JUL 2 5 1996 (21) Sta. 15

ENGINEERING DATA TRANSMITTAL

1. EDT 602622

2. To: (Receiving Organization) TWRS SAR Engineering	3. From: (Originating Organization) TWRS SAR Engineering	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: 8M100	6. Cog. Engr.: G. W. Ryan	7. Purchase Order No.: N/A
8. Originator Remarks: The attached document is being submitted for approval and release.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: TWRS
11. Receiver Remarks: N/A		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: 7/23/96

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	WHC-SD-WM-CN-044	N/A	0	Calculation Notes That Support Accident Scenario and Consequence Development for the Steam Intrusion From Interfacing Systems Accident.	N/A	1,2	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	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1	1	Cog.Eng. G. W. Ryan	[signature]	7/23/96	A3-37						
1	1	Cog. Mgr. D. S. Leach	[signature]		A3-34						
		QA - n/a									
		Safety - n/a									
		Env. - n/a									
1	1	Tech. Peer Review - B. D. Board	[signature]	7/23/96	A3-37						

18.	19.	20.	21. DOE APPROVAL (if required) Ctrl. No.
G. W. Ryan [signature] 7/23/96 Signature of EDT Originator / Date	N/A Authorized Representative for Receiving Organization / Date	D. S. Leach [signature] 7/24/96 Cognizant Manager / Date	[] Approved [] Approved w/comments [] Disapproved w/comments

Calculation Notes That Support Accident Scenario and Consequence Development for the Steam Intrusion From Interfacing Systems Accident

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U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 602622 UC: 510
Org Code: 8M100 Charge Code: N1FC3
B&R Code: EW3120071 Total Pages: 59

Key Words: pipe, pipeline, piping, steam, steam jet, tank farms, TWRS

Abstract: This document supports the development and presentation of the following accident scenario in the TWRS Final Safety Analysis Report:

Steam Intrusion From Interfacing Systems.

The calculations needed to quantify the risk associated with this accident scenario are included within.

Karen L. Noland 7/25/96
Release Approval Date

JUL 25 1996
DATE: HANFORD
STA: 15 RELEASE ID: 21
Release Stamp

Approved for Public Release

CALCULATION NOTES THAT SUPPORT ACCIDENT SCENARIO AND CONSEQUENCE DEVELOPMENT FOR THE STEAM INTRUSION FROM INTERFACING SYSTEMS ACCIDENT

REVISION 0

Tank Waste Remediation System Final Safety Analysis Report Project
Safety Analysis & Nuclear Engineering

July 1996

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LIST OF TERMS

cfm	cubic feet per minute
FSAR	final safety analysis report
HEDOP	Hanford Environmental Dose Overview Panel
rem	radiation effective man
DST	double-shell tank
PFP	Plutonium Finishing Plant
PUREX	Plutonium-Uranium Extraction Plant
SST	single-shell tank
Sv	sievert
TWRS	Tank Waste Remediation System
WHC	Westinghouse Hanford Company

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CALCULATION NOTES THAT SUPPORT ACCIDENT SCENARIO AND CONSEQUENCE DEVELOPMENT FOR THE STEAM INTRUSION FROM INTERFACING SYSTEMS ACCIDENT

1.0 INTRODUCTION AND PURPOSE

This document supports the development and presentation of the following accident scenario in the TWRS Final Safety Analysis Report (FSAR):

Steam Intrusion From Interfacing Systems.

The calculations needed to quantify the risk associated with this accident scenario are included in the following sections to aid in the understanding of this accident scenario.

Information validation forms citing assumptions that were approved for use specifically in this analysis are included in Appendix A. Copies of these forms are also on file with TWRS Project Files.

Calculations performed in this document, in general, are expressed in traditional (English) units to aid understanding of the accident scenario and related parameters.

1.1 ACCIDENT SCENARIO DESCRIPTION

The hazard analysis performed for the tank farms identified operations at interfacing facilities or systems that may impact tank farm operations. This document investigates steam jet transfers from interfacing facilities. Potential accident causes and conditions relating to steam jet waste transfers are documented in Appendix B.

It is postulated that the introduction of raw steam (at the end of a waste transfer) into a waste storage tank may increase the tank headspace pressure and result in an aerosol release through unfiltered pathways (e.g., cover blocks, and capped risers). Additionally, if the differential pressure in the tank is shown to be approximately 10" water gauge, HEPA filter rupture is considered to occur and the quantity of waste from a HEPA filter rupture should be added to the inventory released from the headspace air. An accident scenario such as this may potentially result in significant onsite consequences.

Interfacing facilities or systems that could potentially impact tank farms by the use of a steam jet include Z-Plant (PFP), 222-S Laboratory, 242-A Evaporator, PUREX, and T-Plant. The 244-AR Vault is not considered an interfacing facility (since it is a TWRS facility) but the potential flowrate of steam from this facility to tank farms was considered to be bounding in this analysis (see *Assumptions*, Section 1.3). This is considered appropriate since steam has not been physically blanked-off to this facility and future transfers of waste out of this facility will most likely be initiated by the steam jet transfer method. Performing the analysis in this manner allows maximum flexibility in future operations.

In the scenario analyzed, a liquid waste transfer to a double-shell tank is initiated from a process facility (e.g., the 242-A Evaporator) using a steam jet as the motive force to move the liquid. After the waste has been transferred, the steam jet is not shut off (as a result of operator error or equipment failure) and pure steam is routed to the headspace of the receiving tank. It is assumed that 90 psig saturated steam is exhausted into the headspace of a full double-shell tank at a flow rate of 2,400 lb_m/hr.

It is understood that in order to send raw steam to the tank from a steam jet transfer, a significant period of time may be needed to heat up the transfer pipe to a temperature that would allow steam to be exhausted into the headspace. Until the transfer pipe is thermally heated to support steam flow, the steam is expected to condense in the line and only water would reach the tank. This condensation is expected to scrub the transfer line so that when steam reaches the headspace it is not contaminated. In the scenario analyzed it is assumed that this time period has lapsed and steam is being exhausted into the tank headspace. The time period discussed has not been calculated since it is situation specific and at a minimum is a function of initial pipe temperature, soil temperature, and length of pipe involved.

As a second part of this accident scenario, the tank dome is assumed to be filled with steam. After the discovery of the steam leak, the steam source is shut-off and the steam in the headspace condenses to water.

Due to the subsequent condensation of steam in the headspace it is important to know what the required inflow to the tank would need to be to not create a vacuum and possibly cause damage to the tank structure. This analysis for the double-shell tank scenario is provided.

1.2 ACCIDENT FREQUENCY DEVELOPMENT

The prior operational history of the tank farms was the single factor considered when a frequency of *anticipated* was qualitatively assigned to this accident scenario. Although no written documentation of previous incidents could be located, prior operational history has shown that a scenario such as this has occurred and is still possible today (due to the use of steam jets for transferring waste).

The frequency of this accident will diminish as the use of steam jets from process facilities is further limited due to ongoing and future decontamination and decommissioning activities.

The consequences associated with this accident scenario are compared to the risk acceptance guidelines for *anticipated* accidents as provided in WHC-CM-4-46, Rev. 1.

1.3 ASSUMPTIONS

The following assumptions are considered in the analysis of this accident scenario:

A The saturated steam in this accident scenario is assumed to behave as an ideal gas, so ideal gas relationships hold (i.e., $PV=nR^*T$).

B The injection of steam into the tank headspace is conservatively assumed to be adiabatic (i.e., no heat transfer to the tank walls or waste surface).

C Saturated steam is injected into the tank headspace (not into the waste.)

D The steam introduced into the headspace mixes perfectly with the headspace air.

E The saturated steam flow rate introduced into the tank headspace is 2,400 lbm/hr (0.667 lb_m/sec). This is the steam flow rate associated with a steam jet waste transfer from the 244-AR Vault to the tank farms and is considered to bound steam jet transfers from Z-Plant (PFP), 222-S Laboratory, 242-A Evaporator, PUREX, and T-Plant. These are all the known locations (i.e., interfacing facilities or systems) that have the ability to send steam to the tanks (both double-shell and DCRTs).

This corresponds to a molar flow rate of:

$$n_{steam} = m/MW_{steam}$$

$$= (0.667\ lb_m/sec)/(18\ lb_m/lbmole) = 0.037\ lbmole/sec$$

In 10 seconds, n_{steam} = 0.37 lbmole.

Higher flow rates may be possible, but will only serve to pressurize the headspace faster than the scenario analyzed.

F The saturated steam pressure is 90 psig (~105 psia).

