ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 609900

Proj. ECN

2. ECN Category (mark one) Supplemental [] Direct Revision [X] Change ECN [] Temporary [] Standby [] Supersedure [] Cancel/Void []	3. Originator's Name, Organization, MSIN, and Telephone No. R. J. Van Vleet/S.E. Lindberg, Safety Analysis and Risk Assessment, A3-34, 376-2613	4. USQ Required? [] Yes [X] No	5. Date 2-20-97
	6. Project Title/No./Work Order No. TWRS FSAR Development	7. Bldg./Sys./Fac. No. Tank Farms	8. Approval Designator N/A
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-WM-CN-044, REV. 1	10. Related ECN No(s). 605031	11. Related PO No. N/A

12a. Modification Work	12b. Work Package No.	12c. Modification Work Complete	12d. Restored to Original Condition (Temp. or Standby ECN only)
[] Yes (fill out Blk. 12b) [X] No (NA Blks. 12b, 12c, 12d)	N/A	N/A Design Authority/Cog. Engineer Signature & Date	N/A Design Authority/Cog. Engineer Signature & Date

13a. Description of Change — 13b. Design Baseline Document? [] Yes [X] No

Full replacement of Revision 1 document with Revision 2 document.

Calculation notes are used to document the originator's analysis but are not to be used as the final or sole document to authorize activities or justify facility modifications.

14a. Justification (mark one)

Criteria Change	[X]	Design Improvement	[]	Environmental	[]	Facility Deactivation	[]
As-Found	[]	Facilitate Const	[]	Const. Error/Omission	[]	Design Error/Omission	[]

14b. Justification Details

Modifications have been made as a result of a detailed review of this calculation note.

15. Distribution (include name, MSIN, and no. of copies)

R. D. Crowe	A3-34	1
B. E. Hey	A3-34	1
S. E. Lindberg	A3-34	1
G. W. Ryan	A3-37	1
R. J. Van Vleet	A3-34	1
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16. Design Verification Required	17. Cost Impact				18. Schedule Impact (days)	
	ENGINEERING		CONSTRUCTION			
[] Yes	Additional	[] $	Additional	[] $	Improvement	[]
[X] No	Savings	[] $	Savings	[] $	Delay	[]

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]	None	[X]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision
N/A		

21. Approvals

	Signature	Date		Signature	Date
Cog. Eng.	R. J. Van Vleet/S. E. Lindberg *(signature)*	2/21/97	PE		
Cog. Mgr.	B. E. Hey *(signature)*	2/21/97	QA		
QA			Safety		
Safety			Design		
Environ.			Environ.		
Peer Reviewer	R. M. Marusich *(signature)*	RMM 2/24/97	Other		

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

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

G. W. Ryan
Duke Engineering Services Hanford, Richland, WA 99352

R. J. Van Vleet, R. D. Crowe, and S.E. Lindberg
Fluor Daniel Northwest, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

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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.

Janis Bishop 3/4/97
Release Approval Date

Release Stamp

Approved for Public Release

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(2) Title

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

CHANGE CONTROL RECORD

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release (5) Cog. Engr.	(6) Cog. Mgr. Date
0	(7) New document released via EDT #602622 on 7/25/96.	G. W. Ryan 7/23/96	D. S. Leach 7/23/96
0-A	Replace pages 21/22 and 23/24 via ECN #185064 on 8/27/96.	G. W. Ryan 8/24/96	D. S. Leach 8/24/96
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1-A RS	Replace pages 19/20 of Revision 1 document with Revision 1-A pages via ECN #605036.	G. W. Ryan 9/27/96 G.W. Ryan	D. S. Leach 9/27/96

RECORD OF REVISION	(1) Document Number HNF-SD-WM-CN-044	Page 2

(2) Title

Calculation Notes that Support Accident Scenario and Consequence Development for the Steam Intrusion from Interfacing Systems Accident

CHANGE CONTROL RECORD

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release	
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CALCULATION NOTES THAT SUPPORT ACCIDENT SCENARIO AND CONSEQUENCE DEVELOPMENT FOR THE STEAM INTRUSION FROM INTERFACING SYSTEMS ACCIDENT

REVISION 2

Tank Waste Remediation System Final Safety Analysis Report Project
Specialty Engineering

February 1997

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CONTENTS

LIST OF TABLES

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.

Both double-shell tanks and double-contained receiver tanks may receive steam jet waste transfers. A double-shell tank was chosen to be analyzed since it has a potentially larger headspace (allowing for more particulates in a release). Lesser consequences would be calculated for a double-contained receiver tank, given the reduced headspace available.

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 is 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=nRT).

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. The heat released from the steam is assumed to be absorbed uniformly by the headspace constituents.

E The saturated steam flow rate, mdot, introduced into the tank headspace is 2,400 lbm/hr (0.667 lb_m/sec) from IVF-Chapter 3-07 in Appendix A. This flow rate is considered to bound steam jet transfers from the two facilities identified with steam intrusion potential, 242-A Evaporator (200E) and PFP (200W).

F The saturated steam pressure is 90 psig (~105 psia) from IVF-Chapter 3-07 in Appendix A. Facilities using process steam have equipment (pressure reducing valves, etc.) to ensure that the steam used for a particular process is at the correct pressure (e.g., 90 psig for the 242 Evaporator and 50 psig for PFP). The higher steam pressure would heat up the headspace gases faster (the enthalpy of 225 psig steam is higher than 90 psig steam) resulting in less than a 5% increase in the 15 minute averaged flow rate.

G The saturated steam is introduced into a partially full double-shell tank. The headspace volume, vol_{hs}, is calculated here:

$$vol_{hs} = (1.406 * 10^6 \text{ gal}) - (\text{waste depth}) * (2750 \text{ gal/in})$$
$$= (1.406 * 10^6 \text{ gal}) - (212 \text{ in}) * (2750 \text{ gal/in})$$
$$= 823{,}200 \text{ gal} = 110{,}000 \text{ ft}^3$$

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. No credit is taken for the HEPA filters in mitigating the release, but the radioactive and toxic material previously trapped by the HEPA filters is included in the release.

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 gas that will leave the tank through the unfiltered in-leakage pathways the following modified Darcy equation is used (Crane, eq. 3-20):

$$W_{vent} = c_{vd} \sqrt{\Delta P \;\; \rho_{air}}$$

$$c_{vd} = \frac{W_{vent}}{\sqrt{\Delta P_{norm} \, \rho_{air}}}$$

$$c_{vd} = 87.7 \; \frac{ft^3}{sec} \left[\frac{atm \; lb}{ft^3} \right]^{-0.5}$$

where:

$$W_{vent} = 100 \; cfm = 1.67 \; \frac{ft^3}{sec}$$

$$\Delta P_{norm} = 2 \; in. \; WG = 0.0049 \; atm$$

$$\rho_{air} = 0.073 \; \frac{lb}{ft^3} \; at \; 80 \; F$$

L Credit is taken for flow out a ventilation duct pathway during the pressurization by doubling the vent coefficient.

M The atmosphere in the headspace during the accident is treated as an ideal gas comprised of air and steam with the following properties (Cengel and Boles, 1994):

The density of the air in the headspace, rho_{air}, is a function of the headspace temperature, headspace pressure and the number of moles of air left in the headspace.

$cp_{air} = 0.235$ BTU/lb_m-°F

$mw_{air} = 28.97$ lb_m/lbmole

The steam introduced into the headspace also treated as an ideal gas with the following properties (Cengel and Boles, 1994):

The density of the steam, rho_{steam}, is a function of the headspace temperature, headspace pressure and the number of moles left in the headspace. Treating steam as an ideal gas over estimates the density by less than 2% at the initial temperature and under estimates the density by 6% at the maximum transient temperature as compared to the actual steam tables.

$cp_{steam} = 0.44$ BTU/lb_m-°F

$mw_{steam} = 18.015$ lb_m/lbmole

N Mass and number of moles of air initially in the headspace:

$$m_{air} = \rho_{air}(150°F)\ vol_{hs}$$
$$= (0.065\ lb/ft^3)\ (1.10 \times 10^5\ ft^3)]$$
$$= 7,160\ lb$$

$$n_{air} = m_{air} /\ mw_{air}$$
$$= 247\ lbm\_moles$$

O Standard steam tables are used to find enthalpy of saturated steam (Cengel and Boles, 1994).

$h_g(90\ psig) = 1188.8$ BTU/lb_m

$h_g(150\ F) = 1126.1$ BTU/lb_m

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

$$\Delta q_{released\ from\ steam} = m_{steam}\ (h_{g\ @105\ psia} - h_{g\ @150F})$$

$$= (0.667\ \frac{lb_m}{s})\ (1188.8\ \frac{Btu}{lb_m} - 1126.1\ \frac{Btu}{lb_m})$$

$$= 41.8\ \frac{Btu}{s}$$

Q The universal gas constant, $R^* = 0.73023\ (ft^3\ atm)/(lbmole\text{-}°R)$.

