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ENGINEERING DATA TRANSMITTAL

1. EDT 636626

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Nuclear Safety & Licensing	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: Tank Farms	6. Design Authority/Design Agent/Cog. Engr.: J.J. Zach	7. Purchase Order No.: N/A
8. Originator Remarks: This is the inital release of the Technical Basis Document addressing the aboveground tank failure representative accident and associated represented hazardous conditions.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: Tank Farms
		12. Major Assm. Dwg. No.: N/A
11. Receiver Remarks: For release.	11A. Design Baseline Document? ☐ Yes ☒ No	13. Permit/Permit Application No.: N/A
		14. Required Response Date: March 21, 2003

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	RPP-13175	N/A	0	Technical Basis Document	N/A			
				for the Aboveground Tank				
				Failure Representative				
				Accident and Associated				
				Represented Hazardous				
				Conditions	2	1	1	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority N/A									
		Design Agent N/A									
2	1	Cog. Eng. J.J. Zach	James Zach	3/21/03							
2	1	Cog. Mgr. J.M. Grigsby	JMG	3/21/03							
		QA N/A									
		Safety N/A									
		Env. N/A									

18.	19.	20.	21. DOE APPROVAL (if required)
James Zach J.J. Zach 3/21/03 Signature of EDT Originator / Date	James Zach J.J. Zach 3/21/03 Authorized Representative for Receiving Organization / Date	JMG J.M. Grigsby 3/21/03 Design Authority/ Cognizant Manager / Date	Ctrl No. ____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

BD-7400-172-2 (10/97)

BD-7400-172-1

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Nuclear Safety & Licensng	Date March 21, 2003
Project Title/Work Order: Technical Basis Document for the Aboveground Tank Failure Representative Accident and Associated Represented Hazardous Conditions		EDT No. 636626
		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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Technical Basis Document for the Aboveground Tank Failure Representative Accident and Associated Represented Hazardous Conditions

J.J. Zach, Longenecker & Associates, Inc. for
CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: 636626 UC: N/A
Cost Center: 7B300 Charge Code: 501570
B&R Code: N/A Total Pages: 51

Key Words: Aboveground, tank failure, accident, frequency, consequence, technical basis document, risk bin, 242-T Evaporator

Abstract: This document qualitatively evaluates the frequency and consequences of the representative aboveground tank failure accident and associated represented hazardous conditions without controls. Based on the evalation, it was determined that safety-signficant structures, systems, and components, and/or technical safety requirements were not required to prevent or mitigate aboveground tank failure accidents.

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Liam Fox 3-21-03
Release Approval Date

DATE: HANFORD RELEASE
STA: 4 ID: 2
MAR 21 2003
Release Stamp

Approved For Public Release

RPP-13175
Revision 0

Technical Basis for the Aboveground Tank Failure Representative Accident and Associated Represented Hazardous Conditions

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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J.J. Zach
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Date Published
March 2003

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LIST OF TERMS

ARF	aerosol release fraction
DSA	Tank Farms Documented Safety Analysis
DST	double-shell tank
ERPG	emergency response planning guideline
HEPA	high-efficiency particulate air (filter)
MAR	material at risk
RF	respirable fraction
SST	single-shell tank
SSC	structures, systems, and components
SOF	sum of fractions
TEEL	Temporary Emergency Exposure Limit
TSR	technical safety requirement
ULD	unit-liter dose
USOF	unitless sum of fractions

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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 and the technical basis for assigning risk bins for the aboveground tank failure 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 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

Aboveground structures may fail from one of several possible causes (e.g., seismic event, high winds, tornado, structural degradation, etc.) and fall on the equipment contained inside, leading to failure of that equipment. The 242-T Evaporator was built in the 1950s and is susceptible to failure and the waste assumed to remain in the 242-T Evaporator could be released to the environment. Specifically, in the unlikely event of either a high wind or a seismic event, or the anticipated continued degradation of the structure, roof panels may fall on the 242-T Evaporator vessel, which is assumed to contain up to 300 gal of waste remaining from its previous function of reducing waste volume through the evaporation process.

A review of unusual occurrences involving building failures was performed and none were found to be significant. A review of other tank farm facilities did not identify any other facility that stores waste in an aboveground tank; although, there are aboveground facilities that contain contaminants. The 242-S Evaporator is an abandoned evaporator; however, it was flushed when it was shutdown so that modifications (which were not subsequently activated) could be performed. While the 242-A Evaporator is an active evaporator, it is not subject to the DSA. The 204-AR Waste Unloading Facility is addressed separately. The In-Tank Solidification System 1 and the 241-A-431 ventilation building both have de-entrainers, which may retain contaminants aboveground, but not liquid and solid tank waste.

1.2.2 Bounding Offsite Accident

An aboveground tank failure is a moderate energy, atmospheric vapor/gas/aerosol release event that is bounded by the dome collapse accident, which 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 dome collapse accident is documented in RPP-12395, *Offsite Radiological Consequences of Waste Tank Dome Collapse*, 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 moderate 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 toxicological, or facility worker exposures). These exposures were evaluated for the aboveground tank failure 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 approximately twenty hazardous conditions that are represented by the aboveground tank failure accident. Some of these hazardous conditions are similar to the representative accident, although the initiators and aerosol release paths may be different. They were assigned to the aboveground tank failure representative accident because these events all involve moderate energy, atmospheric releases of vapors and aerosols.

1.3 RISK BINNING METHODOLOGY

The risk binning process was conducted in accordance with direction 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. It is important to note that for offsite toxicological, onsite radiological, and onsite toxicological exposures, 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 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

Notes:

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 Analysis Reports*, Change Notice No. 2, Appendix A, U.S. Department of Energy, Washington D.C.

ERPG = emergency response planning guideline.
SSC = structure, system, and component.
TEEL = Temporary Emergency Exposure Limit.
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

Notes:

Safety SSCs and/or TSR-level controls required.

Safety SSCs and/or TSR-level controls considered.

ERPG = emergency response planning guideline.
SSC = structure, system, and component.
TEEL = Temporary Emergency Exposure Limit.
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 held July 22, 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. (Note the attendance list is labeled "above grade structure failure." However, the list was used for two meetings as noted at the bottom of the page.) After the meeting, the risk binning results were distributed to the Technical Working Group for review and concurrence. With some minor clarifications, the Technical Working Group concurred with the final risk bin results, which are shown in Table 4.

Table 4. Summary of Results for Representative Scenarios.

Postulated accident/ hazardous condition	Frequency	Consequences				Risk bin		
		Onsite radiological	Offsite toxicological	Onsite toxicological	Environmental	Onsite radiological	Offsite toxicological	Onsite toxicological
Release of radioactive and hazardous material from 242-T Evaporator due to facility degradation.	A	L	L	L	E1	III	III	III

Notes:
A = anticipated.
L = low.

2.1 ABOVEGROUND TANK FAILURE REPRESENTATIVE ACCIDENT WITHOUT CONTROLS

2.1.1 Scenario

The 242-T Evaporator was constructed in the early 1950s and has been idle since the 1970s. The structure was not designed to current standards and has not been maintained. This establishes the scenario in which the building fails due either to degradation or natural phenomena. The roof panels collapse on the evaporator vessel and it splits open, spilling the contents, which are then picked up by the wind and dispersed. The potential initiators of this accident are structural failure of the roof or wall collapse because of aging or corrosion, roof overload because of snow or ash, high winds, or a seismic event. Documentation as to what was done when the facility was shut down is limited, so it is unclear as to what the remaining contents in the 242-T Evaporator are.