Steam is generated by powerhouses in the 200 East and 200 West Areas and exits at a nominal stagnation pressure of 225 psig. Each facility using process steam has the required equipment (pressure reducing valves, etc.) to ensure that the steam used for a particular process is at the correct pressure (e.g., 90 psig). The use of a higher steam pressure in this analysis would only serve to heat up the headspace air faster (the enthalpy of 225 psig steam is slightly higher than 90 psig steam) and ultimately pressurize the tank faster.

G The saturated steam is introduced into a full double-shell tank with the available headspace modelled as a hemisphere with a radius of 37.5 ft. This is considered a conservative geometry since it slightly overestimates the available steam expansion volume (and ultimately, the condensation surface area). The headspace volume is calculated here:

$$V_{sphere} \approx 4.189 \bullet r^3$$

$$V_{hemisphere} \approx [4.189 \bullet (37.5\ ft)^3]/2$$

$$V_{HS} = V_{hemisphere} \approx 1.10 \times 10^5\ ft^3$$

H The headspace air temperature (T_{HS}) is assumed to be initially at 150 °F (610 °R).

I The double-shell tank is assumed to be passively ventilated (i.e., ventilation system is shutdown) with HEPA filters installed in the ventilation system.

J Initial pressure inside tank headspace (P_{HS}) is atmospheric at 14.7 psia.

K To obtain the value of the flow coefficient for the amount of air that will leave the tank through the unfiltered in-leakage pathways the following equation is used (modified Darcy equation):

$$W_{vent} = k\sqrt{\Delta P}$$

$$k = \frac{W_{vent}}{\sqrt{\Delta P_{norm}}}$$

$$\text{where} \quad W_{vent} = 100\ cfm$$

$$\Delta P_{norm} = 2\ in.\ WG$$

$$k = (100\ ft^3/min)/[(2\ in\ WG)(0.0361\ lb/in^3\ WG)(144\ in^2/ft^2)]^{0.5}$$

$$k = 31.01\ ft^4/lb^{0.5}\text{-}min\ (0.517\ ft^4/lb^{0.5}\text{-}sec)$$

L No credit is taken for flow out a ventilation duct pathway during the pressurization.

M For air (values assumed to be constant):

$\rho_{air@150°F} = 0.065275\ lb/ft^3$

$c_v = 0.1714\ BTU/lb_m\text{-}°F$

$MW = 29\ lb_m/lbmole$

For steam (values assumed to be constant):

$\rho_{steam@14.7\ psia} = 0.0373\ lb/ft^3$

$c_v = 0.36\ BTU/lb_m\text{-}°F$

$MW = 18\ lb_m/lbmole$

The values for the density and specific heat of air and the specific heat of steam will decrease with increasing temperature, so assuming that these remain constant as the headspace temperature increases is a conservative assumption.

N Moles of air initially in the headspace:

$n_{air} = (\rho_{air@150°F})(V_{HS})/MW_{air}$

where $V_{HS} = 1.10 \times 10^5\ ft^3$

$MW_{air} = 29\ lb_m/lbmole$

$n_{air}(0) = [(0.065275\ lb/ft^3)(1.10 \times 10^5\ ft^3)]/29\ lb_m/lbmole$

$n_{air}(0) = 2.4759 \times 10^2\ lbmoles$

O Standard steam tables are used to find enthalpies.

$h_{g\ @90\ psig\ (\sim 105\ psia)} = 1188.1\ BTU/lb_m$ (interpolated)

$h_{g\ @14.7\ psia} = 1150.4\ BTU/lb_m$

$h_{fg\ @14.7\ psia} = 970.3\ BTU/lb_m$

P A constant heat addition from the steam is assumed, calculated as shown:

$$\Delta q_{released\ from\ steam}(t) = m_{steam}(h_{g\ @90\ psig\ (\sim 105\ psia)} - h_{g\ @14.7\ psia})$$

$$\Delta q_{released\ from\ steam}(t) = (0.667\ lb_m/s)(1188.1\ Btu/lb_m - 1150.4\ Btu/lb_m)$$

$$\Delta q_{released\ from\ steam}(t) = 25.15\ Btu/s$$

In 10 seconds, $\Delta Q_{released\ from\ steam} = 251.5\ Btu$

Q The heat released from the steam is assumed to be absorbed by the headspace constituents. Initially, only air is present in the headspace but after first time interval both air and steam are present in the headspace.

$$Q_{released\ from\ steam}(t) = Q_{absorbed\ by\ headspace\ constituents}(t)$$

To calculate the temperature of the headspace constituents after each time interval heat addition, the following equation is developed:

$$\sum \Delta Q_{added\ in\ previous\ intervals} + \Delta Q_{absorbed\ by\ headspace\ constituents} =$$

$$[m_{air}(t) \cdot c_{v\,air} \cdot \Delta T_{HS}(t)][1-y(t)] + [m_{steam}(t) \cdot c_{v\,steam} \cdot \Delta T_{steam}][y(t)]$$

where $y(t)$ = *molar percentage of steam in the headspace*

Understanding that the steam present in the headspace will not be able to absorb any heat introduced by the incoming steam (since $\Delta T_{steam} = 0$), this component is disregarded when calculating ΔT_{HS}.

Solving the equation for ΔT_{HS} gives:

$$\Delta T_{HS}(t) = \frac{\sum Q_{added\ in\ previous\ intervals} + \Delta Q_{absorbed\ by\ HS\ air}(t)}{[m_{air}(t) \cdot c_{v\ air}]\,[(1-y(t))]}$$

$$where\ c_{v\ air} = 0.1714 \frac{Btu}{lb_m\text{-}°F}$$

$$y(t) = molar\ percentage\ of\ steam\ in\ atmosphere$$

R The percentage of steam in the headspace is calculated and tracked at each time interval by the equation:

% Steam in HS (t) = Steam (t) lbmoles/(Air(t) + Steam (t)) lbmoles

S The universal gas constant, R^* = 1545.33 ft-lb_f/lbmole-°R.

1.4 METHODOLOGY AND ANALYSIS TECHNIQUES

Considering the assumptions described in Section 1.3, the steam introduction into the tank headspace is analyzed using the ideal gas law and thermodynamic principles. During each 10 second time interval steam (i.e., mass and energy) is added to the headspace which increases both the temperature and pressure of the tank headspace. At each interval, the new temperature and pressure of the tank headspace is calculated to determine the amount of heat and headspace constituents (air and steam) that are vented through unfiltered pathways.

Analysis starts with the initial headspace conditions.

At t = 0:

$T_{HS}(0)$ = 150°F

$P_{HS}(0)$ = 14.7 psia

$n(0) = n_{air}(0) + n_{steam}(0)$

$= 2.4759 \times 10^2$ lbmoles + 0 lbmoles

At t = 10 sec (time elapsed, 10 seconds), reference Table C-1 in Appendix C, the process of analysis can be described in the following 10 steps:

Step 1: Determine the lbmoles of steam that have been added to the tank headspace.

$n_{steam}(10)$ = 0.37 lbmoles

Step 2: Calculate the total lbmoles present in the headspace after this time interval.

$$n_{total}(10) = 2.4759 \times 10^2 \text{ lbmoles} + 0.37 \text{ lbmoles}$$

$$= 2.4796 \times 10^2 \text{ lbmoles}$$

Step 3: Determine the percentage of steam in the tank headspace (the percentage of air in the headspace can be found after the steam value is known).

% Steam in HS (10) = Steam (10) lbmoles /[Air(t) + Steam (t)] lbmoles

% Steam in HS (10) = 0.37 lbmoles/(2.4796 x 10^2 lbmoles)

% Steam in HS (10) = 1.4922 x 10^{-3} (0.149 %)

% Air in HS (10) = 99.85 %

Step 4: Determine the amount of heat added to the headspace during this time interval.

$\Delta Q_{released\ from\ steam}(10)$ = 251.5 BTU.