1.4 METHODOLOGY AND ANALYSIS TECHNIQUES

Using the assumptions described in Section 1.3, the dynamic behavior of the steam intrusion into the tank headspace is analyzed using the ideal gas law and the principles of conservation of energy and mass. During each time step in the calculation, the intruded steam adds mass and energy to the totals within headspace. Mass and energy are also lost from the headspace via the venting. At each time interval, dt, a new temperature and pressure of the tank headspace is calculated to determine the net change in the heat and mass within the headspace. The calculation continues until an equilibrium temperature and pressure is reached where the mass and energy of the steam flow into the tank is equal to the mass and energy flow out the vent system.

Analysis starts with the following initial headspace conditions (IVF-Chapter 3-07). The initial headspace temperature, T_{hs}, is used as a reference for calculating the energy flow in and out of the tank.

T_{hs} = 150°F

P_{HS} = 14.7 psia

$m_{hs} = m_{air} + m_{steam}$

$= 7{,}160\ lb_m + 0\ lb_m$

The calculation process uses the conditions from previous step to calculate the new conditions in the following steps:

Step 1: Calculate the properties of the mixture of air and steam in the tank headspace for the present conditions.

$m_{mix}(t) = m_{air}(t) + m_{steam}(t)$

$rho_{mix}(t) = m_{mix}(t)\ /\ vol_{hs}$

$cp_{mix}(t) = [cp_{air}\ m_{air}(t) + cp_{steam}\ m_{steam}(t)]\ /\ m_{mix}(t)$

$n_{mix}(t) = m_{air}(t)/mw_{air} + m_{steam}(t)/mw_{steam}$

Step 2: Calculate the mass fraction of steam and air, mf_i in the headspace.

$mf_{air}(t) = m_{air}(t) / m_{mix}(t)$

$mf_{steam}(t) = m_{steam}(t) / m_{mix}(t)$

Step 3: Calculate the flow of the headspace mixture out the vent paths.

$flow_{vent}(t) = c_{vd} [press(t) \; rho_{mix}(t)]^{0.5}$

Step 4: Determine the mass of air and steam in the headspace for the next time interval.

$m_{air}(t+dt) = m_{air}(t) - [flow_{vent}(t) \; rho_{mix}(t) \; mf_{air}(t)] \; dt$

$m_{steam}(t+dt) = m_{steam}(t) + mdot_{steam} \; dt - [flow_{vent}(t) \; rho_{mix}(t) \; mf_{steam}(t)] \; dt$

Step 5: Determine the new headspace temperature resulting from the addition of steam into the headspace and the lost of energy by the venting gas mixture. The energy in the system is referenced to the initial temperature in the headspace.

$q_{vent}(t) = (T_{hs}(t)-150°F) \; flow_{vent}(t) \; rho_{mix}(t) \; cp_{mix}(t)$

$T_{hs}(t+dt) = T_{hs}(t) + [q_{steam} - q_{vent}(t)] \; dt / [m_{mix}(t) \; cp_{mix}(t)]$

Step 6: Finally the new pressure in the headspace using the ideal gas equation and the new headspace conditions:

$P_{hs}(t) = R_{gas} \; n_{mix}(t) \; T_{hs}(t) / vol_{hs}$

These six steps are repeated for each new time interval for the length of the transient.

1.4.1 Analysis Results

The analysis results (Appendix E) show that for assumed steam parameters and tank conditions, the tank headspace is pressurized. Table C-1 gives the temperature, pressure and flow rates predicted for this accident. There is sufficient pressure to challenge the ventilation filter HEPA filters.

After the HEPA filters fail, the steam flow into the tank is assumed to continue until the headspace is filled with steam and the temperature and pressure reach an equilibrium. At this condition, the mass and energy flow out the ventilation system matches the input flow by definition.

When the steam supply is finally shut-off upon the discovery of upset steam flow, the steam in the steam-filled headspace would begin to condenses to water. With the steam condensation, the pressure in the tank would decrease, potentially creating a negative pressure in the tank. However, because the length of time of the accident, the tanks walls and dome should be near the same temperature as the headspace gas at the end of the accident. Head loss from a passive tank by conduction through the covering soil is very slow allowing the headspace pressure easily remain equalized with the atmospheric pressure.

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 of a half-full tank ($V_{HS} = 3.1 \times 10^3$ m^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 half-full tank scenario was conservatively chosen as the example used for this analysis because the accident consequence was more severe for this scenario than for a tank full of waste. The consequences calculated for the empty tank were similar to those for the half-full tank. The results of these analyses are included in the tables in Appendix F.

The partition fraction used to determine the amount of contamination in the headspace air is 1.0×10^{-8}. This is the value for agitated 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

$$(3.1 \times 10^3\ m^3)(1.0 \times 10^{-8}) = 3.1 \times 10^{-5}\ m^3$$

Converting to liters,

$$(3.1 \times 10^{-5}\ m^3)(1{,}000\ L/m^3) = 3.1 \times 10^{-2}\ L$$

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 (Van Vleet 1996).

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:

Q1a	DST	0.0009790 L	(Appendix F)
Q1b	AWF	0.005618 L	(Appendix F)

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:

$$\underset{Q_{2a}}{3.1 \times 10^{-2}\ L} + \underset{Q_{1a}}{9.79 \times 10^{-4}\ L} = 3.2 \times 10^{-2}\ L$$

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 total respirable amount of waste produced during venting of the headspace air and the HEPA filter rupture (i.e., 3.21×10^{-2} L). This ensures that toxicological consequences are developed conservatively for both the onsite and offsite receptor.

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)
$ULD_I = 0.07$ 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.

The following onsite and offsite χ/Q's are from Van Keuren 1996a.

Onsite - The χ/Q' for the **acute** release is 3.4 X 10^{-2} s/m^3

The χ/Q' for the **2-hour** release is 1.13 X 10^{-2} s/m^3

The χ/Q' for the **chronic** release is 4.03 X 10^{-4} s/m^3

Offsite - The χ/Q' for the **acute** release is 2.8 X 10^{-5} s/m^3

The χ/Q' for the **2-hour** release is 2.12 X 10^{-5} s/m^3

The χ/Q' for the **chronic** release is 1.24 X 10^{-7} s/m^3

The χ/Q' values for releases greater than 2 hours but less than 1 year (8760 hrs) are determined using logarithmic interpolation.

$$\frac{\log\left(\frac{\chi}{Q}\right)_{2-hr} - \log\left(\frac{\chi}{Q}\right)_{x-hr}}{\log\left(\frac{\chi}{Q}\right)_{2-hr} - \log\left(\frac{\chi}{Q}\right)_{8760-hr}} = \frac{\log(2) - \log(x)}{\log(2) - \log(8760)}$$

Thus, for χ equal to some time greater than 2 hours but less than 8760 hrs, the equation can be solved for the $(\chi/Q')_{\chi\text{-hr}}$. This value is what is used in the calculation. See Appendix F for the time periods and interpolated χ/Q' values.

Breathing Rate (BR)

3.3 x 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 = 3.2 x 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) = (3.2 x 10^{-2} L)(7.51 x 10^{-3} s/m^3)(3.3 x 10^{-4} m^3/s)(6.1 x 10^3 Sv/L)

D (Sv) = 4.838 x 10^{-4} Sv

Offsite Consequences:

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

$$D\ (Sv) = (3.2 \times 10^{-2}\ L)(1.13 \times 10^{-5}\ s/m^3)[(3.3 \times 10^{-4}\ m^3/s)(6.1 \times 10^3\ Sv/L) + 0.068\ Sv\text{-}m^3/s\text{-}L]$$

$$D\ (Sv) = 7.279 \times 10^{-7}\ Sv$$

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]). The worst constituents, toxicologically, reported in the preceding reference include corrosives and irritants such as ammonia and tributyl phosphate. This event is 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 1.0×10^4 s/L (DST liquids) / 2.6 s/m^3 (DST vapor space).

The sum-of-fraction value for the offsite receptor is 8.4 s/L (DST liquids) / 2.3×10^{-3} s/m^3 (DST vapor space).

Quantity Released

The quantity of material released was calculated previously to be a total of 3.2×10^{-2} L.

1.7.2 Calculations

By directly multiplying the sum-of-fraction value by the waste release rate divided by the time it takes to vent 95% of the headspace gases to the atmosphere, the toxicological consequences can be calculated for both the onsite and offsite receptors. The following are for the average flow rate example. The results of the maximum flow rate are included in Appendix F.

HEPA filter consequence for the half-full tank:

Onsite - Calculation: $[9.79 \times 10^{-4}\ L/(335\ min \times 60\ s/min)](1.0 \times 10^4/L) = 4.87 \times 10^{-4}$.

Offsite - Calculation: $[9.79 \times 10^{-4}\ L/(335\ min \times 60\ s/min)](8.4\ L) = 4.1 \times 10^{-7}$.