Adding to the waste in the evaporator is material assumed to be on the high-efficiency particulate air (HEPA) filters. This material is assumed to blow out during the pressure pulse through the ventilation system when the roof panels fall.

2.1.2 Frequency Determination

The initiator for the scenario is the collapse of the roof panels on the evaporator vessel. The evaporator vessel is the largest component in the evaporator system and contains the most waste (based on radiation surveys). There are no other initiators with the potential energy to cause the vessel to rupture and create a release to the environment that is essentially unrestricted. The creation of the hazardous conditions with the greatest consequences then addressed the causes for a roof panel falling on the evaporator vessel.

A frequency of "unlikely" was qualitatively assigned to this accident based on natural phenomena initiators. RPP-4780, *Calculation Notes with Structural Analysis for the 242-T Evaporator*, Appendix B, contains a failure mode analysis for the 242-T Building to estimate the frequency of roof collapse scenarios caused by snow or volcanic ash fall, wind loading, or seismic events. The frequency of roof collapse from these natural phenomena loads was approximately 2.9×10^{-3} per year, placing this event in the "unlikely" frequency class (10^{-2} to 10^{-4}/yr).

A frequency of "anticipated" was qualitatively assigned to this accident based on degradation of the structure. There is a 10^{-2} or greater likelihood that the building may fall down on its own if no maintenance is performed.

2.1.3 Consequence Determination

After the building collapses, the postulated release results from splash/splatter and wind entrainment.

An input into the qualitative assessment of consequences was the Appendix B calculation, using conservative modeling assumptions documented in Table 5. The analysis assumes that the waste remaining in the evaporator is released to the environment when the evaporator fails due to the roof panels falling on it.

It is important to note that the analysis assumptions listed in Table 5 were selected to maximize the calculated consequences of the aboveground tank failure accident and that it is the combination of conservative assumptions that truly drive the accident consequences. Because a combination of conservative analysis assumptions was used and because of the large difference between the calculated radiological and toxicological consequences and the risk bin guidelines, sensitivity studies were not conducted on each of the individual input parameters. However, each of the assumptions, the potential effect of changes in the assumption on the frequency or consequence level (qualitatively judged), and the need to protect the assumptions are detailed in Table 5.

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (4 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (consequence)	Need to protect AA	Protection Basis
The released waste is equivalent to SST waste that is 78% liquids and 22% solids based on RPP-7277 analysis. Evaporator operation was to process salt slurries, not sludge. 242-T received its feed from 241-TX-118, which received feed from the T farm complex, all SSTs. The feed material had to be liquid to be pumped to the evaporator and drain (not pumped) from the evaporator to a diversion box.	Conservative based on the physical configuration.	The SST waste characteristics (ULD and SOF) are either higher than other waste types, or are relatively close; assuming the highest value would not cause the consequences to change risk bins. ULD would increase 50% if the waste were assumed to be 100% solids. SOFs would change (either increase or decrease, depending on the TEEL) approximately 20%.	No	NA
The maximum volume of waste in the evaporator vessel for the analysis = 300 gal of SST waste. (The volume documented in RPP-7277 in the evaporator vessel is 212 gal. This is based on field measurements of radiation levels at the bottom of the evaporator of 15 rem/h and calculating the contents.) Because of the uncertainty in the best estimate, it was increased by approximately 50%. There is no connection to add more waste to the evaporator.	Reasonably conservative based on evaporator design, field surveys, and operational practices.	The entire inventory is assumed to be in the evaporator vessel based on radiation surveys in the facility. This consolidates the inventory making it more probable that it would be affected by falling roof panels than if it is spread throughout the building. To challenge the threshold for the "moderate" consequence category, the material in the vessel would have to be increased from the conservative 300 gal by another 40% with the same ULD and SOF.	No	NA
The amount of waste assumed on each HEPA filter is such that the dose from each is 200 mrem/h. Based on 22% solids and 78% liquid, the amount of waste is 0.311 L per filter. Appendix B assumed that all eight HEPA filters were contaminated with 242-T waste to the point where they read 200 mrem/h. Then the equivalent of one more filter was included for contaminants in the duct.	Reasonably conservative based on operational practices (As Low as Reasonably Achievable).	Increasing the MAR by two orders of magnitude would not cause the results to change. Both filter banks would have to be on line to produce the full release, even though one bank normally will be isolated by manually operated dampers.	No	NA
The ARF and RF for splash/splatter were selected from DOE-HDBK-3010-94. The approximation in DOE-HDBK-3010-94 is for the free-fall of a concentrated heavy metal solution for fall distances of 9.8 ft or less to a hard, unyielding surface. The fall distance for 242-T is approximately 3 ft or less. DOE-HDBK-3010-94's correlation for ARF with a conservatively low viscosity is a valid approach. RF = 0.7 is considered reasonable. (DOE-HDBK-3010-94, Section 3.2.3.1).	Reasonably conservative based on the physical configuration and use of DOE-HDBK-3010-94.	If the viscosity is higher than the low value, the ARF decreases by the rate of the inverse square. If the spill is more than 3 ft, the ARF increases by the inverse square.	No	NA

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (4 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (consequence)	Need to protect AA	Protection Basis
A breathing rate of 3.33 x 10^{-4} m^3/s was used to estimate the radiological consequences. This is the breathing rate associated with light activity (i.e., it is an 8-hr average, which assumes 2.5 hr of sitting and 5.5 hr of light exercise) as derived by the International Commission on Radiological Protection. (RPP-5924.)	Reasonably conservative.	This is a standard analysis assumption.	No	NA
Onsite exposure of 2 hr. The normal work shift for tank farm personnel is longer than 2 hr. However, this accident would be quite obvious and 2 hr is a reasonable time for normal protective actions to occur.	Reasonably conservative.	Increased exposure time will cause an almost linear increase in wind entrainment consequences with the caveat that the released MAR will decrease with time as the pool is depleted. Maximum exposure time for the wind entrainment consequences would be a factor of 6 higher than calculated, which would not change the risk bin.	No	NA
Inhalation ULD for SST waste of 7.7 x 10^3 Sv/L. This is a composite of ULDs in RPP-5924 based on waste type and liquid/solids content (78%/22%).	Bounding of current liquid and solids ULDs.	No anticipated effect on consequence bin. Relationship with consequences is linear. The specific radioactivity of SST solids is higher than that of DST solids and the difference between the liquids is nominal. Therefore, the SST waste is a conservative choice.	No	NA
For the purpose of estimating toxicological consequences, the released waste is assumed to be SST liquids and solids. Toxicological consequences are calculated per the methodology established in RPP-8369. The values used are composites of numbers in RPP-8369 based on waste type and liquid/solids content (78%/22%). The onsite USOF for anticipated events is 6.1 x 10^8 s/L; the offsite USOF for anticipated events is 3.4 x 10^9 s/L.	Bounding of current SST liquid and solids SOFs.	No anticipated effect on consequence bin.	No	NA