Since

$$\sum \Delta Q_{released\ from\ steam}(t) = \sum \Delta Q_{absorbed\ by\ headspace\ constituents}(t)$$

$$\sum \Delta Q_{released\ from\ steam}(t) = \sum \Delta Q_{absorbed\ by\ headspace\ constituents}(t) = 251.5\ BTU$$

Step 5: Determine the temperature difference and new temperature in the tank headspace as a result of the heat addition from the steam.

$$\Delta T_{HS}(t) = \frac{\sum Q_{added\ in\ previous\ intervals} + \Delta Q_{absorbed\ by\ HS\ air}(t)}{[m_{air}(t) \cdot c_{v\ air}]\,[(1-y(t))]}$$

$$where\ c_{v\ air} = 0.1714 \frac{Btu}{lb_m\text{-}^\circ F}$$

$$y(t) = molar\ percentage\ of\ steam\ in\ atmosphere$$

$\Delta T_{HS}(10)$ = (0 + 251.5 BTU)/[(2.4759 x 10^2 lbmoles•29 lb_m/lbmoles) (0.1714 BTU/lb_m-°F)(0.9985)]

$\Delta T_{HS}(10)$ = 0.20 °F

New headspace temperature is found from:

$$T_{HS}(t) = T_{HS\ initial} + \int_0^t \Delta T_{HS}(t)$$

$$where\ T_{HS\ initial} = 150\ ^\circ F$$

$T_{HS}(10)$ = 150.20 °F

Step 6: Determine the new pressure in the headspace ($P_{HS}(10)$) using the ideal gas equation:

$$P\,V = n\,R^*T$$

$$P(t)_{HS} = \frac{[n_{air}(t) + n_{steam}(t)]\ R^*\ T_{HS}(t)}{V_{headspace}}$$

$P_{HS}(10)$ = (2.4796 x 10^2 lbmoles)(1545.33 ft-lb_f/lbmole-°R)(150.20+460 °R)/ [1.10 x 10^5 ft^3]

$P_{HS}(10)$ = 2.126 x 10^3 lb/ft^2 (14.76 lb/in^2)

Step 7: Determine the unfiltered flow out of the tank through the in-leakage pathways, using the equation shown in the assumptions section.

$$W(t) = [k\sqrt{\Delta P(t)}]\ \Delta t$$

$$w(t) = [k\sqrt{(P_{HS}(t) - P_{HS\ initial})\ (144\ in^2/ft^2)}] \bullet 10\ sec$$

$$where\ \ k = 0.517\ \frac{ft^4}{lb^{0.5}\text{-sec}}$$

$$= [(0.517\ ft^4/lb^{0.5}sec) \bullet [(14.76\ psia - 14.7\ psia) \bullet 144\ in^2/ft^2)^{0.5}] \bullet 10\ sec$$

$$W(10) = 15.20\ ft^3$$

Roundoff error in the calculation of $P_{HS}(10)$, as shown here, produces a value slightly smaller than the value shown in Table C-1 [$W(10) = 15.39\ ft^3$].

Step 8: Using the percentages of steam and air in the headspace, the amount of each can be determined from the vented flow.

$$\Delta n_{steam}(t) = \frac{[W(t)]\ [y(t)]\ [\rho_{steam}]}{MW_{steam}}$$

$$where\ \rho_{steam} = 0.0373\ \frac{lb}{ft^3}$$

$$MW_{steam} = 18\ \frac{lb_m}{lbmole}$$

$y(t)$ = *molar percentage of steam in headspace*

$$= (15.39\ ft^3 \bullet 1.4922 \times 10^{-3} \bullet 0.0373\ lb_m/ft^3)/(18\ lb_m/lbmoles)$$

$$= 4.76 \times 10^{-5}\ \text{lbmoles steam released}$$

By the same method, the remaining flow is made up of air.

$$\Delta n_{air}(t) = \frac{[W(t)]\,[1-y(t)]\,[\rho_{air}]}{MW_{air}}$$

$$where\ \rho_{air} = 0.065275 \frac{lb}{ft^3}$$

$$MW_{air} = \frac{29\, lb_m}{lbmole}$$

$$y(t) = molar\ percentage\ of\ steam\ in\ headspace$$

$= (15.40\ ft^3 \cdot 0.9985 \cdot 0.065275\ lb_m/ft^3)/(29\ lb_m/lbmoles)$

$= 3.46 \times 10^{-2}$ lbmoles air released

Step 9: Determine the new molar quantities of both air and steam that are present in the tank headspace at the start of the next time interval.

The quantity of air remaining in the headspace is the quantity that was in the headspace minus the amount that escaped through the unfiltered pathways.

$$n_{air}(t + \Delta t) = n_{air}(t) - \Delta n_{air}(t)$$

$$where\ n_{air}(0) = 2.4759 \times 10^2\ lbmoles$$

For this interval,

$$n_{air}(t + \Delta t) = (2.4759 \times 10^2 - 0.0346)\, lbmoles$$

$$n_{air}(t + \Delta t) = 2.4756 \times 10^2\ lbmoles$$

Similarly for steam,

$$n_{steam}(t + \Delta t) = \sum n_{steam}(t) - \Delta n_{steam}(t)$$

$$where\ n_{steam}(0) = 0\ lbmoles$$

For this interval,

$$n_{steam}(t + \Delta t) = [(0 + 0.37) - 4.76 \times 10^{-5}]\ lbmoles$$

$$n_{steam}(t + \Delta t) = 0.37\ lbmoles$$

Step 10: Determine the amount of heat vented with the flow out of the tank headspace.

$$Q = mc\Delta T$$

$$\Delta Q_{vented}(t) = (\Delta n_{air}(t) \cdot MW_{air} \cdot c_{v\,air} + \Delta n_{steam}(t) \cdot MW_{steam} \cdot c_{v\,steam}) \cdot [T_{HS}(t) - T_{HS\,initial}]$$

$$\Delta Q_{vented}(10) = [(3.46 \times 10^{-2}\ \text{lbmoles} \bullet 29\ \text{lb}_m/\text{lbmole} \bullet 0.1714\ \text{BTU/lb}_m\text{-°F}) + (4.76 \times 10^{-5}\ \text{lbmoles} \bullet 18\ \text{lb}_m/\text{lbmole} \bullet 0.36\ \text{BTU/lb}_m\text{-°F})] \bullet (150.20-150\text{°F})$$

$$\Delta Q_{vented}(10) = 3.45 \times 10^{-2}\ \text{BTU}$$

Each 10 second time interval is analyzed in a similar manner. This analysis is documented in Table C-1 of Appendix C, with each column described.

1.4.1 Analysis Results

The analysis (Table C-1 of Appendix C) shows that at the assumed steam parameters and tank conditions, pressurization of the tank headspace is possible. As shown in Table C-1, by the time that the headspace will not support additional steam ($T_{HS} \approx 212$ °F) the pressure in the dome increases to approximately 17 psia (~64 inches water gauge). This is sufficient pressure to fail the HEPA filters that are in the shutdown ventilation system.

After the HEPA filters fail, the steam flow into the tank is assumed to continue until the headspace is filled with steam. The pressure in the headspace after the HEPA filters fail is assumed to equalize with the outside environment to a pressure slightly above atmospheric. A value for the equalized pressure is not calculated but assumed to be 15.0 psia.

After the discovery of tank conditions (steam filled headspace), the steam supply is shut-off and the steam in the headspace condenses to water. Due to the condensation of steam in the headspace, a vacuum in the tank will be created. The peak vacuum in the headspace is analyzed by finding out how much steam is present in the headspace immediately after condensation starts to occur.

Entropy changes are used to determine the quantity (and quality) of steam that remains after condensation starts. This method is used in this analysis since the process being analyzed is considered similar to a power cycle process of either steam being expanded through a turbine or being condensed in a condenser.

In this portion of the accident scenario, the tank atmospheric conditions are conservatively assumed to be at 65 °F. Higher headspace temperatures will result in less condensation (and less vacuum).

The following values are obtained from standard steam tables:

$s_{g@212\ °F} = 1.7566\ BTU/lb_m\text{-}°R$

$s_{f@65\ °F} = 0.065\ BTU/lb_m\text{-}°R$

$s_{fg@65\ °F} = 2.01475\ BTU/lb_m\text{-}°R$

Quantity (and quality) of the steam is found by:

$x = (s_{g@212\ °F} - s_{f@65\ °F})/s_{fg@65\ °F}$

x = 0.83961 (84% steam, 16% water)

If, prior to condensation, the mass of steam in the headspace is assumed to be equal to 1 (i.e., $m_s = 1$), then the mass of steam after condensation is $m_{s'} = 0.84$.

From the ideal gas law,

$$P_1/P_2 = m_s/m_{s'}$$

P_1 = 15.0 psia, as discussed above.

P_2, the pressure (actually a vacuum) after condensation starts is calculated to be 12.6 psia. This vacuum is not expected to cause damage to the tank since it is not a closed system and equalization to atmospheric conditions should be easily achievable. Information presented in Marusich (1996) shows that the dome can withstand vacuums of up to -5 psig (in this case, P_2 could safely approach 10 psia). It is known from the pressurization portion of the accident that the ventilation pathway is open and the unfiltered in-leakage pathways are still available to equalize the pressure.

