerosol = $[(1.0 \times 10^3 \text{ Sv/L})(0.9)] + [(1.9 \times 10^5 \text{ Sv/L})(0.1)]$
= 1.99×10^4 Sv/L .

Onsite aerosol dose = (aerosol released) (onsite χ/Q) (onsite ULD) (breathing rate)

Onsite $D_{aerosol}$ = $(2.0 \text{ L})(0.0328 \text{ s/m}^3)(1.99 \times 10^4 \text{ Sv/L})(3.33 \times 10^{-4} \text{ m}^3/\text{s})$
= 4.3×10^{-1} Sv

where:

0.0328 s/m^3 = onsite χ/Q (RPP-13482, *Atmospheric Dispersion Coefficients and Radiological/Toxicological Exposure Methodology for Use in Tank Farms*)

$3.33 \times 10^{-4} \text{ m}^3/\text{s}$ = breathing rate (RPP-5924).

B1.2 CONTRIBUTION OF THE HIGH-EFFICIENCY PARTICULATE AIR FILTER

Since a significant quantity of carbon dioxide is released, it is assumed that the tank pressurizes sufficiently to fail the HEPA filters.

DST HEPA filter dose due to overpressure = 6.1×10^{-6} Sv (RPP-13437, *Technical Basis Document for Ventilation System Filtration Failures Leading to Unfiltered Release).*

B1.3 OVERALL ONSITE RADIOLOGICAL CONSEQUENCES

Total onsite radiological consequences = (aerosol contribution) + (HEPA contribution)

Onsite D_{Total} = $(4.3 \times 10^{-1} \text{ Sv}) + (6.1 \times 10^{-6} \text{ Sv}) = 4.3 \times 10^{-1}$ Sv
= $4.3 \times 10^{+1}$ rem.

B2.0 TOXICOLOGICAL CONSEQUENCES

The Mixing of Incompatible Materials accident scenario, without controls, assumes that a cargo tanker filled with 5,000 gal of concentrated sulfuric acid (18.7 M) is emptied into a DST, instead of the chemical expected (e.g., caustic or nitrite). The rate of addition is assumed to be 175 gal/min, which is considered to be a reasonably conservative flow rate. The receiving tank is assumed to contain sufficient carbonate waste to completely react with the incoming acid. The

carbon dioxide formed is released into the tank headspace carrying with it a fraction of tank waste. It is assumed that the HEPA filters fail, contributing to the consequences. Condensation of the aerosol on the walls of the tank was assumed to be insignificant. The reaction was conservatively considered to be instantaneous. The contributors to the toxicological consequences are the HEPA filter release, the aerosolized waste, and sulfuric acid fumes.

B2.1 CONTRIBUTION FROM AEROSOLIZED WASTE

Sulfuric acid is a common industrial chemical. It is also typically transported at nearly 100% concentration (18.7 M) to reduce costs and lower its corrosion potential. The reaction of sulfuric acid with sodium carbonate is shown below:

$$H_2SO_4 + Na_2CO_3 \longrightarrow CO_{2\,(gas)} + Na_2SO_4 + H_2O\,.$$

It can be seen that each mole of sulfuric acid would result in the generation of one mole of carbon dioxide.

Calculating the rate of release of carbon dioxide:

(175 gal/min) (3.785 L/gal) (1min/60 s) (18.7 g moles/L) (44 g/g mole) = 9.08×10^3 g/s

(175 gal/min) (3.785 L/gal) (1min/60 s) (18.7 g moles/L) (24.5 L/g mole) = 5.06×10^3 L/s

where:

175 gal/min	= assumed rate of sulfuric acid addition
3.785 L/gal	= conversion factor (Weast 1981)
18.7 g moles/L	= molarity of concentrated 98% sulfuric acid (Weast 1981)
44 g/g mole	= molecular weight of carbon dioxide (Weast 1981)
24.5 L/g mole	= the volume of carbon dioxide gas at 25 °C (298 K)
	= (22.4 L/g mole at 273K) (298 K/273 K).