Headspace release consequence for the half-full tank:

Onsite - Calculation: $[3.116 \times 10^{-2}$ L/(335 min X 60 s/min)] $(1.0 \times 10^{4}$ s/L) $= 1.6 \times 10^{-2}$.

Offsite - Calculation: $(3.116 \times 10^{-2}$ L / 335 min X 60 s/min)(8.4 s/L) $= 1.302 \times 10^{-5}$.

Gas release consequence for the half-full tank:

Onsite - Calculation: $(3.1 \times 10^{3}\ m^{3}$ / 335 min X 60 s/min)(2.6 s/m^{3}) $= 4.01 \times 10^{-1}$

Offsite - Calculation: $(3.1 \times 10^{3}\ m^{3}$ / 335 min X 60 s/min) $(2.3 \times 10^{-3}\ s/m^{3}) = 3.54 \times 10^{-4}$

1.8 RESULTS

1.8.1 Radiological

The onsite radiological dose consequence value (4.9×10^{-4} 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 (7.6×10^{-7} 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 4.2×10^{-1} as a fraction of the risk guidelines. Similarly, the exposure to the offsite receptor is calculated to be 3.7×10^{-4}, as a fraction of the risk guidelines. The values for both the onsite and offsite receptors are below the risk guidelines (<1). Even when the maximum flow rate is used, the onsite exposure is 9.1×10^{-1} as a function of the risk guidelines.

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.

The radiological dose consequences for the both the onsite and offsite receptors are below the risk guidelines (Tables in Appendix F).

The toxicological exposure consequences show that the values for both the onsite and offsite receptors are below the risk guidelines (Tables in Appendix F).

Table 1.9-1 is a summary of the accident consequences as developed in the calculation note for a double-shell tank with average flow. Other consequences are calculated in a similar fashion and are presented in Appendix F.

Table 1.9-1. Summary of Accident Consequences

Accident	Consequenses			
	Radiological (Sv)		Toxicological	
	Onsite	Offsite	Onsite	Offsite
Steam intrusion from interfacing facilities	4.9×10^{-4}	7.6×10^{-7}	4.2×10^{-1}	3.7×10^{-4}

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.

Van Vleet, R. J., 1996, *Waste Tank Ventilation System Waste Material Accumulations*, WHC-SD-WM-CN-054, Rev. 0, 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.

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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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 SCRT 241-TX, at a ventilation flowrate of 30 cfm for the tank a vacuum of 3.2 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 7	Basis for Decision 8

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

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Alternatives	Consequences to Alternatives
5 N/A	6 N/A
Decision Reached 7	Basis for Decision 8

Date Requested	Sent To	Date Requested By
9 June 25, 1996	10 R. Tucker, Project Files	11 June 28, 1996 (earlier response would be appreciated)

Response #1

12

Response #2

13

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

POC: Filed: Routed:

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

18

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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 12 DAILY.)	
Response #2 13	
Attachments (List) 14	References (List) 15
Responder #1 Name and Signature 16 R.P. Tucker R.P.T.	Responder #2 Name and 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-PRES05	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

WASTE TANK HEADSPACE GAS VENT FLOW DURATION

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Case	Maximum Headspace Pressure	Maximum Headspace Temperature	Maximum Headspace Gas Flow (15 minute average)	Time to Vent 95% of the original headspace gas
	psia	F	ft^3/min	min
Nominal	3.3	292	732	335
Increased steam temperature from 90 F to 225 F	3.5	319	751	325
Double steam flow from 0.677 lb/sec to 1.333 lb/sec	7.2	293	974	197
Increase in headspace volume equivalent to tank with 10 in. waste.	3.3	292	733	560
Decrease in headspace volume equivalent to tank with 410 in. waste.	3.3	292	703	113
Double the outlet flow resistance	7.2	292	491	391
Half the outlet flow resistance	1.2	291	981	305

Table C-1. Waste Tank Headspace Gas Vent Flow Duration

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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.

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APPENDIX E

CALCULATION NOTES FOR STEAM INTRUSION

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Calculation Notes for Steam Intrusion

Ralph Crowe
Safety Analysis and Risk Assessment
Specialty Engineering
Fluor Daniel Nortwest, Inc.

References

Cengel, Y. A. and M.A. Boles, 1994, *Thermodynamics, An Engineering Approach, 2nd Edition,* McGraw Hill Publishing, Inc. New York, New York.

Crane, 1985, *Flow of Fluids Through Valves, Fittings and Pipe*, Crane Co. New York, New York.

Holman, J. P., 1990, *Heat Transfer*, 7th. Edition, McGraw Hill Publishing Inc, New York, New York.

MathSoft, 1995, *MathCad Plus 6.0, User's Guide*, Mathsoft Inc., Cambridge, Massachuetts.

This report was written in MathCad Plus 6.0 Professional Edition (Maftsoft 1995) . The following constants and equations were used as a part of the calculation.

Constants

$R_{gas} := 8.31434 \cdot 10^3 \cdot \frac{joule}{kg\_mole \cdot K}$ $R_{gas} = 0.73023 \cdot \frac{ft^3 \cdot atm}{lb\_mole \cdot R}$

$\rho_{gas}(P, T, M) := \left(\frac{P \cdot M}{R_{gas} \cdot T} \right)$

$mw_{steam} := 18.015 \cdot \frac{lb}{lb\_mole}$ $mw_{air} := 28.97 \cdot \frac{lb}{lb\_mole}$

Steam Flow into tank, (IVF Chapter 3-07)

$P_{steam} := 105 \cdot psi$ $T_{steam} := 331.7 \cdot F$ $h_{steam} := 1188.8 \cdot \frac{BTU}{lb}$

$T_{atm} := 150 \cdot F$ $h_{atm} := 1126.1 \cdot \frac{BTU}{lb}$

Mass and energy flow into tank, (IVF Chapter 3-07)

$steam\_flow := 0.667 \cdot \frac{lb}{sec}$ $steam\_flow = 0.303 \cdot \frac{kg}{sec}$

$heat\_in := \left(h_{steam} - h_{atm}\right) \cdot steam\_flow$ $heat\_in = 41.8 \cdot \frac{BTU}{sec}$ $heat\_in = 44.1 \cdot kW$

Time to heat 560 ft of schedule 40 10" pipe

Weight of pipe per foot, (Crane page B-17) $w_{pipe} := 40.48 \cdot \frac{lb}{ft}$

Specific heat of pipe, (Holman 1990) $cp_{pipe} := 0.11 \cdot \frac{BTU}{lb \cdot F}$

Heat of vaporization at 240 F (Crane) $h_{fg} := 950 \cdot \frac{BTU}{lb}$

$$\frac{\left(w_{pipe}\right) \cdot (560 \cdot ft) \cdot \left(cp_{pipe}\right)}{steam\_flow \cdot h_{fg}} \cdot \left(T_{steam} - T_{atm}\right) = 11.9 \cdot min$$

Initial tank conditions

$P_{air} := 1 \cdot atm$ $\qquad$ $T_{air} := 150 \cdot F + 460 \cdot R$

$P_{air} = 101.3 \cdot kPa$ $\qquad$ $T_{air} = 338.9 \cdot K$

$\rho_{air} := \rho_{gas}(P_{air}, T_{air}, mw_{air})$ $\qquad$ $\rho_{air} = 0.065 \cdot \frac{lb}{ft^3}$ $\qquad$ $\rho_{air} = 1.042 \cdot \frac{kg}{m^3}$

Headspace volume $\quad$ $head\_space(waste\_depth) := 187976 \cdot ft^3 - waste\_depth \cdot 2750 \cdot \frac{gal}{in}$

$hsv := head\_space(212 \cdot in)$ $\qquad$ $hsv = 1.10 \cdot 10^5 \cdot ft^3$ $\qquad$ $hsv = 3.1 \cdot 10^3 \cdot m^3$

Vent modeling

normal vent flow conditions
(IVF Chapter 3-07)

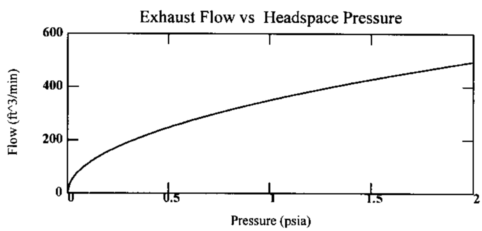
$Q := 100 \cdot \frac{ft^3}{min}$ $\qquad$ $\Delta P := 2 \cdot in\_H2O$ $\qquad$ $T_{vent} := 80 \cdot F + 460 \cdot R$

$\rho_{vent} := \rho_{gas}(1 \cdot atm, T_{vent}, mw_{air})$ $\qquad$ $cv := \frac{Q}{\sqrt{\Delta P \cdot \rho_{vent}}}$ $\qquad$ $cv \cdot \sqrt{2 \cdot in\_H2O \cdot \rho_{vent}} = 100.0 \cdot \frac{ft^3}{min}$