An alternate analysis is provided in Appendix E that treats the steam condensation as a heat conduction problem. The required air inflow to the tank is calculated be approximately 273 cfm to prevent the tank dome from experiencing vacuum conditions (negative pressure). This flow can be easily provided by the available ventilation pathways in the tank involved in the accident or from the inflow from other tanks on the ventilation system which are not affected by this accident. This analysis is consistent with information presented in Marusich (1996) regarding worst case vacuum from cooling of the dome space due to water spraydown of saturated water vapor (i.e., steam).

1.5 RADIOLOGICAL AND TOXICOLOGICAL SOURCE TERM

To conservatively calculate the dose consequences from this accident scenario, the entire volume of contaminated air that was initially present in the headspace ($V_{HS} = 1.10 \times 10^5\ ft^3$ of air) is assumed to be vented directly to the atmosphere without being filtered. This is a conservative value since analysis shows that less than 4% of the headspace air is vented prior to the assumed HEPA filter rupture. Subsequent releases from the headspace volume are assumed to be comprised of "clean" steam and are not quantified or considered in the dose calculation.

The partition fraction used to determine the amount of contamination in the headspace air is 1.0×10^{-8}. This is the value for waste storage tanks under active ventilation and is based on information that has been published in RHO-RE-SA-216, *Characterization of Airborne Radionuclide Particulates in Ventilated Liquid Waste Tanks*. This is considered to be a conservative value since a major assumption in this analysis is that the tank is under passive ventilation, although this value would account for any material that may have been suspended from the waste transfer that occurred prior to the start of this accident scenario. From the same reference, a partition fraction of 1.0×10^{-10} can be inferred for use with passively ventilated tanks.

Calculating the amount of respirable material released from the headspace air:

V_{HS} x (partition fraction) = Amount of respirable material released

$$(1.1 \times 10^{5}\ ft^{3})(1.0 \times 10^{-8}) = 1.1 \times 10^{-3}\ ft^{3}$$

Converting to liters,

$$(1.1 \times 10^{-3}\ ft^{3})(0.028317\ m^{3}/ft^{3}) = 3.1149 \times 10^{-5}\ m^{3}$$

$$(3.1149 \times 10^{-5}\ m^{3})(1{,}000\ L/m^{3}) = 3.1149 \times 10^{-2}\ L$$

Additionally, since it is possible to pressurize the tank headspace to a point that would rupture contaminated HEPA filters present in the shutdown ventilation system, this quantity is added to the total released. For consistency between various analyses, the values for HEPA filter release amounts are taken from standard information that has been developed specifically for this FSAR effort. Charts that include the information used are included in Appendix D.

The conservative release fraction used to determine the amount of waste released from the HEPA filter rupture is 1.0×10^{-2}. This value is based on information presented in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* and is intended to be applied to HEPA filter media with no enclosure or for which the enclosure has been totally destroyed and the filter media widely scattered and impacted. This is not typically a foreseeable condition in this accident scenario. This value is considered to be conservative for this reason and the fact that the filter media would likely be at least moist (if not soggy) from being exposed to a sizeable steam flow (or very humid atmosphere), allowing less to be released in a rupture event.

The amount of respirable material released from the HEPA filter rupture:

$$9.79 \times 10^{-4}\ L \text{ (Appendix D)}$$

The resulting airborne source term in the accident scenario was determined by adding the fractions released from the vented headspace air and the HEPA filter rupture. This total is:

$$3.1149 \times 10^{-2} \text{ L} + 9.79 \times 10^{-4} \text{ L} = 3.21 \times 10^{-2} \text{ L}$$

It is assumed that the airborne source term both entrained in the headspace and present on the HEPA filters is made up of DST liquids. All of the resulting airborne source term is conservatively assumed to be released in a short period time such that this is considered an acute release. Appropriate dispersion coefficients and breathing rates are applied to develop the radiological consequences (Van Keuren 1996a).

Toxicological consequences are calculated using as a peak release, the respirable amount of waste produced during the HEPA filter rupture. This ensures that toxicological consequences are developed conservatively for both the onsite and offsite receptor.

There are no radiological or toxicological consequences associated with the steam condensation/vacuum portion of the accident scenario.

1.6 CALCULATED RADIOLOGICAL DOSES

The methodology that is used to calculate radiological dose consequences is documented in WHC-SD-WM-SARR-016, Rev. 2, *Tank Waste Compositions and Atmospheric Dispersion Coefficients for use in ASA Consequence Assessments* and WHC-SD-WM-SARR-037, Rev. 0, *Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations.*

1.6.1 Input Data

Unit Liter Doses (ULDs)

The ULDs for this analysis are taken from WHC-SD-WM-SARR-037, Rev. 0, *Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations.*

$ULD_H = 6.1 \times 10^3$ Sv/L (inhalation dose)
$ULD_I = 0.068$ Sv-m^3/s-L (ingestion dose)

Dispersion Coefficients (χ/Q's)

The onsite receptor is chosen to be at a distance of 100 m and the offsite receptor is chosen to be at a distance of 8,760 m to the North. The *Methodology* section of the TWRS FSAR contains additional details concerning the receptor locations.

Onsite - The χ/Q' for the acute release is 3.41×10^{-2} s/m^3 (Van Keuren 1996a).

Offsite - The χ/Q' for the acute release is 2.83×10^{-5} s/m^3 (Van Keuren 1996a).

Breathing Rate (BR)

3.3×10^{-4} m^3/s light activity breathing rate is used to calculate consequences to both the onsite and offsite receptors (Van Keuren 1996a).

Amount of Material Released (Q)

$Q = 3.21 \times 10^{-2}$ L.

Using the formula presented on page 4-4 of Van Keuren (1996a) and modifications for a 24 hour ingestion dose to the offsite receptor from Cowley et al. (1996), the radiological dose consequences can be calculated.

1.6.2 Calculations

Onsite Consequences:

$$D\ (Sv) = Q\ (L) \times \frac{X}{Q'}\ (s/m^3) \times R\ [m^3/s] \times ULD_H[Sv/L]$$

Inhalation Dose:

$$D\ (Sv) = (3.21 \times 10^{-2}\ L)(3.41 \times 10^{-2} s/m^3)(3.3 \times 10^{-4}\ m^3/s)(6.1 \times 10^3\ Sv/L)$$

$$D\ (Sv) = 2.2 \times 10^{-3}\ Sv$$

Offsite Consequences:

$$D\ (Sv) = Q\ (L) \times \frac{X}{Q'}\ (s/m^3) \times ((\ R\ [m^3/s] \times ULD_H[Sv/L]) + ULD_I[Sv\text{-}m^3/s\text{-}L])$$

$$D\ (Sv) = (3.21 \times 10^{-2}\ L)(2.83 \times 10^{-5} s/m^3)[(3.3 \times 10^{-4}\ m^3/s)(6.1 \times 10^3\ Sv/L) + 0.068\ Sv\text{-}m^3/s\text{-}L]$$

$$D\ (Sv) = 1.89 \times 10^{-6}\ Sv$$

1.7 CALCULATED TOXICOLOGICAL DOSES

The methodology that is used to calculate toxicological exposure consequences is documented in WHC-SD-WM-SARR-011, Rev. 2, *Toxic Chemical Considerations for Tank Farm Releases.*

1.7.1 Input Data

The probability of this unmitigated accident scenario is anticipated (see Section 1.2) and the waste has the same constituents as DST liquids (Van Keuren [1996b]). This event is considered to be a puff-type release to both the onsite and offsite receptors. Sum-of-fraction values are extracted from Van Keuren (1996b) to determine the toxicological consequences.

Sum-of-Fraction Values from Van Keuren (1996b)

The sum-of-fraction value for the onsite receptor is 2.9×10^3/L.

The sum-of-fraction value for the offsite receptor is 3.4×10^{-2}/L.

Quantity Released

The quantity of material released was calculated previously to be a total of 3.21×10^{-2} L. Conservatively, this total amount is assumed to be released in a puff over a very short period of time (less than 3.5 seconds).

1.7.2 Calculations

By directly multiplying the sum-of-fraction value by the waste release rate, the toxicological consequences can be calculated for both the onsite and offsite receptors.

Onsite - Calculation: $(3.21 \times 10^{-2}\ L)(2.9 \times 10^{3}/L) = 9.3 \times 10^{1}$.

Offsite - Calculation: $(3.21 \times 10^{-2}\ L)(3.4 \times 10^{-2}/L) = 1.1 \times 10^{-3}$.