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (4 sheets)

Analysis assumptions (AA) with references/basis	Assumption type	Sensitivity (consequence)	Need to protect AA	Protection Basis
Consideration for the assumptions of meteorological conditions include the following. Accident duration is less than 1 hr for the HEPA filter release and the splash/splatter from the evaporator vessel. For toxicological consequences, atmospheric dispersion coefficients of 3.28×10^{-2} m^3/s (onsite) and 2.22×10^{-5} m^3/s (offsite) were used to estimate consequences. For onsite radiological consequences, 3.28×10^{-3} m^3/s (HEPA filter), 3.28×10^{-2} m^3/s (splash/splatter), and 5.58×10^{-3} m^3/s (wind entrainment) were used. (RPP-13482.)	Reasonably conservative. These atmospheric dispersion coefficients are based on 95% meteorology, which is recommended for conservative analysis.	No anticipated effect on consequence bin.	No	NA
The entrainment rate for the material after the initial building collapse and waste spill was selected from DOE-HDBK-3010-94 for the aerodynamic entrainment and suspension of the waste from the floor. DOE-HDBK-3010-94, Section 3.2.4.5 provides a bounding value for large pools in high winds (e.g., 30 mi/h). For the 242-T situation, the entrainment rate is 4×10^{-6}/hr.	Bounding value.	For a smaller pool or winds with a lower velocity, the entrainment rate is lower.	No	NA
No credit is taken for the HEPA filters from an aerosol removal standpoint. The scenario assumption is that the building collapses, exposing the MAR to the elements.	Bounding (physically limited).	No anticipated effect on consequence bin. If the HEPA filters are credited with particulate removal then the accident consequences would be reduced.	No	NA
For the HEPA filter overpressurization, the ARF is developed from DOE-HDBK-3010-94, Section 5.4 for shocking, blasting, or impacting a HEPA filter in an unconfined or a confined space providing a limiting ARF of 2.0×10^{-6} and RF = 1.	Bounding value.	In this case, this release fraction is highly conservative because a relatively mild pressure pulse is the initiator rather than a blast or explosion.	No	NA

Table 5. Qualitative Evaluation of Analysis Assumptions for Representative Accident. (4 sheets)

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

Notes:

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

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

RPP-7277, 2003, *Evaluation of Radionuclide Inventory at 242-T Evaporator*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-8369, 2003, *Chemical Source Terms for Tank Farms Safety Analyses*, 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.

AA = analysis assumptions.
ARF = aerosol release fraction.
DST = double-shell tank.
HEPA = high-efficiency particulate air (filter).
MAR = material at risk.
RF = respirable fraction.
SOF = sum of fractions.
SST = single-shell tank.
TEEL = Temporary Emergency Exposure Limit.
ULD = unit-liter dose.
USOF = unitless sum of fractions.

2.2 CALCULATION RESULTS

2.2.1 Assignment of Consequence Bins for the Onsite Receptors

The maximum effects calculated in Appendix B (including HEPA filter effects) produced estimated onsite radiological consequences of 2.7×10^{-2} rem, onsite toxicological consequences (sum of fractions [SOF]) of 0.72 (emergency response planning guide [ERPG]-2) and offsite toxicological consequences (SOFs) of 2.7×10^{-3} (ERPG-1).

In determining the offsite toxicological and onsite radiological and toxicological consequences bins, the meeting participants considered the existing analysis which applied a combination of conservative assumptions to calculate radiological and toxicological consequences. These calculated consequences are low when compared to the guidelines (i.e., the onsite radiological consequence <25 rem and the onsite and offsite toxicological consequences (SOFs) of <1 ERPG-2/TEEL-2 and <1 ERPG-1/TEEL-1 respectively). Therefore, a consequence bin of "low" was assigned to the onsite radiological and the onsite and offsite toxicological exposures.

2.2.2 Assignment of Environmental Consequences

The hot side of the evaporator building (i.e., where the evaporator vessel is located) has a dike at its only door. The height of the dike is sized to retain the operating volume of the evaporator (i.e., 4,000 gal). The analysis in Appendix B conservatively assumes 300 gal of solids and supernatant, which would be easily retained by the dike. If the evaporator vessel were at the operating level (4,000 gal) with an undetected 3,700 gal layer of contaminated water over the 300 gal of waste, the contents would still be retained in the building. The total collapse of the south wall, or the south part of the east and/or west wall, to the point where the waste would be released directly to the ground is not likely.

The aerosol release would be 9.1×10^{-1} L from splash/splatter and 9.0×10^{-3} L from the entrainment. It was concluded that there is limited potential for material release to either the atmosphere or ground. Therefore, an environmental consequence of E1 was assigned to the aboveground tank failure accident.

2.2.3 Assignment of Risk Bins

As discussed previously, the frequency of the aboveground tank failure due to facility degradation was considered to be in the "anticipated" range, and the offsite toxicological and the onsite radiological and toxicological were assigned a consequence bin of "low." Each exposure category for the aboveground tank failure accident was assigned to Risk Bin III.

2.3 ABOVEGROUND TANK FAILURE - ASSOCIATED HAZARDOUS CONDITIONS

There are approximately twenty additional hazardous conditions represented by the aboveground tank failure representative accident. (Note that the specific number of hazardous conditions may change based on changes in field configurations or operations.) The results of the risk binning process for these hazardous conditions are shown in the hazard evalution database under representative accident (Rep Acc) 34. Included in these hazard evaluation database entries is a basis for each consequence and frequency. Most of the related hazardous conditions consider the failure of other components in the 242-T Evaporator building. As noted previously, the evaporator vessel is the largest component in the building and has the largest inventory of waste (based on radiation surveys). The initiators for the failure of the other components would be the same as for the evaporator vessel.

3.0 CONTROL SELECTION

The representative accident and associated hazardous conditions are assigned to Risk Bin III for all receptors; therefore safety SSCs and/or TSR-level controls are not required for the aboveground tank failure accident and associated hazardous conditions. However, defense-in-depth features were identified for the evaporator dump accident and associated represented hazardous conditions as described in RPP-14821, *Technical Basis Document for Defense-In-Depth Features*. No safety SSCs or TSR-level controls were selected within the defense-in-depth features identified for the evaporator dump accident and associated represented hazardous conditions. Facility worker hazardous conditions, including those associated with the evaporator dump representative accident were evaluated for controls as documented in RPP-14286, *Facility Worker Technical Basis Document*.