$\rho_{vent} = 0.073 \cdot \frac{lb}{ft^3}$

$p \equiv 0 \cdot psi, 0.01 \cdot psi .. 2 \cdot psi$

$cv = 87.7 \cdot \frac{ft^3}{sec} \cdot \left(\frac{atm \cdot lb}{ft^3}\right)^{0.5}$



Initialize calculational variables

Number of moles in the headspace $\qquad$ $n_{air} := \frac{P_{air} \cdot hsv}{R_{gas} \cdot T_{air}}$ $\qquad$ $n_{air} = 247.0$

Initial mass of air in headspace $\qquad$ $m_{air} := hsv \cdot \rho_{air}$ $\qquad$ $m_{air} = 7.16 \cdot 10^3 \cdot lb$

$$\mathrm{dump}(n,time,x,q,hs,c_d,stm) \equiv$$

$$\delta t \leftarrow \frac{60\cdot time}{n}$$

$$tox_{15} \leftarrow \frac{15\cdot 60}{\delta t}$$

$$R_{gas} \leftarrow 0.73023$$

$$cp_{air} \leftarrow 0.23$$

$$cp_{stm} \leftarrow 0.44$$

$$mw_{air} \leftarrow 28.97$$

$$mw_{steam} \leftarrow 18.015$$

for $i \in 1..n$

$$x_{i,0} \leftarrow x_{i-1,0} + \frac{\delta t}{60}$$

$$m_{mix} \leftarrow x_{i-1,3} + x_{i-1,4}$$

$$rho_{mix} \leftarrow \frac{m_{mix}}{hs}$$

$$cp_{mix} \leftarrow \frac{x_{i-1,3}\cdot cp_{air} + x_{i-1,4}\cdot cp_{stm}}{m_{mix}}$$

$$n_{mix} \leftarrow \frac{x_{i-1,3}}{mw_{air}} + \frac{x_{i-1,4}}{mw_{steam}}$$

$$x_{i,5} \leftarrow c_d\cdot \mathrm{if}\left[x_{i-1,2}>1, \sqrt{rho_{mix}\cdot\left(x_{i-1,2}-1\right)}, -\sqrt{rho_{mix}\cdot\left(1-x_{i-1,2}\right)}\right]$$

$$x_{i,3} \leftarrow x_{i-1,3}\cdot\left(1-\frac{x_{i,5}\cdot\delta t}{hs}\right)$$

$$x_{i,4} \leftarrow x_{i-1,4}\cdot\left(1-\frac{x_{i,5}\cdot\delta t}{hs}\right) + stm\cdot\delta t$$

$$x_{i,6} \leftarrow \left(x_{i-1,1} - x_{0,1}\right)\cdot x_{i,5}\cdot cp_{mix}\cdot rho_{mix}$$

$$x_{i,1} \leftarrow x_{i-1,1} + \frac{\left(q - x_{i,6}\right)\cdot\delta t}{cp_{mix}\cdot m_{mix}}$$

$$x_{i,2} \leftarrow \frac{n_{mix}\cdot R_{gas}\cdot x_{i,1}}{hs}$$

$$x_{i,7} \leftarrow \frac{x_{i,3}}{mw_{air}\cdot n_{mix}}$$

$$x_{i,8} \leftarrow x_{i-1,8} + \frac{\left(x_{i,5}\cdot x_{i,7} - \mathrm{if}\left(i \ge tox_{15}, x_{i-tox_{15},5}\cdot x_{i-tox_{15},7}, 0\right)\right)\cdot\delta t}{15\cdot 60}$$

x

T_{air}

$x_{0,0} := 0$ **time**

$x_{0,1} := \frac{T_{air}}{R}$ **headspace temperature**

$x_{0,2} := \frac{P_{air}}{atm}$ **pressure**

$x_{0,3} := \frac{P_{air} \cdot hsv}{R_{gas} \cdot T_{air}} \cdot \frac{mw_{air}}{lb}$ **total mass of air**

$x_{0,4} := 0$ **mass of steam in headspace**

$x_{0,5} := 0$ **vent flow**

$x_{0,6} := 0$ **volume of headspace gas vented per unit time**

$x_{0,7} := 0$ **volume of headspace gas vented per unit time**

$x_{0,8} := 0$ **15 minute average headspace flow**

$x_{save} := x$

Calculate transient

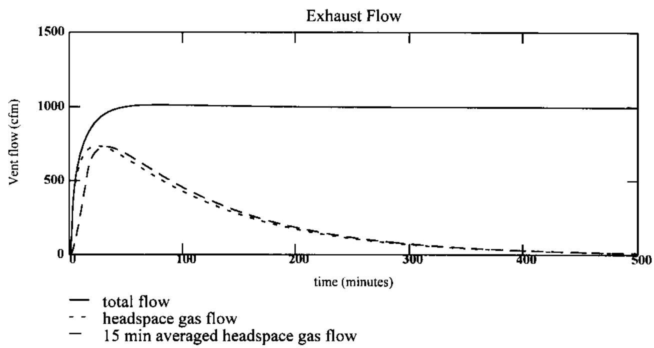
$stm := steam\_flow \cdot \left(\frac{lb}{sec}\right)^{-1}$ $hs := hsv \cdot ft^{-3}$ $q := heat\_in \cdot \left(\frac{BTU}{sec}\right)^{-1}$ $c_d := 2 \cdot cv \cdot \sqrt{atm \cdot \frac{lb}{ft^3}} \cdot \left(\frac{ft^3}{sec}\right)^{-1}$

$time := 500$ $n := \frac{time}{1}$ $i := 1 .. n$ $\frac{15 \cdot n}{time} = 15.0$

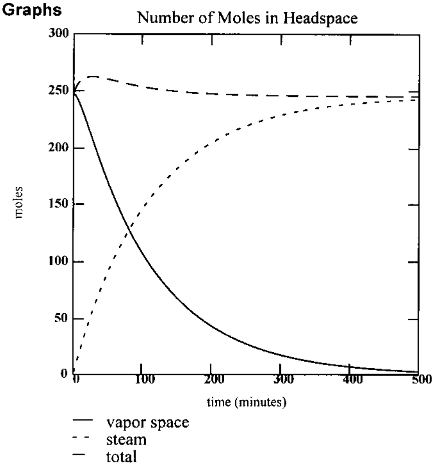
$x := x_{save}$ $x := dump(n, time, x, q, hs, c_d, stm)$ $tox_i := x_{i,8} \cdot \frac{ft^3}{sec}$

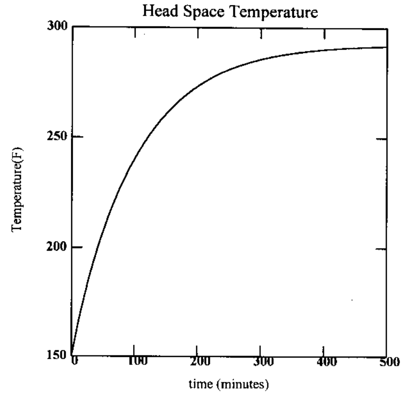
$max(tox) = 732.0 \cdot \frac{ft^3}{min}$ $x_{n,1} \cdot R - 460 \cdot R = 291.8 \cdot F$ $(x_{n,2} - 1) \cdot atm = 3.3 \cdot psi$ $j := floor\left(n \cdot \frac{335}{time}\right)$

$max(tox) = 0.345 \cdot \frac{m^3}{sec}$ $x_{n,1} \cdot R = 417.7 \cdot K$ $(x_{n,2} - 1) \cdot atm = 22.5 \cdot kPa$ $x_{j,7} = 5.07 \cdot \%$



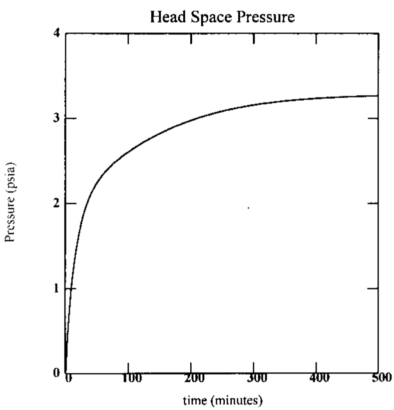
Graphs

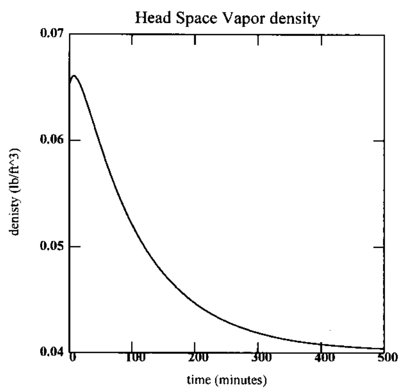




$rho_i := \frac{(x_{i,3} + x_{i,4}) \cdot lb}{hsv}$ $\qquad rho_n = \mathbf{0.040} \cdot \frac{lb}{ft^3}$