1.8 RESULTS

1.8.1 Radiological

The onsite radiological dose consequence value (2.2×10^{-3} Sv) is shown to be below the risk guidelines for an anticipated accident (5.0×10^{-3} Sv) as provided in WHC-CM-4-46, Rev. 1.

The offsite radiological dose consequence value (1.9×10^{-6} Sv) is shown to be below the risk guidelines for an anticipated accident (1×10^{-3} Sv) as provided in WHC-CM-4-46, Rev. 1.

1.8.2 Toxicological

As a result of this accident the exposure to the onsite receptor is calculated to be 9.3×10^{1} as a fraction of the risk guidelines. Similarly, the exposure to the offsite receptor is calculated to be 1.1×10^{-3}, as a fraction of the risk guidelines. The value for the offsite receptor is below the risk guidelines (<1), conversely, the value for the onsite receptor exceeds the risk guidelines. This is due mainly to the sudden release of HEPA filter contents during the pressurization of the tank headspace.

1.9 CONCLUSIONS

Analysis of this accident scenario shows that a pressurization of the tank headspace is possible which could result in a total release of the headspace contents along with the contents of ruptured HEPA filters. After the headspace is filled with steam and the steam source is shut-off analysis shows that the vacuum created in the headspace from condensing steam will not reach a level that will cause damage to the tank structure (since it is not a closed system).

The radiological dose consequences for the both the onsite and offsite receptors are below the risk guidelines (Table 1.9-1).

The toxicological exposure consequences show that the value for the offsite receptor is below the risk guidelines. Conversely, the value for the onsite receptor exceeds the risk guidelines. This is due mainly to the sudden release of HEPA filter contents during the pressurization of the tank headspace.

1.10 REFERENCES

Cowley, W. L., 1996, *Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations*, WHC-SD-WM-SARR-037, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Kimura and Lindsey, 1987, *Characterization of Airborne Radionuclide Particulates in Ventilated Liquid Waste Tanks*, Rockwell Hanford Operations, Richland, Washington.

Marusich, R. M., 1996, WHC-SD-WM-CN-051, Rev. 0, *The Effects of Load Drop, Uniform Load and Concentrated Loads on Waste Tanks*, Westinghouse Hanford Company, Richland, Washington.

Van Keuren, J. C., 1996a, WHC-SD-WM-SARR-016, Rev. 2, *Tank Waste Compositions and Atmospheric Dispersion Coefficients for use in ASA Consequence Assessments*, Westinghouse Hanford Company, Richland, Washington.

Van Keuren, J. C., 1996b, WHC-SD-WM-SARR-011, Rev. 2, *Toxicological Chemical Considerations for Tank Farm Releases*, Westinghouse Hanford Company, Richland, Washington.

WHC, 1991, *Safety Analysis Manual*, WHC-CM-4-46, Section 4.0, Rev. 1, November 15, 1991, Westinghouse Hanford Company, Richland, Washington.

Table 1.9-1. Summary Table of Accident Consequences and Frequencies.

Accident	Consequences								Frequency	
	Radiological (Sv)				Toxicological					
	Unmitigated		Mitigated		Unmitigated		Mitigated		Without controls	With controls
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite		
Steam Intrusion From Interfacing Systems	2.2 E-03	1.9 E-06	Not analyzed*		9.3 E+01	1.3 E-03	Not analyzed*		Anticipated	N/A

*A mitigated analysis was not performed because the unmitigated radiological consequences were within the evaluation guidelines.
N/A = not applicable.

APPENDIX A

INFORMATION VALIDATION FORMS

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Information Validation Form

Tracking # IVF-Chapter 3-07

Name of Originator 1	Organization or Team 2	Date 3
Grant W. Ryan (376-5114)	Chapter 3- Accident Analysis- Steam Pressurization	June 25, 1996

Statement of Problem

ACCIDENT SCENARIO DESCRIPTION

A liquid waste transfer to either a double-shell tank or DCRT is initiated from a facility (e.g., 242-A Evaporator, 244-AR Vault, or Z Plant) using a steam jet as the motive force to move the liquid. After the waste has been transferred, the steam jet is not shut off and pure steam is routed to headspace of the receiving tank.

In the scenario analyzed, 90 psig saturated steam is exhausted into the headspace of a full double-shell tank at a flow rate of 2,400 lb_m/hr. The radiological and toxicological dose consequences, if any, associated with the accident scenario are to be calculated.

Calculations will also be performed to determine if a vacuum can be drawn on the double-shell tank after the steam has been shut-off and the steam filled atmosphere condenses to water completely.

ASSUMPTIONS USED FOR PRESSURIZATION PORTION OF SCENARIO

1. The saturated steam is introduced into a full double-shell tank with available headspace modelled as a hemisphere with a radius of 37.5 ft. This is considered a conservative geometry since it slightly overestimates the available steam expansion volume.

2. Headspace air temperature is initially at 150°F.

3. Headspace pressure initially at 14.7 psia.

4. Tank is under passive ventilation during waste transfer (i.e., no active ventilation).

5. Saturated steam flow rate introduced into the tank headspace is 2,400 lbm/hr. This is the flow rate associated with a steam jet transfer from 244-AR Vault to the tank farms and is considered to bound steam jet transfers from Z-Plant (PFP), 222-S Laboratory, 242-A Evaporator, PUREX, and T-Plant. These are all the known locations where steam may access the tanks (both double-shell and DCRTs).

6. Saturated steam pressure is 90 psig (~105 psia).

7. Saturated steam is injected into the headspace (not into the waste.)

ASSUMPTIONS USED FOR VACUUM PORTION OF SCENARIO

1. The tank wall temperature is assumed to be constant at 50°F. This value is lower than the headspace air temperature (i.e., 150°F) assumed in the pressurization portion of the accident scenario to ensure that the situation is modelled conservatively.

EXPLICITLY concur with or deny (by including appropriate documentation) the assumption made above.

REFERENCES

N/A

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<tr><td colspan="6"></td></tr>
<tr><td colspan="3">Alternatives

5 N/A</td><td colspan="3">Consequences to Alternatives

6 N/A</td></tr>
<tr><td colspan="3">Decision Reached

7</td><td colspan="3">Basis for Decision

8</td></tr>
<tr><td colspan="2">Date Requested
9 June 25, 1996</td><td colspan="2">Sent To
10 R. Tucker, Project Files</td><td colspan="2">Date Requested By
11 June 28, 1996 (earlier response would be appreciated)</td></tr>
<tr><td colspan="6">Response #1

12</td></tr>
<tr><td colspan="6">Response #2

13</td></tr>
<tr><td colspan="3">Attachments (List)

14</td><td colspan="3">References (List) 15</td></tr>
<tr><td colspan="3">Responder #1 Name and Signature
16 R.P. TUCKER [signature]</td><td colspan="3">Responder #2 Name and Signature
17</td></tr>
<tr><td colspan="2">POC:</td><td colspan="2">Filed:</td><td colspan="2">Routed:</td></tr>
<tr><td colspan="6">Further Action Required (i.e., RML, Senior Management Attention, etc.)

18</td></tr>
</table>

Information Validation Form

Tracking # IVF-Chapter 3-08

Name of Originator 1	Organization or Team 2	Date 3
Grant W. Ryan (376-5114)	Chapter 3- Accident Analysis- Steam Pressurization	June 28, 1996

Statement of Problem

For the steam pressurization accident, the following information may be used in the analysis:

For tank 241-AW-102, at a ventilation flowrate of 100 cfm a vacuum of 2 inches water gauge is achievable. Size of the vent header for this tank is 12 inches.

~~For DCRT 244-TX, at a ventilation flowrate of 50 cfm for the tank a vacuum of 0.2 inches water gauge is achievable.~~ GT 7/8/96 Size of the vent header for this tank is 4 inches.

EXPLICITLY concur with or deny (by including appropriate documentation) the assumptions made above, to provide a documentable information source.

REFERENCES

This information was obtained from Scott Pierce on Friday, June 28, 1996 at about 10:20 a.m.

4

Alternatives	Consequences to Alternatives
5 N/A	6 N/A

Decision Reached	Basis for Decision
7	8

Date Requested	Sent To	Date Requested By
9 June 28, 1996	10 R. Tucker, Project Files	11 June 28, 1996

Response #1 244-TX DCRT Ventilation system draws air from both the vault and the tank simultaneously. Due to this, it is not possible to measure flow rate from the tank itself. A review of the roundsheets taken on the tank vacuum however shows a normal vacuum of -0.5" (READING TAKEN DAILY.)