The source term used for the aerosol in this analysis is 10% DST solids and 90% DST liquids. Gas generation will occur in the vicinity of the incoming acid stream. The agitation caused by the gas generation will not cause the solid waste to be thoroughly mixed with the liquid. In addition, the solids will settle out as they pass through the liquid phase toward the surface. The inclusion of 10% solids in the aerosol is a conservative assumption. The toxicological sums of fractions (SOF) for the waste are from RPP-8369, *Chemical Source Terms for Tank Farms Safety Analyses.*

Since the superficial velocity is less than the threshold velocity, the applicable flow regime is bubbly flow (as shown above).

The waste aerosolized is calculated as follows:

$$(5.06 \times 10^3 \text{ L/s})\,(2.3 \times 10^{-7}) = 1.16 \times 10^{-3} \text{ L/s}$$
$$= 1.16 \times 10^{-6} \text{ m}^3\text{/s}.$$

where:

2.3×10^{-7} = bounding entrainment coefficient for $CaCO_3$ suspension in water (RPP-9689)

B2.1.1 Onsite Contribution of Aerosolized Waste

Given

Onsite, high consequence SOF multiplier for DST liquids = 1.27×10^7 (RPP-8369)
Onsite, high consequence SOF multiplier for DST solids = 7.20×10^7 (RPP-8369)

Onsite aerosol, high consequence SOF multiplier = $[(1.27 \times 10^7)(0.9)] + [(7.20 \times 10^7)(0.1)]$
$= 1.86 \times 10^7$.

And

Onsite, moderate consequence SOF multiplier for DST liquids = 3.46×10^8 (RPP-8369)
Onsite, moderate consequence SOF multiplier for DST solids = 7.77×10^8 (RPP-8369)

Onsite aerosol, moderate consequence SOF multiplier = $[(3.46 \times 10^8)(0.9)] + [(7.77 \times 10^8)(0.1)]$
$= 3.89 \times 10^8$.

Onsite aerosol SOF = (aerosol release rate) (onsite SOF multiplier) (onsite χ/Q)

Onsite, high consequence $SOF_{aerosol} = (1.16 \times 10^{-6}\ m^3/s)(1.86 \times 10^7)(0.0328\ s/m^3)$
$= 7.1 \times 10^{-1}$

Onsite, moderate consequence $SOF_{aerosol} = (1.16 \times 10^{-6} m^3/s)(3.89 \times 10^8)(0.0328\ s/m^3)$
$= 1.5 \times 10^{+1}$

where:

$0.0328\ s/m^3$ = onsite χ/Q (RPP-13482).

B2.1.2 Offsite Contribution of Aerosolized Waste

Given

Offsite, high consequence SOF multiplier for DST liquids = 3.46×10^8 (RPP-8369)
Offsite, high consequence SOF multiplier for DST solids = 7.77×10^8 (RPP-8369)

Offsite aerosol, high consequence SOF multiplier = $[(3.46 \times 10^8)(0.9)] + [(7.77 \times 10^8)(0.1)]$
$= 3.89 \times 10^8$.

And

Offsite, moderate consequence SOF multiplier for DST liquids = 2.75×10^9 (RPP-8369)
Offsite, moderate consequence SOF multiplier for DST solids = 1.38×10^9 (RPP-8369)

Offsite aerosol, moderate consequence SOF multiplier

$$= [(2.75 \times 10^9)(0.9)] + [(1.38 \times 10^9)(0.1)]$$
$$= 2.61 \times 10^9.$$

Offsite aerosol SOF = (aerosol release rate) (offsite SOF multiplier) (offsite χ/Q)

Offsite, high consequence $SOF_{aerosol} = (1.16 \times 10^{-6} m^3/s)(3.89 \times 10^8)(2.22 \times 10^{-5} s/m^3)$
$= 1.0 \times 10^{-2}$

Offsite, moderate consequence $SOF_{aerosol} = (1.16 \times 10^{-6} m^3/s)(2.61 \times 10^9)(2.22 \times 10^{-5} s/m^3)$
$= 6.7 \times 10^{-2}$

where:

2.22×10^{-5} s/m^3 = offsite χ/Q (RPP-13482).

B2.2 CONTRIBUTION OF THE HIGH-EFFICIENCY PARTICULATE AIR FILTER

Since the steam volume exceeds the headspace volume, it is assumed that the tank pressurizes sufficiently to fail the HEPA filters.