$P_i := x_{i,2} \cdot atm$ $\qquad \rho\, gas(x_{n,2} \cdot atm, x_{n,1} \cdot R, mw_{steam}) = \mathbf{0.040} \cdot \frac{lb}{ft^3}$





Increased steam inlet temperature

$P_{stm} := 225 \cdot psi$

$T_{stm} := 392 \cdot F$

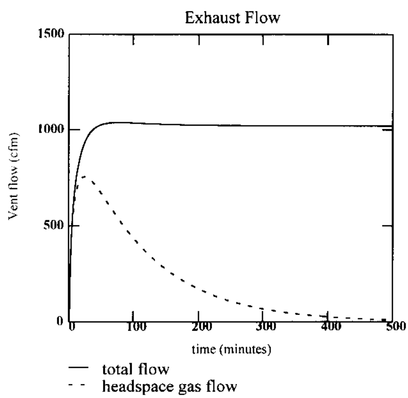
$q := \left(1200.89 \cdot \frac{BTU}{lb} - h_{atm}\right) \cdot steam\_flow \cdot \left(\frac{BTU}{sec}\right)^{-1}$ $q = 49.9$

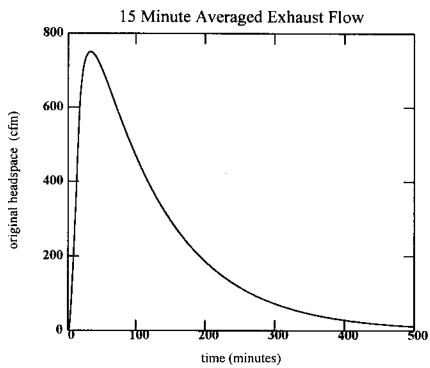
$time := 500$ $n := \frac{time}{1}$ $i := 1..n$ $\frac{15 \cdot n}{time} = 15.0$

$x := x_{save}$ $x := dump(n, time, x, q, hs, c_d, stm)$ $tox_i := x_{i,8} \cdot \frac{ft^3}{sec}$

$max(tox) = 750.9 \cdot \frac{ft^3}{min}$ $x_{n,1} \cdot R - 460 \cdot R = 319.1 \cdot F$ $(x_{n,2} - 1) \cdot atm = 3.5 \cdot psi$ $j := floor\left(n \cdot \frac{325}{time}\right)$

$max(tox) = 0.354 \cdot \frac{m^3}{sec}$ $x_{n,1} \cdot R = 432.8 \cdot K$ $(x_{n,2} - 1) \cdot atm = 24.2 \cdot kPa$ $x_{j,7} = 5.29 \cdot \%$





Increased steam flow

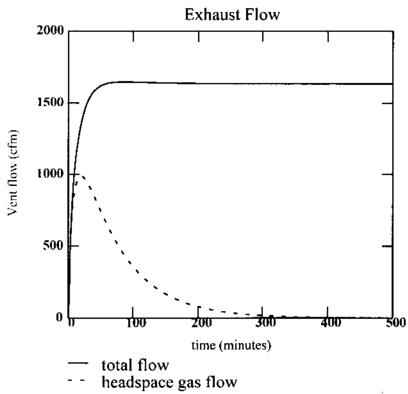
$hs := hsv \cdot ft^3$ $stm := 2 \cdot steam\_flow \cdot \left(\frac{lb}{sec}\right)^{-1}$ $q := 2 \cdot heat\_in \cdot \left(\frac{BTU}{sec}\right)^{-1}$ $c_d := 2 \cdot cv \cdot \sqrt{atm \cdot \frac{lb}{ft^3}} \cdot \left(\frac{ft^3}{sec}\right)^{-1}$

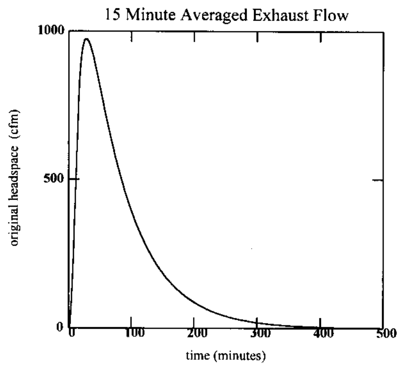
$time := 500$ $n := \frac{time}{1}$ $i := 1 .. n$ $\frac{15 \cdot n}{time} = 15.0$

$x := x_{save}$ $x := dump(n, time, x, q, hs, c_d, stm)$ $tox_i := x_{i,8} \cdot \frac{ft^3}{sec}$

$max(tox) = 974.5 \cdot \frac{ft^3}{min}$ $x_{n,1} \cdot R - 460 \cdot R = 292.6 \cdot F$ $(x_{n,2} - 1) \cdot atm = 7.2 \cdot psi$ $j := floor\left(n \cdot \frac{197}{time}\right)$

$max(tox) = 0.460 \cdot \frac{m^3}{sec}$ $x_{n,1} \cdot R = 418.1 \cdot K$ $(x_{n,2} - 1) \cdot atm = 50.0 \cdot kPa$ $x_{j,7} = 5.01 \cdot \%$





Increased headspace volume

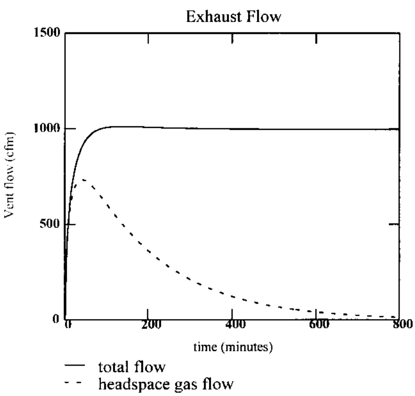
$hs := \text{head\_space}(10 \cdot in) \cdot ft^{-3}$ $\quad stm := \text{steam\_flow} \cdot \left(\frac{lb}{sec}\right)^{-1}$ $\quad q := \text{heat\_in} \cdot \left(\frac{BTU}{sec}\right)^{-1}$ $\quad c_d := 2 \cdot cv \cdot \sqrt{atm \cdot \frac{lb}{ft^3}} \cdot \left(\frac{ft^3}{sec}\right)^{-1}$

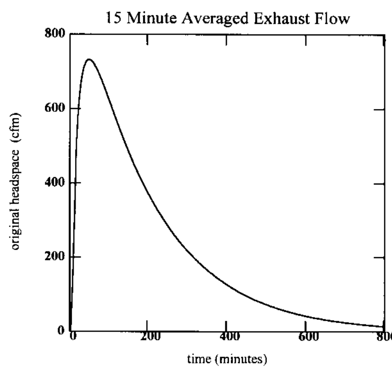
$time := 800 \quad n := \frac{time}{1} \quad i := 1 .. n \quad \frac{15 \cdot n}{time} = 15.0$

$x := x_{save} \quad x_{0,3} := \frac{P_{air} \cdot hs \cdot ft^3}{R_{gas} \cdot T_{air}} \cdot \frac{mw_{air}}{lb} \quad x := \text{dump}(n, time, x, q, hs, c_d, stm) \quad tox_i := x_{i,8} \cdot \frac{ft^3}{sec}$

$\max(tox) = 732.7 \cdot \frac{ft^3}{min} \quad x_{n,1} \cdot R - 460 \cdot R = 291.5 \cdot F \quad (x_{n,2} - 1) \cdot atm = 3.3 \cdot psi \quad j := \text{floor}\left(n \cdot \frac{560}{time}\right)$

$\max(tox) = 0.346 \cdot \frac{m^3}{sec} \quad x_{n,1} \cdot R = 417.5 \cdot K \quad (x_{n,2} - 1) \cdot atm = 22.5 \cdot kPa \quad x_{j,7} = 5.12 \cdot \%$





Decreased headspace volume

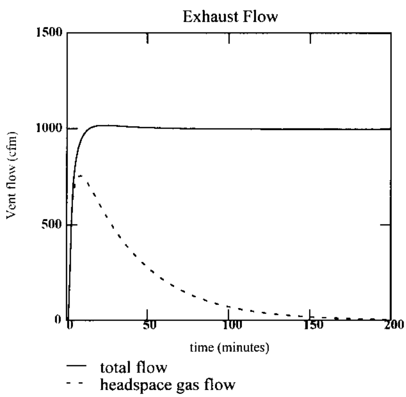
$hs := head\_space(\mathbf{410}\cdot in)\cdot ft^{-3}$ $\quad stm := steam\_flow\cdot\left(\frac{lb}{sec}\right)^{-1}$ $\quad q := heat\_in\cdot\left(\frac{BTU}{sec}\right)^{-1}$ $\quad c_d := \mathbf{2}\cdot cv\cdot\sqrt{atm\cdot\frac{lb}{ft^3}}\cdot\left(\frac{ft^3}{sec}\right)^{-1}$