12

Response #2

13

Attachments (List)	References (List) 15
14	
Responder #1 Name and Signature	Responder #2 Name and Signature
16 R.P. Tucker [signature]	17

POC: Filed: Routed:

Further Action Required (i.e., RML, Senior Management Attention, etc.)

18

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APPENDIX B

HAZARD ANALYSIS RESULTS FOR INTERFACING FACILITIES THAT USE STEAM JETS

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Table B-1. Hazard Analysis Results for Interfacing Facilities That Use Steam Jets (2 sheets).

ID	Hazardous Condition	Cause	Rep Acc
I-242A-6-CMP-A	Release (steam) of aerosols to the atmosphere through unsealed cracks in the cover blocks due to over pressurization of the receiver tank.	Human error - Steam block valve inadvertently left opened.	32
I-242A-2-CMP-B	Release to the atmosphere through unsealed cracks in the cover blocks due to over pressurization of the receiver tank.	Steam block valves inadvertently opened or left open	32X
I-222S-1-LVL-A	Release (steam) of aerosols and entrained particulates to atmosphere through ventilation due to over pressurization of 244-S-DCRT caused by sending just steam to tank farm.	Human Error - Failing to shut off steam after TK-102 is empty	32X
I-222S-2-PRS-A	Release (steam) of aerosols and particulates to atmosphere through ventilation due to over pressurization of 244-S DCRT caused by sending just steam to tank farm.	Steam reducer valve fails open.	32X
I-PUREX-1-LVL-A	Release of aerosols from 105AW through cracks in the cover block due to pressurizing 105AW from transfer of steam.	Human Error - Failure to shut off steam jet when U-3 is empty.	32X
I-PUREX-3-LVL-A	Release of aerosols from 105AW through cracks in the cover block due to pressurizing 105AW from transfer of steam.	Human Error - Failure to shut off steam jet when U-3 is empty.	32X
I-TPLANT-2-CMP-A	Release (steam) of aerosols and entrained particulates to atmosphere through ventilation due to over pressurization of 244-S-DCRT caused by sending just steam to tank farm.	Human Error - Steam block valve inadvertently opened or failure to close valve when tank 15-1 is low	32X
XS-02-FLOWO2	Release of aerosols and particulate from DCRT ventilation filter due to transfer of steam from PFP steam jet into DCRT headspace	Human error (failure to shut off steam jet at completion of transfer) which causes DCRT ventilation filter failure	32X

Table B-1. Hazard Analysis Results for Interfacing Facilities That Use Steam Jets (2 sheets).

ID	Hazardous Condition	Cause	Rep Acc
I-PFP-2-TMP-B	Release (steam) of aerosols and entrained particulate from 244-TX ventilation system due to saturating HEPAs with steam due to failure of steam reducer which sends higher pressure steam to steam jet, gassing it out and sends steam to 244-TX.	Failure of steam reducer	32X
I-PUREX-2-PRS-A	Release (steam) of aerosols and particulates through cracks in the cover block from the receiver tank due to tank pressurization from sending steam caused by steam reducer failure which gasses out the steam jet and sends just steam.	Steam Reducer fails	32X
I-PUREX-4-PRS-A	Release of aerosols and particulates through cracks in the cover block from the receiver tank due to tank pressurization from sending steam caused by steam reducer failure which gasses out the steam jet and sends just steam.	Steam Reducer fails	32X
XS-03-PRESO5	Release of toxic vapors from DCRT due to increased concentrations in DCRT atmosphere	Transfer of steam from PFP causing evolution of toxic gases due to heating tank	32X

APPENDIX C

TABULATED ANALYSIS RESULTS AND CALCULATIONS

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Table C-1. Tabulated Analysis Results Show That The Headspace Temperature Exceeeds 212 °F in Approximately 4 Minutes with a Corresponding Pressure Approaching 17 psia. (2 Sheets).

END TIME (SEC)	STEAM ADDED (PMOLE)	AIR IN HS (PMOLE)	STEAM IN HS (PMOLE)	% AIR IN HS	% STEAM IN HS	HEAT ADDED TO HS (BTU)	TOTAL HEAT IN HS (BTU)	DELTA TEMP IN HS (F)	TEMP. IN HS (F)	PRESS. IN HS (PSIA)	FLOW OUT OF HS (FT^3)	AIR VENTED (PMOLE)	STEAM VENTED (PMOLE)	HEAT VENTED (BTU)	RUNNING TOTAL OF HS VENTED (FT^3)
0	0	247.59	0.00	100.00	0.0	0.0	0.00	150.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00 0.00
10	0.37	247.59	0.37	99.85	0.15	251.5	251.5	0.20	150.20	14.76	15.39	3.46 E-02	4.76 E-05	0.04	15.39
20	0.37	247.56	0.74	99.70	0.30	502.9	502.9	0.41	150.61	14.79	18.76	4.21 E-02	1.16 E-04	0.09	34.15
30	0.37	247.55	1.11	99.55	0.45	754.4	754.3	0.62	151.23	14.83	22.19	4.97 E-02	2.05 E-04	0.15	56.34
40	0.37	247.55	1.48	99.41	0.59	1005.8	1005.7	0.82	152.05	14.87	25.54	5.72 E-02	3.15 E-04	0.24	81.89
50	0.37	247.54	1.85	99.26	0.74	1257.3	1257.1	1.03	153.08	14.92	28.85	6.44 E-02	4.43 E-04	0.33	110.73
60	0.37	247.53	2.22	99.11	0.89	1508.8	1508.4	1.24	154.32	14.97	32.12	7.17 E-02	5.91 E-04	0.45	142.85
70	0.37	247.52	2.59	98.97	1.03	1760.2	1759.8	1.45	155.76	15.02	35.37	7.88 E-02	7.58 E-04	0.57	178.22
80	0.37	247.52	2.96	98.82	1.18	2011.7	2011.1	1.65	157.42	15.09	38.60	8.59 E-02	9.45 E-04	0.72	216.82
90	0.37	247.51	3.33	98.67	1.33	2263.1	2262.4	1.86	159.28	15.15	41.83	9.29 E-02	1.15 E-03	0.87	258.65
100	0.37	247.50	3.70	98.53	1.47	2514.6	2513.7	2.07	161.36	15.23	45.05	9.99 E-02	1.37 E-03	1.05	303.70
110	0.37	247.49	4.06	98.38	1.62	2766.0	2765.0	2.28	163.64	15.31	48.27	1.07 E-01	1.62 E-03	1.24	351.96
120	0.37	247.49	4.43	98.24	1.76	3017.5	3016.3	2.50	166.14	15.39	51.48	1.14 E-01	1.88 E-03	1.44	403.44
130	0.37	247.48	4.80	98.10	1.90	3269.0	3267.5	2.71	168.84	15.48	54.70	1.21 E-01	2.16 E-03	1.66	458.14
140	0.37	247.47	5.17	97.95	2.05	3520.4	3518.8	2.92	171.76	15.57	57.91	1.28 E-01	2.46 E-03	1.90	516.05
150	0.37	247.47	5.54	97.81	2.19	3771.9	3770.0	3.13	174.90	15.67	61.13	1.35 E-01	2.77 E-03	2.15	577.19
160	0.37	247.46	5.90	97.67	2.33	4023.3	4021.2	3.35	178.24	15.78	64.35	1.41 E-01	3.11 E-03	2.42	641.54
170	0.37	247.45	6.27	97.53	2.47	4274.8	4272.4	3.56	181.81	15.89	67.58	1.48 E-01	3.46 E-03	2.71	709.12
180	0.37	247.45	6.64	97.39	2.61	4526.3	4523.6	3.78	185.58	16.00	70.81	1.55 E-01	3.83 E-03	3.01	779.93
190	0.37	247.44	7.00	97.25	2.75	4777.7	4774.7	3.99	189.57	16.12	74.04	1.62 E-01	4.22 E-03	3.33	853.98
200	0.37	247.43	7.37	97.11	2.89	5029.2	5025.9	4.21	193.78	16.25	77.28	1.69 E-01	4.63 E-03	3.66	931.26

Table C-1. Tabulated Analysis Results Show That The Headspace Temperature Exceeeds 212 °F in Approximately 4 Minutes with a Corresponding Pressure Approaching 17 psia. (2 Sheets).