4.0 REFERENCES

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

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

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

RPP-4780, 2000, *Calculation Notes with Structural Analysis for the 242-T Evaporator*, Rev. 0, 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-7277, 2003, *Evaluation of Radionuclide Inventory at 242-T Evaporator*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-8369, 2003, *Chemical Source Terms for Tank Farms Safety Analyses*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-12395, 2003, *Offsite Radiological Consequences of Waste Tank Dome Collapse*, 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-14286, 2003, *Facility Worker Technical Basis Document*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-14821, 2003, *Technical Basis Document for Defense-In-Depth Features*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX A

MEETING ATTENDEES

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APPENDIX A-1

MEETING ATTENDEES
AUGUST 22, 2002

DSA Accident Risk Binning Attendance Sheet

Meeting Subject: Above grade structure failure Date 7/22/02

Name	Organization	Phone	Mail Stop
MILTON V. SHULTZ	CHG-NS&L	372-3740	R1-44
JUSEPH J. BEVELACQUA	ORP	376-8443	H6-60
James J. Zach	CHG-NS&L	373-0670	R1-49
Robert D CARRELL	CRP-support	521-6921	H6-60
Larry J. Johl	CHG Design Eng	376-4608	R3-83
David Foust	CHG-Rad Eng	376-8215	S7-90
Phil Miller	CHG-ENV	373-1920	R1-57
CLIFF HAMPTON	CHG-OPS	372-0566	R2-50
Geoffrey Gelhaus	ORP support	539-1122	
* Delmar Noyes	ORP	376-5166	H6-60
[illegible]	CHG NS&L	372-2646	R1-44
Steve Fischetti	ORP Support	528-5207	
Ed Ford	CHG NS&L	373-1296	R1-44
* AL FRIBERG	CHG DES. ENGRG.	376-1190	R3-83

* present for 242-T Evap. only ≠ present for mixer pump only

APPENDIX A-2

MEETING ATTENDEES
JANUARY 23, 2003

ABOVE GROUND TANK FAILURE
JIM ZACH

Defense In Depth
Meeting Attendance Sheet January 23, 2003

Name	Knowledge Area(s) Represented (see below)	Organization	Telephone Number
Ed Ford	1, 2, 3, 6, 9, 13	NS&L	373-1296
Lawrence T. Kriddy		NSL	376-1061
James Zach	1, 2, 3, 6, 9, 13	NS&L	373-0670
Mark Hasty	5, 9, 13	OPS	373-9378
Rick Hockfeldt	17	Safety	372-3212
Ralph Broz	12, 11	Rad Cor	372-8450
Rich Larson	4, 8, 14, 23	Design Engineering	373-9100

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

APPENDIX B

CALCULATIONS FOR ABOVEGROUND TANK FAILURE

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APPENDIX B

CALCULATIONS FOR ABOVEGROUND TANK FAILURE

B1.0 BACKGROUND

B1.1 SCENARIO

This accident corresponds to a hazardous condition identified in HNF-4508, *Hazard Evaluation for 242-T Evaporator Facility*, caused by a tank failure, in turn, caused by a partial building collapse. This accident is somewhat similar to the existing tank failure due to excessive loads representative accident except that the tank involved is aboveground inside a building. It is assumed that the tank in question ruptures after being hit by one or more falling roof panels and/or walls, and that the resulting pressure transient in the building caused by air displacement is sufficient to breach the high-efficiency particulate air (HEPA) filters in the ventilation system. The consequences of the HEPA filter failure caused by high pressure representative accident (Section B3.1) will be added to those of the tank failure accident to obtain the total consequences.

There is a release of aerosols from the vapor space of the evaporator added to the blowout of the HEPA filter, and a time-dependent release of aerosols from liquid dispersed from the rubble of the 242-T Evaporator building. The entire building inventory is assumed to be in the evaporator vessel, which contains most of the inventory based on radiation readings. Some initiator causes one or more concrete roof panels to fall onto the evaporator vessel. The evaporator vessel is assumed to suffer gross failures and to pour its contents out onto the floor of the facility. It should be noted that the vessel and supports were designed to hold more than 4,000 gal of waste with a specific gravity of 1.2 or more. The design of the tank should be able to support the weight of the roof panels from half the building, if the vessel is empty. This does not consider any structural degradation of the vessel and supports or the impact loading of the panel falling a few feet. Because the building is assumed to be open to the environment after the building collapse, aerosol generated during the tank failure and spill can be ejected directly into the air above the facility. In addition, the air displaced during the roof collapse is assumed to breach the HEPA filters and result in a maximum release from the exhaust system.

The HEPA filter component of accident corresponds to an identified hazardous condition that addresses most of the other tank farm facilities. A filter blowout could be caused by air displacement caused by collapse of the building roof, which consists of a series of 20 concrete panels, each of which is 21 ft 51/2 in. by 4 ft 2 in. Half of the roof panels are over the "cold side" and half over the "hot side." No calculation was performed to determine how many panels would have to fall to develop a pressure pulse to blow out the HEPA filters. Each panel is approximately 80 ft^2 and each half of the building is approximately 800 ft^2. In this scenario, all the HEPA filters are breached and release a fraction of their contents during an over-pressure condition within the facility. Each of the two filter banks has two parallel branches each composed of two HEPA filters in series, or a total of four HEPA filters per bank, for a total of

eight HEPA filters at risk. The system contains no prefilters separate from the HEPA filters. In addition, it is assumed that the venting from the over-pressure condition causes a further release (equal to the release from one HEPA filter) from material deposited in the duct and preheater. Because this facility is assumed to contain no waste outside its tanks and pipes, it is assumed that no appreciable sustained unfiltered release occurs beyond the release from the filters themselves.

In summary, this accident has three primary sources of release:

- The immediate release from the blown filters and exhaust system (Section B3.1)
- The immediate release of the aerosol generated from splash/splatter during the tank failure and agitation of the waste as it pours out onto the floor (Section B3.2)
- A steady release of aerosol entrained by wind from the waste covering the floor of the open building (Section B3.3).

B1.2 ESTIMATED INVENTORY AT RISK

The material at risk (MAR) is the amount of radionuclides available to be acted on by a given physical stress. For tank farm facilities, the MAR is taken to be the maximum quantity of radioactive material present or reasonably anticipated at each accident location.

The contents of the tanks and vessels within the 242-T Evaporator facility process areas are not completely identified. The volume of waste in the 242-T Evaporator facility is contained primarily in the evaporator vessel and associated piping. Radiation surveys, system design, and operating history confirm that other large components (e.g., condensate catch tanks, blend tank, etc.) either are essentially empty, or contain material with little radioactive content (e.g., flush water). The design of the evaporator internals and operating records indicate that the evaporator could have contained between 0 and a maximum 4,000 gal of material when it was shut down.

The tank is 12 ft in diameter and 12 ft tall. It is basically a right circular cylinder with a dished bottom. The straight section of the tank is approximately 4 ft from the floor with the center of the dished bottom being about 2 ft from the floor. The top surface of the operating level of 4,000 gal of waste is 7.5 ft from the floor. The tank is made of 3/8 in. 347 stainless steel.

RPP-7277, *Evaluation of Radionuclide Inventory at 242-T Evaporator*, calculates that the waste inventory present in the 242-T Evaporator vessel is more than 200 gal. The conclusion is that the bounding volume is 47 gal of wetted solids, 165 gal of supernatant, and 16 gal of "crud" residual on the tank wall (solids). The report also says that the 1 rem/h background in the cell would tend to bias the crud in a conservative direction (higher values predicted than likely to exist). In the assumed accident, in which the waste flows out of the evaporator with splash/splatter dynamics and is then entrained by the wind, the 16 gal of crud will be neglected because the likelihood of the crud contributing to and/or affecting the source term would be less than 10%. Therefore, the solids/liquid mix is 22.2%/77.8%. The mix is relatively high in solids compared to the limits imposed on solids concentrations to ensure fluid flow. Because the unit-liter dose (ULD) for solids is almost two orders of magnitude higher than the ULD for corresponding liquid, a high

solids concentration is conservative for radiological consequences. For toxicological consequences, there is a small difference between the solid and liquid factors.