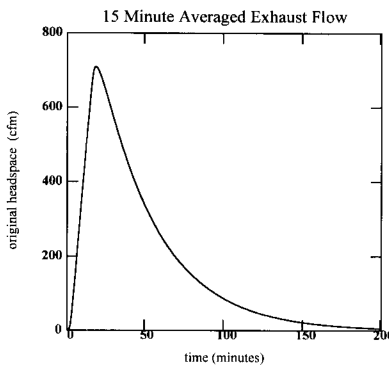
$time := \mathbf{200}$ $\quad n := \frac{time}{\mathbf{1}}$ $\quad i := \mathbf{1}..n$ $\quad \frac{\mathbf{15}\cdot n}{time} = \mathbf{15.0}$

$x := x_{save}$ $\quad x_{0,3} := \frac{P_{air}\cdot hs\cdot ft^3}{R_{gas}\cdot T_{air}}\cdot\frac{mw_{air}}{lb}$ $\quad x := dump(n, time, x, q, hs, c_d, stm)$ $\quad tox_i := x_{i,8}\cdot\frac{ft^3}{sec}$

$max(tox) = \mathbf{709.6}\cdot\frac{ft^3}{min}$ $\quad x_{n,1}\cdot R - \mathbf{460}\cdot R = \mathbf{292.3}\cdot F$ $\quad \left(x_{n,2} - \mathbf{1}\right)\cdot atm = \mathbf{3.3}\cdot psi$ $\quad j := floor\left(n\cdot\frac{\mathbf{113}}{time}\right)$

$max(tox) = \mathbf{0.335}\cdot\frac{m^3}{sec}$ $\quad x_{n,1}\cdot R = \mathbf{417.9}\cdot K$ $\quad \left(x_{n,2} - \mathbf{1}\right)\cdot atm = \mathbf{22.6}\cdot kPa$ $\quad x_{j,7} = \mathbf{5.00}\cdot\%$





Increase the outlet flow resistance

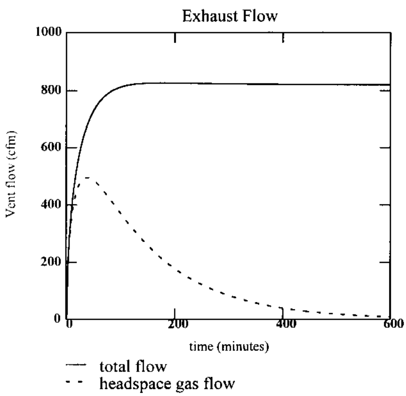
$hs := head\_space(212 \cdot in) \cdot ft^{-3}$ $\quad stm := steam\_flow \cdot \left(\frac{lb}{sec}\right)^{-1}$ $\quad q := heat\_in \cdot \left(\frac{BTU}{sec}\right)^{-1}$ $\quad c_d := cv \cdot \sqrt{atm \cdot \frac{lb}{ft^3}} \cdot \left(\frac{ft^3}{sec}\right)^{-1}$

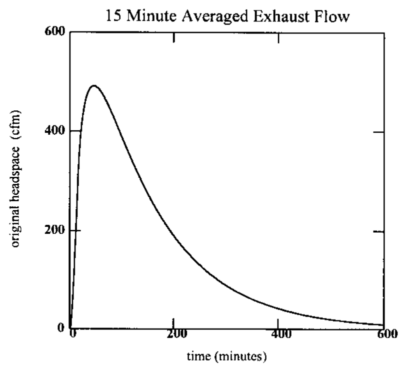
$time := 600$ $\quad n := \frac{time}{1}$ $\quad i := 1..n$ $\quad \frac{15 \cdot n}{time} = 15.0$

$x := x_{save}$ $\quad x_{0,3} := \frac{P_{air} \cdot hs \cdot ft^3}{R_{gas} \cdot T_{air}} \cdot \frac{mw_{air}}{lb}$ $\quad x := dump(n, time, x, q, hs, c_d, stm)$ $\quad tox_i := x_{i,8} \cdot \frac{ft^3}{sec}$

$max(tox) = 491.2 \cdot \frac{ft^3}{min}$ $\quad x_{n,1} \cdot R - 460 \cdot R = 292.4 \cdot F$ $\quad (x_{n,2} - 1) \cdot atm = 7.2 \cdot psi$ $\quad j := floor\left(n \cdot \frac{391}{time}\right)$

$max(tox) = 0.232 \cdot \frac{m^3}{sec}$ $\quad x_{n,1} \cdot R = 418.0 \cdot K$ $\quad (x_{n,2} - 1) \cdot atm = 49.7 \cdot kPa$ $\quad x_{j,7} = 5.17 \cdot \%$





Decrease the outlet flow resistance

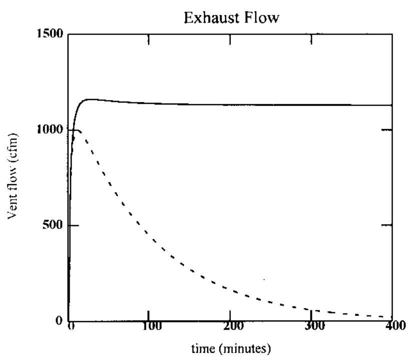
$hs := head\_space(212 \cdot in) \cdot ft^{-3}$ $\quad stm := steam\_flow \cdot \left(\frac{lb}{sec}\right)^{-1}$ $\quad q := heat\_in \cdot \left(\frac{BTU}{sec}\right)^{-1}$ $\quad c_d := 4 \cdot cv \cdot \left[\sqrt{atm \cdot \frac{lb}{ft^3}} \cdot \left(\frac{ft^3}{sec}\right)\right]^{-1}$

$time := 400 \qquad n := \frac{time}{1} \qquad i := 1 .. n \qquad \frac{15 \cdot n}{time} = 15.0$

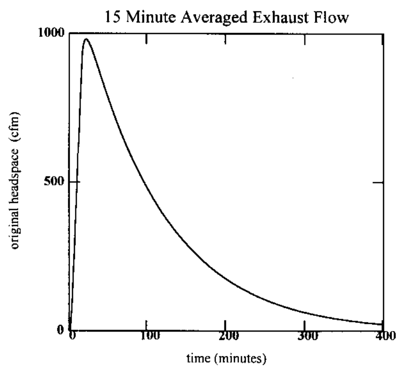
$x := x_{save} \qquad x_{0,3} := \frac{P_{air} \cdot hs \cdot ft^3}{R_{gas} \cdot T_{air}} \cdot \frac{mw_{air}}{lb} \qquad x := dump(n, time, x, q, hs, c_d, stm) \qquad tox_i := x_{i,8} \cdot \frac{ft^3}{sec}$

$max(tox) = 981.2 \cdot \frac{ft^3}{min} \qquad x_{n,1} \cdot R - 460 \cdot R = 290.6 \cdot F \qquad (x_{n,2} - 1) \cdot atm = 1.2 \cdot psi \qquad j := floor\left(n \cdot \frac{305}{time}\right)$

$max(tox) = 0.463 \cdot \frac{m^3}{sec} \qquad x_{n,1} \cdot R = 417.0 \cdot K \qquad (x_{n,2} - 1) \cdot atm = 8.1 \cdot kPa \qquad x_{j,7} = 4.94 \cdot \%$



— total flow
- - headspace gas flow



Steam Properties at 150 F and 290 F (steam tables)

$T_0 := 150 \cdot F + 460 \cdot R$ $\quad P_0 := 3.72 \cdot psi$ $\quad h_0 := 1126.1 \cdot \frac{BTU}{lb}$ $\quad \upsilon_0 := 96.97 \cdot \frac{ft^3}{lb}$

$T_1 := 290 \cdot F + 460 \cdot R$ $\quad P_1 := 18 \cdot psi$ $\quad h_1 := 1187.14 \cdot \frac{BTU}{lb}$ $\quad \upsilon_1 := 27.293 \cdot \frac{ft^3}{lb}$

Comparison of the density using the ideal gas law with the steam tables for:

150 F

$$\frac{\rho_{gas}(P_0, T_0, mw_{steam})^{-1} - \upsilon_0}{\upsilon_0} = 0.7 \cdot \%$$

290 F

$$\frac{\rho_{gas}(P_1, T_1, mw_{steam})^{-1} - \upsilon_1}{\upsilon_1} = -9.1 \cdot \%$$

Heat capacity for water (Cengel and Boles, 1994, Table A-2E)

$$cp_{stm}(T) := \left(7.700 + 0.02552 \cdot 10^{-2} \cdot T + 0.07781 \cdot 10^{-5} \cdot T^2 - 0.1472 \cdot 10^{-9} \cdot T^3\right) \cdot \frac{BTU}{lb\_mole \cdot R} \cdot \frac{lb\_mole}{18.015 \cdot lb}$$

Check of cp of the steam against steam tables

$$\frac{cp_{stm}\left(\frac{T_0}{R}\right) + cp_{stm}\left(\frac{T_1}{R}\right)}{2} = 0.45 \cdot \frac{BTU}{lb \cdot R} \qquad \frac{h_1 - h_0}{(T_1 - T_0)} = 0.44 \cdot \frac{BTU}{lb \cdot R}$$