END TIME (SEC)	STEAM ADDED (PMOLE)	AIR IN HS (PMOLE)	STEAM IN HS (PMOLE)	% AIR IN HS	% STEAM IN HS	HEAT ADDED TO HS (BTU)	TOTAL HEAT IN HS (BTU)	DELTA TEMP IN HS (F)	TEMP. IN HS (F)	PRESS. IN HS (PSIA)	FLOW OUT OF HS (FT^3)	AIR VENTED (PMOLE)	STEAM VENTED (PMOLE)	HEAT VENTED (BTU)	RUNNING TOTAL OF HS VENTED (FT^3)
210	0.37	247.43	7.73	96.97	3.03	5280.6	5277.0	4.42	198.21	16.38	80.53	1.76 E-01	5.06 E-03	4.01	1011.79
220	0.37	247.42	8.10	96.83	3.17	5532.1	5528.1	4.64	202.85	16.52	83.78	1.83 E-01	5.50 E-03	4.38	1095.56
230	0.37	247.41	8.46	96.69	3.31	5783.6	5779.2	4.86	207.71	16.67	87.03	1.89 E-01	5.97 E-03	4.76	1182.60
240	0.37	247.41	8.83	96.55	3.45	6035.0	6030.3	5.08	212.79	16.82	90.29	1.96 E-01	6.45 E-03	5.17	1272.89

See a description of table columns on next page.

A DESCRIPTION OF THE COLUMNS OF THE WORKSHEET:

END TIME (SEC)

Each time interval of 10 seconds is evaluated.

STEAM ADDED (PMOLE[1])

After t = 0, a constant addition of 0.37 lbmoles (in 10 seconds) of steam is added.

AIR IN HS (PMOLE)

The initial lbmoles of air in the headspace at each time interval, after deducting the amount of air vented in the previous time interval. Uses equation:

$$n_{air}(t + \Delta t) = n_{air}(t) - \Delta n_{air}(t)$$

$$where\ n_{air}(0) = 2.4759 \times 10^2\ lbmoles$$

STEAM IN HS (PMOLE)

The amount of steam added in the time interval plus the amount added in the previous time intervals minus the amount of steam vented. Uses equation:

$$n_{steam}(t + \Delta t) = \sum n_{steam}(t) - \Delta n_{steam}(t)$$

$$where\ n_{steam}(0) = 0\ lbmoles$$

% AIR IN HS

At each time interval,

(LBMOLES AIR (t))/(LBMOLES AIR (t) + LBMOLES STEAM (t)) x 100

% STEAM IN HS

At each time interval,

(LBMOLES STEAM (t))/(LBMOLES AIR (t) + LBMOLES STEAM (t)) x 100

---

[1]PMOLE is equivalent to LBMOLE.

HEAT ADDED TO HS (BTU)

The heat added to the headspace in 10 seconds plus the heat added in the previous time steps.

$$\sum Q_{added\ in\ previous\ intervals} + \Delta Q_{absorbed\ by\ HS\ air}(t)$$

TOTAL HEAT IN HS (BTU)

A summation of the total heat added from the *HEAT ADDED TO HS (BTU)* column minus the amount of heat vented.

$$\sum Q_{added\ in\ previous\ intervals} + \Delta Q_{absorbed\ by\ HS\ air}(t) - \Delta Q_{vented}(t)$$

DELTA TEMP IN HS (°F)

The delta T_{HS} calculated after each steam addition to the headspace. Uses equation:

$$\Delta T_{HS}(t) = \frac{\sum Q_{added\ in\ previous\ intervals} + \Delta Q_{absorbed\ by\ HS\ air}(t)}{[m_{air}(t) \cdot c_{v\ air}]\,[(1-y(t))]}$$

$$where\ c_{v\ air} = 0.1714 \frac{Btu}{lb_m\text{-}°F}$$

$$y(t) = molar\ percentage\ of\ steam\ in\ atmosphere$$

TEMP IN HS (°F)

The headspace temperature is the initial temp (150 °F) plus the integrated quantity of all the temperatures. Uses equation:

$$T_{HS}(t) = T_{HS\ initial} + \int_0^t \Delta T_{HS}(t)$$

$$where \quad T_{HS\ initial} = 150\ °F$$

PRESS. IN HS (PSIA)

This column evaluates the time interval pressure due to the steam addition. Uses equation:

$$P V = n R^{*}T$$

$$P(t)_{HS} = \frac{[n_{air}(t) + n_{steam}(t)]\ R^{*}\ T_{HS}(t)}{V_{headspace}}$$

where R^{*} = 1545.33 ft-lb_{f}/lbmole-°R
V_{HS} = 1.10 x 10^{5} ft^{3}
$T_{HS}(t)$ = temperature in degrees Rankine

FLOW OUT OF HS (FT^3)

The quantity of air and steam escaping the tank headspace in each time interval. Uses equation:

$$W(t) = [k\sqrt{\Delta P(t)}]\ \Delta t$$

$$W(t) = [k\sqrt{(P_{HS}(t) - P_{HS\ initial})\ (144\ in^{2}/ft^{2})}\ ] \bullet 10\ sec$$

$$\text{where } k = 0.517 \frac{ft^{4}}{lb^{0.5}\text{-sec}}$$

AIR VENTED (PMOLE)

Calculates the flow of air out of the tank in each time interval. Uses equation:

$$\Delta n_{air}(t) = \frac{[W(t)]\ [1-y(t)]\ [\rho_{air}]}{MW_{air}}$$

$$\text{where } \rho_{air} = 0.065275 \frac{lb}{ft^{3}}$$

$$MW_{air} = \frac{29\ lb_{m}}{lbmole}$$

y(t) = molar percentage of steam in headspace

STEAM VENTED (PMOLE)

Calculates the flow of steam out of the tank in each time interval. Uses equation:

$$\Delta n_{steam}(t) = \frac{[W(t)]\,[y(t)]\,[\rho_{steam}]}{MW_{steam}}$$

$$\text{where } \rho_{steam} = 0.0373\,\frac{lb}{ft^3}$$

$$MW_{steam} = 18\,\frac{lb_m}{lbmole}$$

$$y(t) = \text{molar percentage of steam in headspace}$$

HEAT VENTED (BTU)

Calculates the amount of heat vented in the incremental pressure/temperature increase for each time interval. Uses equation:

$$Q = mc\Delta T$$

$$\Delta Q_{vented}(t) = (\Delta n_{air}(t)\cdot MW_{air}\cdot c_{v\,air} + \Delta n_{steam}(t)\cdot MW_{steam}\cdot c_{v\,steam})$$
$$[T_{HS}(t) - T_{HSinitial}]$$

RUNNING TOTAL OF UNFILTERED HS VENTED (FT^3)

Summary of total (ft^3) headspace atmosphere release after each time interval.

APPENDIX D

PARTITION FRACTION DISCUSSION AND HEPA FILTER RELEASE AMOUNTS

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Development of Headspace Partition Fraction

Radioactive material is carried from the tank waste material into the tank headspace atmosphere through several physical processes. Only a fraction (the partition fraction) of the waste constituents in a tank will migrate to the headspace atmosphere. The partition fraction is the ratio of tank headspace radioactivity concentration to the concentration in that tank's solid or liquid waste, whichever is used as the basis.

Kimura and Lindsey (1987) report on the ratio of activity concentration in tank headspace samples to activity concentration in tank liquid waste material samples taken from DSTs during ALC operation, during waste transfer operations, and during static conditions. The characterization effort focused on cesium because it is prevalent in nearly all of the tank waste analyzed, producing the largest numbers, and is therefore considered bounding. The sample analyses indicated the following:

- ALC operations — Observed ^{137}Cs partition fractions ranged from 1.02×10^{-9} to 2.49×10^{-9}
- Tank waste transfer operations — Observed ^{137}Cs partition fractions ranged from 1.02×10^{-12} to 5.25×10^{-10}
- Static tank waste conditions — Observed ^{137}Cs partition fractions ranged from about 1.00×10^{-13} to 6.9×10^{-11}.

The results indicate the partition fraction for DST and AWF tanks during operations that result in worst-case liquid waste agitation conditions would be bounded by a partition fraction of 10^{-8}, which is the number used in this accident analysis.

For an unagitated tank liquid waste scenario (i.e., long-term passive ventilation), static waste conditions, the above information indicates a partition fraction of about 1×10^{-10}.

References

Kimura and Lindsey, 1987, *Characterization of Airborne Radionuclide Particulates in Ventilated Liquid Waste Tanks*, Rockwell Hanford Operations, Richland, Washington.