Onsite, filter release $SOF_{HEPA} = 1.1 \times 10^{-2}$ (RPP-13437).

Offsite, filter release $SOF_{HEPA} = 5.3 \times 10^{-5}$ (RPP-13437).

Since only moderate consequence SOFs were calculated in RPP-13437 for the release from a HEPA filter, these contributions will also be conservatively applied to the high consequence calculations despite over representing the contribution from the HEPA release by nearly an order of magnitude.

B2.3 CONTRIBUTION FROM THE SULFURIC ACID FUMES

The addition of sulfuric acid to the tank would also result in some quantity of sulfuric acid being present in the gas as it exits from the tank. The quantity can be estimated from the partial pressure of sulfuric acid at the conditions encountered.

Mass sulfuric acid = (5000 gal) (3.785 L/gal) (1.86 kg/L) = 3.52×10^4 kg

Mass tank waste = (50,000 gal) (3.785 L/gal) (1.1 kg/L) = 2.08×10^5 kg

Weight percent sulfuric acid = $[(3.52 \times 10^4 \text{ kg}) / (3.52 \times 10^4 \text{ kg} + 2.08 \times 10^5 \text{ kg})] \times 100 = 14.5$

where:

50,000 gal	= conservatively assumed waste volume
1.1 kg/L	= assumed density of the waste
1.86 kg/L	= density of sulfuric acid (Weast 1981).

The vapor pressures of sulfuric acid and aqueous waste (water) at a conservative 20% sulfuric acid and 120 °C can be found.

Partial pressure of sulfuric acid = 4.32×10^{-12} bar (*Perry's Chemical Engineers' Handbook* [Perry 1984])
= 4.26×10^{-12} Atm

The total amount of sulfuric acid leaving the tank as vapor can then be found as a volumetric proportion of the total release.

$[(9.08 \times 10^{3}\ g/s)/(44\ g/g\ mole\ CO_2)]\ [(4.26 \times 10^{-12}\ Atm)/(1\ Atm)]$
$= 8.8 \times 10^{-10}$ g mole/s sulfuric acid vapors

Converting from gram moles to grams:

$(8.8 \times 10^{-10}\ g\ mole/s)\ (98\ g/g\ mole) = 8.6 \times 10^{-8}\ g/s$

B2.3.1 Onsite Contribution of Sulfuric Acid

Onsite sulfuric SOF = (sulfuric acid release rate) (onsite χ/Q) / (sulfuric acid temporary emergency exposure limit [TEEL])

Onsite, high consequence $SOF_{sulfuric} = (8.6 \times 10^{-8}\ g/s)\ (0.0328\ s/m^3) / (3.0 \times 10^{-2}\ g/m^3)$
$= 9.4 \times 10^{-8}$

Onsite, moderate consequence $SOF_{sulfuric} = (8.6 \times 10^{-8}\ g/s)\ (0.0328\ s/m^3) / (1.0 \times 10^{-2}\ g/m^3)$
$= 2.8 \times 10^{-7}$

where:

$0.0328\ s/m^3$	= onsite χ/Q (RPP-13482)
$3.0 \times 10^{-2}\ g/m^3$	= sulfuric acid TEEL-3 (WSMS-SAE-02-0171, *ERPGs and TEELs for Chemicals of Concern*)
$1.0 \times 10^{-2}\ g/m^3$	= sulfuric acid TEEL-2 (WSMS-SAE-02-0171).

B2.3.2 Offsite Contribution of Sulfuric Acid

Offsite sulfuric SOF = (sulfuric acid release rate) (offsite χ/Q) / (sulfuric acid TEEL)

Offsite, high consequence $SOF_{sulfuric} = (8.6 \times 10^{-8}\ g/s)\ (2.22 \times 10^{-5}\ s/m^3) / (1.0 \times 10^{-2}\ g/m^3)$
$= 1.9 \times 10^{-10}$

Offsite, moderate consequence $SOF_{sulfuric} = (8.6 \times 10^{-8}\ g/s)\ (2.22 \times 10^{-5}\ s/m^3) / (2.0 \times 10^{-3}\ g/m^3)$
$= 9.5 \times 10^{-10}$

where:

$2.22 \times 10^{-5}\ s/m^3$	= offsite χ/Q (RPP-13482)
$1.0 \times 10^{-2}\ g/m^3$	= sulfuric acid TEEL-2 (WSMS-SAE-02-0171)
$2.0 \times 10^{-3}\ g/m^3$	= sulfuric acid TEEL-1 (WSMS-SAE-02-0171).