Heat capacity for air (Cengel and Boles, 1994, Table A-2E)

$$cp_{air}(T) := \left(6.713 + 0.02609 \cdot 10^{-2} \cdot T + 0.03540 \cdot 10^{-5} \cdot T^2 - 0.8082 \cdot 10^{-9} \cdot T^3\right) \cdot \frac{BTU}{lb\_mole \cdot R} \cdot \frac{lb\_mole}{28.97 \cdot lb}$$

$$\frac{cp_{air}\left(\frac{T_0}{R}\right) + cp_{air}\left(\frac{T_1}{R}\right)}{2} = 0.23 \cdot \frac{BTU}{lb \cdot R}$$

Definition of some units for MathCad

$lb\_mole \equiv 1$ $\quad F \equiv R$ $\quad kPa \equiv 10^3 \cdot Pa$ $\quad kJ \equiv 10^3 \cdot joule$

$kg\_mole \equiv \frac{kg}{lb} \cdot lb\_mole$ $\quad C \equiv K$ $\quad in\_H2O \equiv g \cdot 1 \cdot \frac{gm}{cm^3} \cdot 1 \cdot in$

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APPENDIX F

CONSEQUENCE CALCULATION FOR STEAM INTRUSION

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This appendix includes three sets of data and the associated consequence calculations. The first set is for the full tank, the second for the half-full tank, and the third for the empty tank. The example calculations shown in the body of the narrative in Sections 1.5 through 1.9 are for the half-full tank release, at an average flow rate.

Each consequence calculation set presented here includes two pages. The first page of data, and the second page of the calculation results. The calculational methods are described in the preceding sections of the calculational note. These calculations use data from Appendix E.

HALF-FULL TANK SCENARIO

Data and Parameters

Ventilation System Releases — WHC-SD-WM-CN-054, Rev. 0

Q_{1a} = 0.000979 L DST

Q_{1b} = 0.005618 L AWF

Headspace Particulate Loading

Q_{2a} = 0.03116 L DST

Q_{2b} = 0.03116 L AWF

Partition Fraction = 1.00E-08 — WHC-SD-WM-SAR-065, Rev. 0, pg 3.4-225

Headspace Volume

Vol_{DST} = 3.1E+03 m^3 Tank level 5.38 m

Vol_{AWF} = 3.1E+03 m^3 212 in.

Duration and Maximum Flow

t = 335 min 20100 s

$Flow_{max}$ = 0.345 m^3/s

χ/Q Values (s/m^3) — WHC-SD-WM-SARR-016, Rev. 2

	Acute	PM	Chronic	Log. Int.
Onsite	3.41E-02	1.13E-02	4.03E-04	7.51E-03
Offsite	2.83E-05	2.12E-05	1.24E-07	1.13E-05

Breathing Rate

BR = 3.30E-04 m^3/s — Standard man doing light activity

Unit Liter Doses (ULDs) — WHC-SD-WM-SARR-037, Rev. 0

	Inhalation (Sv/L)	Ingestion ($Sv \cdot m^3/s \cdot L$)
DST Liquids	6.10E+03	0.07
DST Solids	5.30E+05	0.48
AWF Liquids	1.40E+03	0.09
AWF Solids	1.70E+06	8.10

Continuous Release Sum-of-Fractions (SOFs) — WHC-SD-WM-SARR-011, Rev. 2

	DST Solids (s/L)	DST Liquids (s/L)	Vapor Space (s/m^3)
10^{+0} to 10^{-2}			
Onsite	1.8E+04	1.0E+04	2.6E+00
Offsite	1.9E+02	8.4E+00	2.3E-03
10^{-2} to 10^{-4}			
Onsite	3.3E+03	7.5E+02	3.3E-01
Offsite	1.5E+01	8.4E+00	2.3E-03
10^{-4} to 10^{-6}			
Onsite	6.3E+02	2.1E+02	7.1E-02
Offsite	2.8E+00	6.2E-01	2.8E-04

HALF-FULL TANK SCENARIO

Radiological Consequences

		HEPA	Particulate	Total
DST	Onsite	1.5E-05	4.7E-04	4.9E-04
	Offsite	2.3E-08	7.3E-07	7.6E-07
AWF	Onsite	2.0E-05	1.1E-04	1.3E-04
	Offsite	3.5E-08	1.9E-07	2.3E-07

Toxicological Exposures

		HEPA	Particulate	Gases	Total
10^{+0} to 10^{-2}					
DST Average Flow	Onsite	4.9E-04	1.6E-02	4.0E-01	4.2E-01
	Offsite	4.1E-07	1.3E-05	3.6E-04	3.7E-04
DST Maximum Flow	Onsite	4.9E-04	1.6E-02	9.0E-01	9.1E-01
	Offsite	4.1E-07	1.3E-05	7.9E-04	8.1E-04
AWF Average Flow	Onsite	2.8E-03	1.6E-02	4.0E-01	4.2E-01
	Offsite	2.3E-06	1.3E-05	3.6E-04	3.7E-04
AWF Maximum Flow	Onsite	2.8E-03	1.6E-02	9.0E-01	9.2E-01
	Offsite	2.3E-06	1.3E-05	7.9E-04	8.1E-04
10^{-2} to 10^{-4}					
DST Average Flow	Onsite	3.7E-05	1.2E-03	5.1E-02	5.2E-02
	Offsite	4.1E-07	1.3E-05	3.6E-04	3.7E-04
DST Maximum Flow	Onsite	3.7E-05	1.2E-03	1.1E-01	1.2E-01
	Offsite	4.1E-07	1.3E-05	7.9E-04	8.1E-04
AWF Average Flow	Onsite	2.1E-04	1.2E-03	5.1E-02	5.3E-02
	Offsite	2.3E-06	1.3E-05	3.6E-04	3.7E-04
AWF Maximum Flow	Onsite	2.1E-04	1.2E-03	1.1E-01	1.2E-01
	Offsite	2.3E-06	1.3E-05	7.9E-04	8.1E-04
10^{-4} to 10^{-6}					
DST Average Flow	Onsite	1.0E-05	3.3E-04	1.1E-02	1.1E-02
	Offsite	3.0E-08	9.6E-07	4.3E-05	4.4E-05
DST Maximum Flow	Onsite	1.0E-05	3.3E-04	2.4E-02	2.5E-02
	Offsite	3.0E-08	9.6E-07	9.7E-05	9.8E-05
AWF Average Flow	Onsite	5.9E-05	3.3E-04	1.1E-02	1.1E-02
	Offsite	1.7E-07	9.6E-07	4.3E-05	4.5E-05
AWF Maximum Flow	Onsite	5.9E-05	3.3E-04	2.4E-02	2.5E-02
	Offsite	1.7E-07	9.6E-07	9.7E-05	9.8E-05

EMPTY TANK SCENARIO

Data and Parameters

Ventilation System Releases — WHC-SD-WM-CN-054, Rev. 0

Q_{1a} = 0.000979 L DST

Q_{1b} = 0.005618 L AWF

Headspace Particulate Loading

Q_{2a} = 0.052188 L DST

Q_{2b} = 0.052188 L AWF

Partition Fraction = 1.00E-08 — WHC-SD-WM-SAR-065, Rev. 0, pg 3.4-225

Headspace Volume

Vol_{DST} = 5.2E+03 m^3 — Tank level 0.25 m

Vol_{AWF} = 5.2E+03 m^3 — 10 in.

Duration and Maximum Flow

t = 560 min — 33600 s

$Flow_{max}$ = 0.346 m^3/s

χ/Q Values (s/m^3) — WHC-SD-WM-SARR-016, Rev. 2

	Acute	PM	Chronic	Log. Int.
Onsite	3.41E-02	1.13E-02	4.03E-04	6.12E-03
Offsite	2.83E-05	2.12E-05	1.24E-07	8.24E-06

Breathing Rate

BR = 3.30E-04 m^3/s — Standard man doing light activity

Unit Liter Doses (ULDs) — WHC-SD-WM-SARR-037, Rev. 0

	Inhalation (Sv/L)	Ingestion ($Sv \cdot m^3/s \cdot L$)
DST Liquids	6.10E+03	0.07
DST Solids	5.30E+05	0.48
AWF Liquids	1.40E+03	0.09
AWF Solids	1.70E+06	8.10

Continuous Release Sum-of-Fractions (SOFs) — WHC-SD-WM-SARR-011, Rev. 2

	DST Solids (s/L)	DST Liquids (s/L)	Vapor Space (s/m^3)
10^{+0} to 10^{-2}			
Onsite	1.8E+04	1.0E+04	2.6E+00
Offsite	1.9E+02	8.4E+00	2.3E-03
10^{-2} to 10^{-4}			
Onsite	3.3E+03	7.5E+02	3.3E-01
Offsite	1.5E+01	8.4E+00	2.3E-03
10^{-4} to 10^{-6}			
Onsite	6.3E+02	2.1E+02	7.1E-02
Offsite	2.8E+00	6.2E-01	2.8E-04