The type and quantity of waste are based on the evaporator vessel operating history and radiation surveys, respectively. The entire inventory is assumed to be in the evaporator vessel, based on radiation surveys in the facility. This consolidates the inventory into a single location, making it more probable that it would be affected by falling roof panels than if it is spread throughout the building.

In addition to the MAR in the evaporator vessel, there is also MAR assumed on the HEPA filters. RPP-13437, *Technical Basis Document for Ventilation System Filtration Failures Leading to an Unfiltered Release*, provides dose rate per liter of waste on the filter. For a 2 ft x 2 ft x 1 ft filter with a survey point on the duct 4 in. from the side of the filter, the dose rates are 702 mrem/h per L of single-shell tank (SST) liquids and 435 mrem/h per L of SST solids. A slurry with 78% liquids would have a dose rate of 643 mrem/h per L of slurry. If the assumption is that the reading on the filter is 200 mrem/h, it would then correspond to 0.243 L of liquid (200/702), 0.460 L of solids (200/435) or 0.311 L (200/494) of slurry.

$$
\begin{aligned}
0.78_{\text{liquid}}(702 \text{ mrem/hr-L}) + 0.22_{\text{solids}}(435 \text{ mrem/hr-L}) \\
&= 548 \text{ mrem/hr} + 96 \text{ mrem/hr} \\
&= 643 \text{ mrem/hr} \times 0.311 \times [0.78_{\text{liquid}}(702 \text{ mrem/hr-L}) + 0.22_{\text{solids}}(435 \text{ mrem/hr-L})] \\
&= 200 \text{ mrem/hr} \times 170 \text{ mrem/hr} + 30 \text{ mrem/hr} \\
&= 200 \text{ mrem/hr}
\end{aligned}
$$

The HEPA filter failure accident is assumed to affect all eight HEPA filters in the system even though only four filters normally are on line; the other four filters are isolated by manually operated dampers. This conservatism allows for the possibility of inadvertently mispositioning the dampers. The total release is assumed to be the equivalent of nine HEPA filters (eight filters plus contaminants in the duct). It is very conservative to assume that all eight HEPA filters reach the maximum loading without having to replace any filters. In addition, it is unlikely that a downstream HEPA filter would reach 200 mrem/h while the upstream HEPA filter stopped loading at 200 mrem/h.

B1.3 OTHER ASSUMPTIONS

The following are the assumptions for the parameters of the calculation.

- The airborne release fraction (ARF) and airborne release rate (ARR) are used to estimate the amount of radioactive material suspended in air as an aerosol and available for transport due to a physical stress from a specific accident. For discrete events, the ARF is a fraction of the material affected; for ongoing events, the ARR is a fraction of the material affected per unit time. For aboveground tank failure, different ARFs are selected for the different parts of the accident (i.e., HEPA filter failure, splash/splatter, wind entrainment).

  For splash/splatter the ARF and respirable fraction (RF) were selected from DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for*

Nonreactor Nuclear Facilities, for the aerodynamic entrainment and suspension of the waste from the ground. The immediate waste release from the evaporator vessel is assumed to be equivalent to a free-fall spill of the entire inventory from a height of 3 ft onto a hard surface. This is conservative because the distance from the bottom of the tank to the floor is approximately 2 ft, and the most likely sources of the spill are ruptures near the tank base caused by the support legs penetrating the base and the bottom drain connection leaking. The waste is largely concentrated within 3 ft of the floor based on radiation readings. DOE-STD-3010-94, Section 3.2.3 provides bounding and median ARFs for alternative waste compositions for spills from 9 ft. Values are provided for two types of solutions: slurries and viscous. A correlation is provided in DOE-STD-3010-94, Section 3.2.3.1 for calculations which "...covers all of the spill data, including slurries and viscous solutions."

$$ARF = 8.9 \times 10^{-10} \times Arch^{0.55}$$

where:

Arch	=	Archimedes Number.
	=	$(density_{air})^2 \times (\text{spill height})^3 \times g/(\text{solution viscosity})^2$
Density$_{air}$	=	1.2×10^{-3} g/cc
Spill height	=	100 cm
g	=	981 cm/s^2
Solution viscosity	=	2.6×10^{-2} poise.

$$Arch = (1.2 \times 10^{-3}\ g/cm^3)^2 \times (100\ cm)^3 \times 981\ cm/s^2/(2.6 \times 10^{-2}\ poise)^2 = 2.1 \times 10^6$$

$$ARF = 8.9 \times 10^{-10} \times (2.1 \times 10^6)^{0.55} = 8.9 \times 10^{-10} \times 3000 = 2.7 \times 10^{-6}$$

The selected viscosity (2.6×10^{-2} poise) corresponds to a value on DOE-HDBK-3010-94, Table 3-9 at the low end of potential values. Higher values decrease the ARF by the inverse of the square.

Air density for ~21 °C (~70 °F) was taken from *Fluid Mechanics with Engineering Applications* (Franzini, J. B., and E. J. Finnemore, 1997)(see Attachment B1). Decreasing the air temperature to 0 °C (32 °F) increase the density to 0.0013 g/cm^3 and increase the Archimedes Number by 17%. However, in the ARF equation Archimedes Number is taken to the 0.55 power, which means the ARF increases by ~8%.

- The RF is the fraction of airborne material that can be transported through the air and inhaled into the human respiratory system. It is commonly assumed to include particles 10-µm aerodynamic equivalent diameter (AED) and less. The term "10-µm AED" means the particle has the same settling speed in air as a 10-µm unit density sphere. The actual diameter could differ from 10 µm due to differences in density and/or shape. The principal emphasis in this document is directed toward the potential downwind hazard to the populations at some distance from the point of source term generation. Note that the loss from airborne particles attaching to fixed objects such as foliage, buildings, and the ground surface is small due to the small size of the particles. An RF of 0.7 is assumed as a reasonably high value, selected from the bounding values for the various types of waste.

- Onsite and 1 hr offsite breathing rate (BR) is 3.33×10^{-4} m^3/s (light physical activity; i.e., it is an 8-hr average, which assumes 2.5 hr of sitting and 5.5 hr of light exercise). The BR is the rate at which people inhale the contaminated air. The light-activity BR for an adult male (RPP-5924, *Radiological Source Terms for Tank Farms Safety Analysis*) is used to calculate both onsite and offsite receptor inhalation doses for all release scenarios. The adult male inhalation rate is chosen to maximize the intake and resulting dose equivalent.

- Onsite exposure duration is 2 hr. All of the hazardous conditions are initiated by a significant event (e.g., roof collapse), which would be obvious to the co-located worker. If a single roof panel falls due to degradation, it would likely come down partially in pieces (halves). The evaporator would likely not be damaged to the point of failure by such an event. Increased exposure time will cause an almost linear increase in consequences with the caveat that the released MAR will decrease with time as the pool is depleted. If a complete work shift with overtime were assumed, maximum exposure time (12-hr shift) would be a factor of 6 higher than assumed.