B2.4 OVERALL TOXICOLOGICAL CONSEQUENCES

B2.4.1 Total Onsite Toxicological Consequences

Total onsite toxicological consequences = (aerosol contribution) + (HEPA contribution) + (sulfuric acid contribution)

Onsite, high consequence SOF_{Total} $= (7.1 \times 10^{-1}) + (1.1 \times 10^{-2}) + (9.4 \times 10^{-8})$
$= 7.2 \times 10^{-1}$

Onsite, moderate consequence SOF_{Total} $= (1.5 \times 10^{+1}) + (1.1 \times 10^{-2}) + (2.8 \times 10^{-7})$
$= 1.5 \times 10^{+1}$

B2.4.2 Total Offsite Toxicological Consequences

Total offsite toxicological consequences = (aerosol contribution) + (HEPA contribution) + (sulfuric acid contribution)

Offsite, high consequence SOF_{Total} $= (1.0 \times 10^{-2}) + (5.3 \times 10^{-5}) + (1.9 \times 10^{-10})$
$= 1.0 \times 10^{-2}$

Offsite, moderate consequence SOF_{Total} $= (6.7 \times 10^{-2}) + (5.3 \times 10^{-5}) + (9.5 \times 10^{-10})$
$= 6.7 \times 10^{-2}$.

B3.0 RESULTS

Tables B3-1 and B3-2 compare the accident consequences with the risk evaluation guidelines. Reviewing the consequences shows that the mixing of incompatible materials accident is below the onsite radiological guidelines. Offsite toxicological consequences are also below the guidelines. However, the toxicological release exceeds the onsite moderate toxicological guidelines.

Table B3-1. Summary of Onsite Radiological Consequences Without Controls for the Mixing of Incompatible Materials.

Case	Onsite Radiological Consequences		
	Calculated dose (rem)	Moderate consequence guideline (rem)	High consequence guideline (rem)
Mixing of incompatible materials	$4.3 \times 10^{+1}$	$2.5 \times 10^{+1}$	$1.0 \times 10^{+2}$

Table B3-2. Summary of Toxicological Consequences Without Controls for the Mixing of Incompatible Materials.

Case	Toxicological Consequences							
	Onsite				Offsite			
	Moderate consequence		High consequence		Moderate consequence		High consequence	
	SOF	Guideline	SOF	Guideline	SOF	Guideline	SOF	Guideline
Mixing of incompatible materials	1.5×10^{1}	1	7.2×10^{-1}	1	6.7×10^{-2}	1	1.0×10^{-2}	1

Note:

SOF = sum of fractions.

B4.0 REFERENCES

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APPENDIX C

MIXING OF INCOMPATIBLE MATERIALS CONTROL DECISION MEETING ATTENDEES

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APPENDIX C

MIXING OF INCOMPATIBLE MATERIALS CONTROL DECISION MEETING ATTENDEES

MIXING OF INCOMPATIBLE MATERIALS
CONTROL DECISION MEETING ATTENDANCE
SEPTEMBER 16, 2002

Name	Knowledge Area(s) Represented (see below)	Organization	Telephone Number
LAWRENCE T KRIPS	1,2,3,6,7,9,10	NS&L - CHG	376-1061
Kevin Sandgren	1,2,3,6,,9,10	NS&L - CHG	373-0377
JOSEPH BEVERLOUA	1-23	ORG	376-8743
Jon C GEISBOSH		CHG/ADI	373-0486
CLIFF HAMPTON		CHG OPS	372-0566
Nancy Wilker	1,2,3,4,10	NS&L DSA	373-9045
Jennifer Stewart	1,7,9		
Ed Ford	1,2,3,6,7,9,10	NS&L-CHG	373-1296
MILTON V. Shultz	1,2,3,6,7,9,10	NS&L - CHG	372-3740
Tim Trapuzzano	1,2,3,4,5,9,10		
Mark Sandman		DNFSB	373-0101
Curt Reichmuth	5	SST	6-4796
Brad Smith		CHG NS&L	376 1907