EMPTY TANK SCENARIO

Radiological Consequences

		HEPA	Particulate	Total
DST	Onsite	1.2E-05	6.4E-04	6.6E-04
	Offsite	1.7E-08	9.0E-07	9.1E-07
AWF	Onsite	1.6E-05	1.5E-04	1.6E-04
	Offsite	2.6E-08	2.4E-07	2.6E-07

Toxicological Exposures

		HEPA	Particulate	Gases	Total
10^{+0} to 10^{-2}					
DST Average Flow	Onsite	2.9E-04	1.6E-02	4.0E-01	4.2E-01
	Offsite	2.4E-07	1.3E-05	3.6E-04	3.7E-04
DST Maximum Flow	Onsite	2.9E-04	1.6E-02	9.0E-01	9.2E-01
	Offsite	2.4E-07	1.3E-05	8.0E-04	8.1E-04
AWF Average Flow	Onsite	1.7E-03	1.6E-02	4.0E-01	4.2E-01
	Offsite	1.4E-06	1.3E-05	3.6E-04	3.7E-04
AWF Maximum Flow	Onsite	1.7E-03	1.6E-02	9.0E-01	9.2E-01
	Offsite	1.4E-06	1.3E-05	8.0E-04	8.1E-04
10^{-2} to 10^{-4}					
DST Average Flow	Onsite	2.2E-05	1.2E-03	5.1E-02	5.2E-02
	Offsite	2.4E-07	1.3E-05	3.6E-04	3.7E-04
DST Maximum Flow	Onsite	2.2E-05	1.2E-03	1.1E-01	1.2E-01
	Offsite	2.4E-07	1.3E-05	8.0E-04	8.1E-04
AWF Average Flow	Onsite	1.3E-04	1.2E-03	5.1E-02	5.3E-02
	Offsite	1.4E-06	1.3E-05	3.6E-04	3.7E-04
AWF Maximum Flow	Onsite	1.3E-04	1.2E-03	1.1E-01	1.2E-01
	Offsite	1.4E-06	1.3E-05	8.0E-04	8.1E-04
10^{-4} to 10^{-6}					
DST Average Flow	Onsite	6.1E-06	3.3E-04	1.1E-02	1.1E-02
	Offsite	1.8E-08	9.6E-07	4.3E-05	4.4E-05
DST Maximum Flow	Onsite	6.1E-06	3.3E-04	2.5E-02	2.5E-02
	Offsite	1.8E-08	9.6E-07	9.7E-05	9.8E-05
AWF Average Flow	Onsite	3.5E-05	3.3E-04	1.1E-02	1.1E-02
	Offsite	1.0E-07	9.6E-07	4.3E-05	4.5E-05
AWF Maximum Flow	Onsite	3.5E-05	3.3E-04	2.5E-02	2.5E-02
	Offsite	1.0E-07	9.6E-07	9.7E-05	9.8E-05

FULL TANK SCENARIO

Data and Parameters

Ventilation System Releases — WHC-SD-WM-CN-054, Rev. 0

Q_{1a} = 0.000979 L DST

Q_{1b} = 0.005618 L AWF

Headspace Particulate Loading

Q_{2a} = 0.010548 L DST

Q_{2b} = 0.010548 L AWF

Partition Fraction = 1.00E-08 — WHC-SD-WM-SAR-065, Rev. 0, pg 3.4-225

Headspace Volume

Vol_{DST} = 1.1E+03 m^3 Tank level 10.41 m

Vol_{AWF} = 1.1E+03 m^3 410 in.

Duration and Maximum Flow

t = 113 min 6780 s

$Flow_{max}$ = 0.335 m^3/s

χ/Q Values (s/m^3) — WHC-SD-WM-SARR-016, Rev. 2

	Acute	PM	Chronic	Log. Int.
Onsite	3.41E-02	1.13E-02	4.03E-04	1.16E-02
Offsite	2.83E-05	2.12E-05	1.24E-07	2.20E-05

Breathing Rate

BR = 3.30E-04 m^3/s — Standard man doing light activity

Unit Liter Doses (ULDs) — WHC-SD-WM-SARR-037, Rev. 0

	Inhalation (Sv/L)	Ingestion ($Sv \cdot m^3/s \cdot L$)
DST Liquids	6.10E+03	0.07
DST Solids	5.30E+05	0.48
AWF Liquids	1.40E+03	0.09
AWF Solids	1.70E+06	8.10

Continuous Release Sum-of-Fractions (SOFs) — WHC-SD-WM-SARR-011, Rev. 2

	DST Solids (s/L)	DST Liquids (s/L)	Vapor Space (s/m^3)
10^{+0} to 10^{-2}			
Onsite	1.8E+04	1.0E+04	2.6E+00
Offsite	1.9E+02	8.4E+00	2.3E-03
10^{-2} to 10^{-4}			
Onsite	3.3E+03	7.5E+02	3.3E-01
Offsite	1.5E+01	8.4E+00	2.3E-03
10^{-4} to 10^{-6}			
Onsite	6.3E+02	2.1E+02	7.1E-02
Offsite	2.8E+00	6.2E-01	2.8E-04

FULL TANK SCENARIO

Radiological Consequences

		HEPA	Particulate	Total
DST	Onsite	2.3E-05	2.5E-04	2.7E-04
	Offsite	4.5E-08	4.8E-07	5.3E-07
AWF	Onsite	3.0E-05	5.6E-05	8.6E-05
	Offsite	6.8E-08	1.3E-07	2.0E-07

Toxicological Exposures

		HEPA	Particulate	Gases	Total
10^{+0} to 10^{-2}					
DST Average Flow	Onsite	1.4E-03	1.6E-02	4.0E-01	4.2E-01
	Offsite	1.2E-06	1.3E-05	3.6E-04	3.7E-04
DST Maximum Flow	Onsite	1.4E-03	1.6E-02	8.7E-01	8.9E-01
	Offsite	1.2E-06	1.3E-05	7.7E-04	7.8E-04
AWF Average Flow	Onsite	8.3E-03	1.6E-02	4.0E-01	4.3E-01
	Offsite	7.0E-06	1.3E-05	3.6E-04	3.8E-04
AWF Maximum Flow	Onsite	8.3E-03	1.6E-02	8.7E-01	8.9E-01
	Offsite	7.0E-06	1.3E-05	7.7E-04	7.9E-04
10^{-2} to 10^{-4}					
DST Average Flow	Onsite	1.1E-04	1.2E-03	5.1E-02	5.3E-02
	Offsite	1.2E-06	1.3E-05	3.6E-04	3.7E-04
DST Maximum Flow	Onsite	1.1E-04	1.2E-03	1.1E-01	1.1E-01
	Offsite	1.2E-06	1.3E-05	7.7E-04	7.8E-04
AWF Average Flow	Onsite	6.2E-04	1.2E-03	5.1E-02	5.3E-02
	Offsite	7.0E-06	1.3E-05	3.6E-04	3.8E-04
AWF Maximum Flow	Onsite	6.2E-04	1.2E-03	1.1E-01	1.1E-01
	Offsite	7.0E-06	1.3E-05	7.7E-04	7.9E-04
10^{-4} to 10^{-6}					
DST Average Flow	Onsite	3.0E-05	3.3E-04	1.1E-02	1.1E-02
	Offsite	9.0E-08	9.6E-07	4.4E-05	4.5E-05
DST Maximum Flow	Onsite	3.0E-05	3.3E-04	2.4E-02	2.4E-02
	Offsite	9.0E-08	9.6E-07	9.4E-05	9.5E-05
AWF Average Flow	Onsite	1.7E-04	3.3E-04	1.1E-02	1.2E-02
	Offsite	5.1E-07	9.6E-07	4.4E-05	4.5E-05
AWF Maximum Flow	Onsite	1.7E-04	3.3E-04	2.4E-02	2.4E-02
	Offsite	5.1E-07	9.6E-07	9.4E-05	9.5E-05

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APPENDIX G

PEER REVIEW AND HEDOP REVIEW CHECKLISTS

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CHECKLIST FOR PEER REVIEW

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

[■] [ ] [ ] **Document approved.**

Robert Marusich Robert M Marusich 02/21/1996

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):

Calculation Notes That Support Accident Scenario and Consequence Development for the Steam Intrusion from Interfacing Systems Accident, G.W. Ryan and R.J. Van Vleet, HNF-SD-WM-CN-044 Rev 2, February 1997

Submitted by: R.J. Van Vleet Date Submitted: 2/21/97

Scope of Review: entire document

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.

D.A. Hines [signature] 2/21/97
HEDOP-Approved Reviewer (Printed Name and Signature) Date

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

The 2h (PM) X/Q could have been used in the Full Tank scenario instead of interpolating below 2 hours. The difference is not significant, however, and is in a conservative direction.