- The composite inhalation ULD for SST waste of 7.7×10^3 Sv/L based on Table 4-1 of RPP-5924. The evaporator processed waste from SSTs in the 200 West Area, particularly from the T Tank Farm complex. Its feed tank was SST 241-TX-118. Therefore, the ULDs in RPP-5924, Table B-1, are the values for SST salt cake (SST 241-TX-118 is the tank with the highest value) and SST saltcake liquid (SST 241-U-106 is the bounding tank). The two possible columns that could be selected from RPP-5924, Table 4-1, "Dome Failure All Tanks" and "Balance of Scenarios Bounding Cases," are identical. The mix is 22.2%/77.8% solids/liquid.

Table B-1. Single-Shell Tank 22/78 Solids/Liquid Mix Unit-Liter Doses (Sv/L).

Receptor	Solid	Liquid	Composite
Onsite	3.3×10^4 Saltcake	4.5×10^2 Saltcake or Liquid	$(0.73 + 0.04) \times 10^4$ 7.7×10^3

- Toxicological consequences are calculated per the methodology established in RPP-8369, *Chemical Source Terms for Tank Farms Safety Analyses.* The composite onsite sum of fractions (SOF) for anticipated and unlikely events is listed in Table B-2 with the source of the component values.

Table B-2. Single-Shell Tank 22/78 Solids/Liquid Mix Sum of Fractions.

	RPP-8369 Table	Anticipated and Unlikely
Solids (TEEL-2, onsite)	Table 6-8	7.3×10^8
Liquids (TEEL-2, onsite)	Table 6-20	5.8×10^8
Solids (TEEL-1, offsite)	Table 6-5	2.2×10^9
Liquids (TEEL-1, offsite)	Table 6-17	3.8×10^9
Solids fraction in waste	--	22%
Liquids fraction in waste	--	78%
Composite (TEEL -2) onsite)	--	6.1×10^8
Composite (TEEL -1 offsite)	--	3.4×10^9

Notes:

RPP-8369, 2003, *Chemical Source Terms for Tank Farms Safety Analyses,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

TEEL = Temporary Emergency Exposure Limit.

- Because there are three components of the accident with radiological consequences for the onsite worker and toxicological consequences for both onsite and offsite calculated, selection of the atmospheric dispersion factors (χ/Q') includes different values. Table B-3 is the matrix of the different types of releases. The toxicological consequences from the entrainment are not calculated because the concentrations are low compared to the peak concentrations from the HEPA filters and the splash/splatter.

  Based on the assumptions in RPP-13482, *Atmospheric Dispersion Coefficients and Radiological/Toxicological Exposure Methodology for Use in Tank Farms,* was used to determine which value should be used. Table B-3 lists the source of the χ/Q's from RPP-13482. (Note that the column entitled "Meteorological Condition" is considered Column 1 in the RPP-13482 tables.)

  Table B-3 also provides the χ/Q' values from RPP-13482 that are assumed in the calculations for the aboveground tank failure.

Table B-3. Type of Release Assumed, Information Source, and Atmospheric Dispersion Factor

Release mechanism	Onsite radiological			Onsite toxicological			Offsite toxicological		
	Model assumed	**Information source in RPP-13482**	**χ/Q' (s/m^3)**	**Model assumed**	**Information source in RPP-13482**	**χ/Q' (s/m^3)**	**Model assumed**	**Information source in RPP-13482**	**χ/Q' (s/m^3)**
Filter release	1 hour (95th %)	Table 2-4, Column 2	3.28×10^{-2}	1 hour (95th %)	Table 2-4, Column 2	3.28×10^{-2}	1 hour (95th %)	Table 2-5, Column 2	2.22×10^{-5}
Splash/splatter	1 hour (95th %)	Table 2-4, Column 2	3.28×10^{-2}	1 hour (95th %)	Table 2-4 Column 2	3.28×10^{-2}	1 hour (95th %)	Table 2-5, Column 2	2.22×10^{-5}
Entrainment	8 hour (95th %)	Table 2-4, Column 4	5.58×10^{-3}	NA	NA	NA	NA	NA	NA

Notes:

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.

NA = not applicable.

- Because the cell (i.e., the roof, door, and possibly portions of the walls) is assumed to be open after the roof collapse, the pool is subject to direct entrainment by wind, which has a much higher velocity than ventilation airflow within a facility. Because this facility is a small, one-story structure and could be only partially collapsed, no credit is taken for any mitigation caused by a sheltering effect of rubble. The entrainment rate for the material after the initial building collapse and waste spill was selected from DOE-HDBK-3010-94, for the aerodynamic entrainment and suspension of the waste from the floor. DOE-HDBK-3010-94, Section 3.2.4.5 provides a bounding value for large pools in high winds (e.g., 30 mi/h). For a smaller pool or winds with a lower velocity, the entrainment rate is lower. The rate of 4×10^{-6}/hr is consistent with the information provided with DOE-HDBK-3010-94, Figure 3-8. It states, "With a fetch of 10 m (~33 ft), a wind speed of 15 m/s (~ 33.6 mi/hr), and an effective active layer (depth of liquid actually involved in drop generation) under these conditions of 1 mm to 1 cm, the airborne suspension rate would range from 4E-6/hr to 4E-8/hr." The fetch is the pool diameter; for the 242-T Evaporator this would be the length of the building (~ 40 ft). Lower air entrainment values are presented for liquids indoors exposed to forced ventilation (4×10^{-7}/hr in Section 3.2.4.5), or for liquid in remnants and debris (4×10^{-8}/hr in Section 3.2.4.5). A conservative value of 4×10^{-6}/hr (1.1×10^{-9}/sec) was selected for the analysis.

- DOE-HDBK-3010-94, Section 5.4, for shocking, blasting, or impacting a HEPA filter in an unconfined or a confined space provides an ARF range from 1.0×10^{-6} to 1.0×10^{-2}. The phenomenon of the roof panel falling and creating a mild pressure pulse is best described as a shock. This analysis assumes the same value, 2.0×10^{-6} as used in RPP-13437. (see Table B-4).

Table B-4. High-Efficiency Particulate Air Filter Airborne Release Fractions for Various Initiators.

Scenario	ARF	RF
Shock	2×10^{-6}	1.0
Blast	1×10^{-2}	1.0
Free-fall or impact	5×10^{-3}	1.0
Enclosed	5×10^{-4}	1.0
Open	1×10^{-2}	1.0

Notes:
ARF = aerosol release fraction.
RF = respirable fraction.

B2.0 CONSEQUENCE CALCULATION METHODS

B2.1 SOURCE TERM

Both radiological and toxicological consequences are estimated using standardized factors to account for the source term, atmospheric dispersion, and hazard index.

The airborne source term is typically estimated via a five-component linear equation. The total released (Equation B1) is used for radiological dose calculations and the release rate (Equation B2) is used for toxicological calculations.

$$Q = MAR \times DR \times ARF \times RF \times LPF \tag{B1}$$

$$Q' = MAR \times DR \times ARR \times RF \times LPF \tag{B2}$$

where:

- Q = quantity released as respirable particles (L)
- MAR = material-at-risk (L)
- DR = damage ratio (= 1.0 for this analysis = unitless)
- ARF = airborne release fraction (unitless)
- RF = respirable fraction (unitless)
- LPF = leak path factor (= 1.0 for this analysis = unitless)
- Q' = respirable release rate (L/s)
- ARR = airborne release rate fraction (= $ARF/T_{(REL)}$ = 1/s)
- $T_{(REL)}$ = release duration (sec).

$$Q = MAR \times 1.0 \times ARF \times RF \times 1.0 \tag{B1a}$$

$$Q' = MAR \times 1.0 \times ARF/60 \times RF \times 1.0 \tag{B2a}$$

The factors in Equations B1 and B2 are described in more detail in Section B1.