WHC-SD-WM-SARR-037					SX, C-106			SSTs with Passive Breather Filters					
	SST Solids	SST Liquids	DST Liquids	AWF Liquids	SST Solids on a 3X3 Array of 24x24x12 Filters			SST Solids on a 24x24x12 Filter			SST Solids on a 12x12x12 Filter		
	(Bq/L)	(Bq/L)	(Bq/L)	(Bq/L)	(Ci)	(Bq)	(L)	(Ci)	(Bq)	(L)	(Ci)	(Bq)	(L)
Co60	4.2E+08	9.5E+06	7.0E+06	7.7E+05									
Sr90	1.6E+12	1.1E+10	4.6E+09	5.6E+09	0.4840	1.8E+10	0.011	0.4840	1.8E+10	0.011	0.4840	1.8E+10	0.011
Y 90	1.6E+12	1.1E+10	4.6E+09	5.6E+09	0.4840	1.8E+10	0.011	0.4840	1.8E+10	0.011	0.4840	1.8E+10	0.011
Cs137	1.0E+11	2.2E+10	5.9E+10	8.8E+10	0.0303	1.1E+09	0.011	0.0303	1.1E+09	0.011	0.0303	1.1E+09	0.011
Eu154	5.8E+09	2.4E+09	4.2E+07	0.0E+00	0.0017	6.3E+07	0.011	0.0017	6.3E+07	0.011	0.0017	6.3E+07	0.011
Np237	3.0E+07	0.0E+00	2.3E+05	9.2E+04									
Pu238	1.9E+08	9.2E+04	1.8E+06	2.8E+03									
Pu239	4.4E+08	3.6E+07	7.7E+06	1.2E+06									
Pu241	3.2E+09	2.6E+08	1.8E+07	3.4E+05									
Am241	2.3E+08	4.2E+07	3.4E+07	1.1E+06									
Cm244	2.3E+06	4.2E+05	1.2E+05	1.1E+04									
				TOTAL	1.00	3.7E+10	0.011	1.00	3.7E+10	0.011	1.00	3.7E+10	0.011
MicroShield Calculated Dose for HEPA (mSv/hr)							0.257			1.77			4.75
HEPA Operating Limit (mSv/hr)							2			2			2
OL/CD							7.782101			1.129944			0.421053
HEPA Loading to give OL (L)							0.087245			0.012668			0.00472
1% Release (L)							0.000872			0.000127			4.72E-05
MicroShield Calculated Dose for Prefilter (mSv/hr)							0.34			No Prefilter			No Prefilter
Prefilter Operating Limit (mSv/hr)							2						
OL/CD							5.882353						
Prefilter Loading to give OL (L)							0.065947						
1% Release (L)							0.000659						
Volume Released from One Filter Bank (L)						D	3.06E-03		P	1.27E-04		P	4.72E-05
umber of Parallel Banks Operating at the Same Time							2			1			1
TOTAL RELEASED (L)							6.13E-03			1.27E-04			4.72E-05

D = Two HEPAs, a Prefilter, and another volume equal to the prefilter for stuff coming out of the ventilation ducting
= 2*HEPA Volume + 2* Prefilter Volume
P = Passive breather HEPA, no prefilter, no second HEPA, and no appreciable ventilation ducting
= 1*HEPA Volume
A = Two (2) HEPAs, no prefilter but there are two (2) de-entrainers and material in the ventilation ducting (1)
= 5*HEPA Volume
C = Two HEPAs, a prefilter, a low efficiency filter (treated as a prefilter), and another volume equal to the prefilter for material in the vent. ducting.
= 2*HEPA Volume + 3*Prefilter Volume

DCRTs			SY, AN, AP, AW			AY & AZ			204AR/244AR		
[illegible]			[illegible]			AWF Liquids on a 24x24x12 Filter			[illegible]		
(Ci)	(Bq)	(L)	(Ci)	(Bq)	(L)	(Ci)	(Bq)	(L)	(Ci)	(Bq)	(L)
0.9016	3.3E+10	1.509	1	3.7E+10	0.631	1	3.7E+10	0.419	1	3.7E+10	0.631
0.0984	3.6E+09	1.549									
1.00	3.7E+10	1.549	1.00	3.7E+10	0.631	1.00	3.7E+10	0.419	1.00	3.7E+10	0.631
		130.00			44.7			44.7			44.7
		2			2			2			2
		0.015385			0.044743			0.044743			0.044743
		0.023835			0.028251			0.018727			0.028251
		0.000238			0.000283			0.000187			0.000283
		220.00			61			No Prefilter			61
		2			2						2
		0.009091			0.032787						0.032787
		0.014084			0.020702						0.020702
		0.000141			0.000207						0.000207
	D	7.58E-04		D	9.79E-04		A	9.36E-04		C	1.19E-03
		3			1			6			2
		2.28E-03			9.79E-04			5.62E-03			2.37E-03

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APPENDIX E

HEADSPACE STEAM CONDENSATION TREATED AS A CONDUCTION PROBLEM

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HEADSPACE STEAM CONDENSATION TREATED AS A CONDUCTION PROBLEM

The tank dome is filled with steam. After discovery of the steam leak, the steam source is shut-off. The steam present in the headspace condenses to water.

For conduction heat flow: $Q_{hemisphere} = 2 \pi k \Delta T [(r_i \bullet r_o)/(r_o - r_i)]$

In the analysis the subscript i is used to describe the inside tank bulk conditions. The subscript O refers to the outside wall conditions. For simplicity, as in the pressurization portion of the accident scenario, the tank dome is modelled as a hemisphere, with no heat transfer to or from the waste surface. This is conservative since it slightly overestimates the dome surface area.

All calculations are taken at time = 0 minutes.

The following variables are defined:

r_i = 37.5 ft (tank dome inside radius)

r_o = 38.75 ft (tank dome outside radius)

$T_i(0)$ = 212 °F (headspace temperature)

$T_o(0)$ = 50 °F (outside temperature remains constant)

$\rho_i(0)$ = 0.0373 lb/ft^3 (steam density @ 14.7 psia)

k = 0.5 BTU/hr•ft•°F (conductivity of concrete)

$v_i = 1.1 \times 10^5$ ft^3 (tank dome modelled as hemisphere)

$m_i = (\rho_i(0)) \bullet (v_i) = 4.1 \times 10^3 \ lb_m$

$Q_{hemisphere} = 2 \pi k \Delta T [(r_i \bullet r_o)/(r_o - r_i)] = 5.92 \times 10^5$ BTU/hr (164.3 BTU/sec)

The heat of vaporization (h_{fg}) is determined from standard steam tables to be:

h_{fg} = 970.3 BTU/lb$_m$

In one minute at this heat transfer rate, water condenses in the amount of mass m_c.

$m_c = (Q_{hemisphere}/h_{fg}) \bullet 60$ s/min = 10.16 lb$_m$/min

The associated volume reduction due to condensation is v_c.

$v_c = m_c/\rho_i(0) = 272.39$ ft^3

Thus a volume inflow rate of approximately 273 cfm is required to ensure that pressure in the dome does not become negative. This flow can be easily provided by the available ventilation pathways in the tank involved in the accident or from the inflow from other tanks on the ventilation system which are not affected by this accident.

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APPENDIX F

PEER REVIEW AND HEDOP REVIEW CHECKLISTS

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CHECKLIST FOR PEER REVIEW

Document Reviewed: WHC-SD-WM-CN-044, Rev. 0, *Calculation Notes That Support Accident Scenario and Consequence Development for the Steam Intrusion From Interfacing Systems Accident.*

Scope of Review: Entire document.

Yes	No	NA	
[X]	[ ]	[ ] *	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[X]	Software input correct and consistent with document reviewed.
[ ]	[ ]	[X]	Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[X]	[ ]	[ ]	Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]		[X] *	Review calculations, comments, and/or notes are attached.

[X] [ ] [ ] **Document approved.**

Brett D. Board *Brett Board* — *7/16/96*

Reviewer (Printed Name and Signature) — Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document reviewed (include title or description of calculation, document number, author, and date, as applicable):

WHC-SD-WM-CN-044, Rev. 0, *Calculation Notes That Support Accident Scenario and Consequence Development for the Steam Intrusion From Interfacing Systems Accident.*

Submitted by: Grant W. Ryan Date Submitted: 7/16/96

Scope of Review: Radiological and Toxicological Calculations.

YES	NO*	N/A		
[X]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[X]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[ ]	[ ]	[X]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[X]	4.	Receptor locations were selected according to HEDOP recommendations.
[ ]	[ ]	[X]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[X]	[ ]	[ ]	6.	Hanford site data were used.
[ ]	[ ]	[X]	7.	Model adjustments external to the computer program were justified and performed correctly.
[X]	[ ]	[ ]	8.	The analysis is consistent with HEDOP recommendations.
[ ]		[X]	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
[X]	[ ]		10.	**Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.**

* All "NO" responses must be explained and use of nonstandard methods justified.

DA. Hines [signature] 7/19/96

HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary):

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