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

MIXING OF INCOMPATIBLE MATERIALS
CONTROL DECISION MEETING ATTENDANCE
SEPTEMBER 16, 2002

Name	Knowledge Area(s) Represented (see below)	Organization	Telephone Number
Don Quilici	19	EH&S	6-6549
Robin Fogg	19	EH&S	3-0030
BC Wyatt	5	CHG	3-3355
MA White	5	CHG	3-3355
K.D. Fowler	16-Crit Safety, 22	CHG	3-5936
R.D Carrell	2 3 6 7 9 10	ORP support	947-6421
Tom Black	4	SYS Eng	373-3880

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

MIXING OF INCOMPATIBLE MATERIALS
CONTROL DECISION MEETING ATTENDANCE
AUGUST 23, 2002

Name	Knowledge Area(s) Represented (see below)	Organization	Telephone Number
LAWRENCE J KRAUS	2,3,9,10	NSL	376-K61
Kevin Sandgren	1,2,3,6,9	NS&L	372-0374
Bobby McDaniel	2,3,5,9	OPS	373-1450
CHUNN MALCOM	5	OPS	373-2525
Johnston, Julie	5	CPO	3-3578
HAMPTON, CLIFFORD	2,3,5,9,13	OPS	2-0585
Bob Carrell	2 6 7 9 10	ORP-support	521-6421
Brad Evans	1-3,6,7,9,10		
MILTON SHULTZ	2,3,6,7,9,10	CHG - NS&L	322-3740
Ed Ford	2,3,6,7,9,10	CHG - NS&L	373-1296
Mark Sautmen		DNFSB	373-0101
KENNY FOWLER	4,22,16-Crit Safety	CHG Proc Engr	373-5930
Greg Jones	1,2,3,5,7,9,10	OPS	373-5717

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

MIXING OF INCOMPATIBLE MATERIALS
CONTROL DECISION MEETING ATTENDANCE
AUGUST 23, 2002

Name	Knowledge Area(s) Represented (see below)	Organization	Telephone Number
Don Quilici	17/19	EBOS	6-6549
TODD Blank	4	DST SYS Eng	3-3880
W.J. Powell	4	Design Eng	373-1072
M.A. Fish	4	Design Eng.	372-3657
J.L. Stewart	1,7,9	NS&L	376-5633
JON SPADES		QA	372-1749
Craig Carro	1,2,3,6,7 (PARTIAL)		
Eustolio Salamanca	5	EAST TANK FARM	373-3475
Nyjeler Walker	1 2 3 4 7 9 10	NS&L	373-1342
Tim Trapuzzano	1,2,3,4,5,7,9,10	NS&L	373-1342
Curt Reichmuth	5	557 OPS	6479C

Knowledge Areas:

1 Licensing
2 Safety Analysis
3 Hazard Analysis
4 Engineering
5 Operations
6 Accident Analysis
7 Nuclear Safety
8 Design Authority
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10 Safety Structures, Systems, and Components
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APPENDIX D

PEER REVIEW CHECKLIST

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APPENDIX D

PEER REVIEW CHECKLIST

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: RPP-12646, *Mixing of Incompatible Materials in Waste Tanks Technical Basis Document*, Revision 2.

Scope of Review: Changes made for Revision 2 of the document.

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**

Brian D. Oberg B.D. Oberg 10-8-03

Reviewer (Printed Name and Signature) Date

- If No or NA is chosen, provide an explanation on this form.

6, 15, 16, 17 No computer codes or data files have been used. Hence, no software inputs are involved.

24 Draft references will be changed to "released" status prior to issuance of the calculation note.

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: RPP-12646, Rev. 2

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)*
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[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".

Comments:

Tech Edit: CAROL LYNCH C J Lynch 10-8-03
Reviewer (Printed Name and Signature) Date

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