B2.2 RADIOLOGICAL DOSE CONSEQUENCE METHOD

The total onsite dose can include inhalation and submersion (i.e., immersion in the cloud of radioactive material). Usually the dominant exposure pathway is via inhalation. RPP-5924 describes the individual dose as Equation B3:

$$D = Q \times \chi/Q' \times BR \times ULD \tag{B3}$$

where:

- D = inhalation dose at a downwind location (Sv)
- Q = amount released as respirable particles, the source term from Equation B1a (L)
- χ/Q' = air transport factor (s/m^3)
- BR = breathing rate (m^3/s)
- ULD = unit-liter dose (Sv/L).

The source term, Q, is the amount of radioactive material released to the environment as described in Section B2.1 (Equation B1a).

B2.3 TOXICOLOGICAL CONSEQUENCE METHOD

The methodology that is used to calculate the toxicological exposure consequences is documented in RPP-8369. In this method, the source release rate is multiplied by the air transport factor and an appropriate unitless sum of fractions (USOF). The USOF is a sum of the ratios of each mean analyte concentration for the waste type (e.g., SST solids) to its respective Temporary Emergency Exposure Limit (TEEL) or allowable concentration in air. The value of the USOF is dependent on the waste composition and the event frequency (Equation B4).

$$SOF = Q' \times \chi/Q' \times USOF \qquad \text{(B4)}$$

where:

SOF = sum of fractions
Q' = release rate from Equation B2a (L/s)
χ/Q' = air transport factor for a plume (s/m^3)
$USOF$ = unitless sum of fractions, computed as the sum of the unitless ratios of the analyte concentration divided by its TEEL.

The SOF represents the total fraction of the air concentration guideline that the release caused. The SOF risk guideline for a given release is 1.

The release rate, Q', is computed as shown in Section B2.1, Equation B2a. When using the SOF values from RPP-8369, the calculations require the application of a conversion factor (1 m^3/10^3 L) to convert the release rate from the L/s to release rate values of m^3/s.

B3.0 CONSEQUENCES

B3.1 HIGH-EFFICIENCY PARTICULATE AIR FAILURE CAUSED BY HIGH PRESSURE

Each filter is assumed to contain 3.11×10^{-1} L of SST waste equivalent (Section B1.2): 9 "filters" x material per filter x ARF ($9 \times 3.11 \times 10^{-1}$ L x 2.0×10^{-6}) = 5.58×10^{-6} L. The duration of the release caused by overpressure is expected to be less than 1 min, so the minimum 1-min averaging time for corrosive/irritant agents was used; assuming the entire release to be averaged over a 1-min (60 sec) period produces a release rate of 9.27×10^{-8} L/s. Consistent with the assumption in Section B1.3, RF = 1 for the HEPA filter failure.

The resulting radiological doses and SOFs ("anticipated" frequency class) for the HEPA filter failure caused by the over-pressure accident without controls were calculated as follows:

Radiological Dose = (Q)(χ/Q')(BR)(ULD)

Onsite dose = (5.58 x 10^{-6} L)(3.28 x 10^{-2} s/m^3)(3.33 x 10^{-4} m^3/s)(7.7 x 10^3 Sv/L)

= 4.7 x 10^{-7}Sv (4.7 x 10^{-5} rem).

Toxicological Dose = (Q')(χ/Q')(SOF)(1 m^3/10^3 L)

Onsite = (9.27 x 10^{-8} L/s)(3.28 x 10^{-2} s/m^3)(6.1 x 10^8)(1 m^3/10^3 L) = 1.8 x 10^{-3}

Offsite = (9.27 x 10^{-8} L/s)(2.22 x 10^{-5} s/m^3)(3.4 x 10^9)(1 m^3/10^3 L) = 7.0 x 10^{-6}.

where:

Q = 5.56 x 10^{-6} (L)
χ/Q' (radiological) = 3.28 x 10^{-2} (s/m^3)
BR = 3.33 x 10^{-4} (m^3/s)
ULD = 7.7 x 10^3 (Sv/L)
Q' = 9.27 x 10^{-8} (L/s)
SOF = 6.1 x 10^8 (onsite) and 3.4 x 10^9 (offsite)
χ/Q' (toxicological) = 3.28 x 10^{-2} (s/m^3) onsite and = 2.22 x 10^{-5} (s/m^3) offsite.

B3.2 INITIAL RELEASE OF SUSPENDED AEROSOLS FROM TANK FAILURE

The initial spill from the evaporator vessel is modeled as a spill of liquid on to a hard surface from some height. To determine the respirable material from the splash/splatter, solve Equation 1a, assuming 300 gal of waste in the evaporator (i.e., 50% more than calculated in RPP-7277):

$$Q = 300 \text{ gal} \times 3.79 \text{ L/gal} \times 2.7 \times 10^{-6} \times 0.7 = 2.1 \times 10^{-3} \text{ L}.$$

This is the amount assumed for the release from splash/splatter including the RF of 0.7. For toxicological consequences, the amount is averaged over 1 min (i.e., divide by 60 sec [Q' = 3.6 x 10^{-5} L/s]).

The radiological doses and SOFs for the initial release of suspended aerosols component of the tank failure accident without controls were calculated as follows:

Onsite dose: *Inhalation* ➔ *(Q)(χ/Q')(BR)(ULD_{inh})*

= (2.1 x 10^{-3} L)(3.28 x 10^{-2} s/m^3)(3.33 x 10^{-4} m^3/s)(7.7 x 10^3 Sv/L)

= 1.8 x 10^{-4} Sv (0.018 rem).

Onsite SOF: *SOF = Q' x (χ/Q') x USOF*

➔ (3.6 x 10^{-5} L/s)(3.28 x 10^{-2} s/m^3)(6.1 x 10^8) (1 m^3/10^3 L) = 0.72

Offsite SOF: $SOF = Q' \times (\chi/Q') \times USOF$

➔ $(3.6 \times 10^{-5}\ L/s)(2.22 \times 10^{-5}\ s/m^3)(3.4 \times 10^9)\ (1\ m^3/10^3\ L) = 2.7 \times 10^{-3}$.

where:

$Q = 2.1 \times 10^{-3}$ (L)
χ/Q' *(radiological)* $= 3.28 \times 10^{-2}$ (s/m^3)
$BR = 3.33 \times 10^{-4}$ (m^3/s)
$ULD = 7.7 \times 10^3$ (Sv/L)
$Q' = 3.6 \times 10^{-5}$ (L/s)
$SOF = 6.1 \times 10^8$ (onsite) and 3.4×10^9 (offsite)
χ/Q' *(toxicological)* $= 3.28 \times 10^{-2}$ (s/m^3) onsite and $= 2.22 \times 10^{-5}$ (s/m^3) offsite.

B3.3 CONTINUOUS RELEASE FROM MATERIAL SPILLED ON FLOOR

After the initial energetic release of aerosol, the release rate from the pool of material inside the facility will fall to a constant level. Applying the release rate 4×10^{-6}/hr (1.1×10^{-9}/sec) to the equivalent evaporator vessel inventory (300 gal) gives a constant release rate of 8.8×10^{-7} L/s. The corresponding 2-hr radiological release (7.2×10^3 sec) to the onsite receptor is 6.3×10^{-3} L.

$$Q = 300\ gal \times 3.79\ L/gal \times 1.1 \times 10^{-9}/sec \times 0.7 = 8.8 \times 10^{-7}\ L/sec.$$

Because the toxicological exposure is rate dependent and the highest rate occurs at the beginning of the accident (the first minute), toxicological calculations are not done for the long-term exposure that would result from entrainment.

The resulting radiological doses for the continuous release from the floor-spill component of the tank failure caused by a building or roof collapse accident without controls were calculated as follows:

Onsite dose (2-hr): *Inhalation* ➔ $(Q)(\chi/Q')(BR)(ULD_{inh})$

$= (6.3 \times 10^{-3}\ L)(5.58 \times 10^{-3}\ s/m^3)(3.33 \times 10^{-4}\ m^3/s)(7.7 \times 10^3\ Sv/L)$

$= 9.1 \times 10^{-5}$ Sv (0.009 rem).

B4.0 SUMMARY

The total consequences for the tank failure caused by a building or roof collapse accident are the sum of the consequences of the three component releases: (1) aerosols suspended by the evaporator vessel rupture (Section B3.2); (2) the continuous release from the material spilled onto the floor of the room (Section B.3.3); and (3) the release from the failed filters in the exhaust system (Section B3.1). Note that the peak release rates from the initial aerosol release and the filter failure occur at the same time in the first minute of the accident and so are directly

additive (along with the constant release rate from the spill). The resulting totals are as follows for the tank failure caused by a building or roof collapse without controls:

Onsite dose: *Sections B3.2 + B3.3 + B3.1*

➔ 1.8×10^{-4} Sv + 9.1×10^{-5} Sv + 4.7×10^{-7} Sv

= 2.7×10^{-4} Sv (0.027 rem = 27 mrem).

Onsite SOF: *Sections B3.2 + B3.1*

➔ $7.2 \times 10^{-1} + 1.8 \times 10^{-3} = 7.2 \times 10^{-1}$

Offsite SOF: *Sections B3.2 + B3.1*

➔ $2.7 \times 10^{-3} + 7.0 \times 10^{-6} = 2.7 \times 10^{-3}$.

The following tables give the consequences of the 242-T Evaporator building collapse. Both Tables B-5 and B-6 show that onsite radiological consequences are quite low. They also show the onsite and the offsite toxicological consequences are well below guidelines.

Table B-5. Consequences of 242-T Evaporator High-Efficiency Particulate Air Filter Failure Caused by High Pressure Without Controls.

Hazard	Receptor	Dose/exposure	Evaluation guideline (anticipated)
Radiological	Onsite	4.7×10^{-7} Sv	NA
Toxicological	Onsite	1.8×10^{-3}	1
	Offsite	7.0×10^{-6}	1

Note:
NA = not applicable.

Table B-6. Consequences of 242-T Evaporator Vessel Failure Without Controls.

Hazard	Receptor	Dose/exposure	Evaluation guideline (anticipated)
Radiological	Onsite	2.7×10^{-4} Sv	NA
Toxicological	Onsite	7.2×10^{-1}	1
	Offsite	2.7×10^{-3}	1

Note:
NA = not applicable.

B5.0 REFERENCES

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

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ATTACHMENT B1

Fluid Mechanics with Engineering Applications

NINTH EDITION

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Table A.2
Physical properties of air at standard sea-level atmospheric pressure[a]

Temperature T	Density, ρ	Specific weight, γ	Viscosity,[b] μ	Kinematic viscosity,[b] ν
°F	slug/ft³	lb/ft³	10^{-6} lb·s/ft²	10^{-3} ft²/s
−40°F	0.002 940	0.094 60	0.312	0.106
−20°F	0.002 807	0.090 30	0.325	0.116
0°F	0.002 684	0.086 37	0.338	0.126
10°F	0.002 627	0.084 53	0.345	0.131
20°F	0.002 572	0.082 77	0.350	0.136
30°F	0.002 520	0.081 08	0.358	0.142
40°F	0.002 470	0.079 45	0.362	0.146
50°F	0.002 421	0.077 90	0.368	0.152
60°F	0.002 374	0.076 40	0.374	0.158
70°F	0.002 330	0.074 95	0.382	0.164
80°F	0.002 286	0.073 57	0.385	0.169
90°F	0.002 245	0.072 23	0.390	0.174
100°F	0.002 205	0.070 94	0.396	0.180
120°F	0.002 129	0.068 49	0.407	0.189
140°F	0.002 058	0.066 20	0.414	0.201
160°F	0.001 991	0.064 07	0.422	0.212
180°F	0.001 929	0.062 06	0.434	0.225
200°F	0.001 871	0.060 18	0.449	0.240
250°F	0.001 739	0.055 94	0.487	0.280
°C	kg/m³	N/m³	10^{-6} N·s/m²	10^{-6} m²/s
−40°C	1.515	14.86	14.9	9.8
−20°C	1.395	13.68	16.1	11.5
0°C	1.293	12.68	17.1	13.2
10°C	1.248	12.24	17.6	14.1
20°C	1.205	11.82	18.1	15.0
30°C	1.165	11.43	18.6	16.0
40°C	1.128	11.06	19.0	16.8
60°C	1.060	10.40	20.0	18.7
80°C	1.000	9.81	20.9	20.9
100°C	0.946	9.28	21.8	23.1
200°C	0.747	7.33	25.8	34.5

[a] In these tables, if (for example, at −40°F) μ is given as 0.312 and the units are 10^{-6} lb·s/ft² then $\mu = 0.312 \times 10^{-6}$ lb·s/ft².
[b] For viscosity, see also Figs. 2.3 and 2.4.

APPENDIX C

PEER REVIEW CHECKLIST

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APPENDIX C

PEER REVIEW CHECKLIST

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: RPP-13175, *Technical Basis Document for the Above-Ground Tank Failure Representative Accident and Associated Represented Hazardous Conditions*

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

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. [No codes used]
[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)* [No derivations]
[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. [None used]
[ ]	[ ]	[x]	16. Software output is consistent with the input and with the results reported in the document reviewed. [None used]
[ ]	[ ]	[x]	17. Software verification and validation are addressed adequately. *(ORP QAPP criterion 2.6)* [None used]
[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.
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[x]	[ ]	[ ]	31. All figure, table, and section callouts are correct.
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D.M. Carson 25Feb03
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Yes	No	NA*	
[ ]	[ ]	[X]	1. Previous reviews are complete and cover the analysis, up to the scope of this review, with no gaps.
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[ ]	[ ]	[X]	19. Safety margins are consistent with good engineering practices.
[ ]	[ ]	[X]	20. Conclusions are consistent with analytical results and applicable limits.

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NA check for those items not responsibility of tech editor.

Laurie L. Kraemer Laurie L. Kraemer 3/17/03

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