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ENGINEERING CHANGE NOTICE

1. ECN 605732

Proj. ECN

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	4. USQ Required?	5. Date
Supplemental ○	D. A. Himes, 403, B4-47, 376-8190	○ Yes ◉ No	04/22/99
Direct Revision ⊗	6. Project Title/No./Work Order No.: Project W-320	7. Bldg./Sys./Fac. No.: Tank Farms	8. Approval Designator: N/A
Change ECN ○	9. Document Numbers Changed by this ECN (includes sheet no. and rev.): HNF-SD-W320-CN-004, Rev 0	10. Related ECN No(s).: N/A	11. Related PO No.: N/A
Temporary ○			
Standby ○			
Supersedure ◉			
Cancel/Void ○			

12a. Modification Work	12b. Work Package No.	12c. Modification Work Completed	12d. Restored to Original Condition (Temp. or Standby ECNs only)
○ Yes (fill out Blk. 12b) ◉ 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 ◉ No

Replacement of Rev. 0 with Rev 1.

The attached Calulation Note documents the originator's analysis only. It shall not be used as the final or sole document for affecting changes to an authorization basis or safety basis for a facility or activity.

14a. Justification (mark one)	14b. Justification Details
Criteria Change ○	Revision 0 has been updated to include more realist assumptions and more detailed analysis.
Design Improvement ◉	
Environmental ○	
Facility Deactivation ○	
As-Found ○	
Facilitate Const. ○	
Const. Error/Omission ○	
Design Error/Omission ○	

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

See attached distribution sheet.

RELEASE STAMP

DATE: JUN 2 1999
STA: 4
HANFORD RELEASE
ID: 58

A-7900-013-2 (10/97)

A-7900-013-1 (06/92)

ENGINEERING CHANGE NOTICE

1. ECN (use no. from pg. 1): 605732

16. Design Verification Required	17. Cost Impact — ENGINEERING	17. Cost Impact — CONSTRUCTION	18. Schedule Impact (days)
○ Yes	Additional ○ $ ____	Additional ○ $ ____	Improvement ○ ____
◉ 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	☐	____	☐
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
Design Authority	N/A		Design Agent		
Cog. Eng.	D. A. Himes [signature]	5/5/99	PE		
Cog. Mgr.	B. E. Hey [signature]	5/5/99	QA		
QA	N/A		Safety		
Safety	N/A		Design		
Environ.	N/A		Environ.		
Other	Peer Review T. B. McCall [signature]	5/5/99	Other		

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

DISTRIBUTION SHEET

To	From	
DE&S Hanford, Project W-320	FDNW, Specialty Engineering	Page 1 of 1
Project Title/Work Order		Date 4/20/99
Consequence Analysis of a Liner Breach Due to Steam Under the Liner		EDT No. N/A
		ECN No. 605732

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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Consequence Analysis of a Liner Breach Due to Steam Under the Liner

D. A. Himes
Fluor Daniel Northwest, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 605732 UC: 510
Org Code: 403 Charge Code: CACN101943
B&R Code: EW3130010 Total Pages:

Key Words: SST, liner breach, W-320, C-106, sluicing

Abstract: Radiological and toxicological consequences are estimated for a steam release from tank C-106 associated with a breach of the tank liner due to formation of steam under the liner after dry-out of the sludge layer in the tank. The consequences are shown to be well below the most restrictive risk guidelines.

6/1/99

Release Approval Date

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RECORD OF REVISION

(1) Document Number	Page
HNF-SD-W320-CN-004	1

(2) Title

Consequence Analysis Of A Liner Breach Due To Steam Under The Liner

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) Initial document released via EDT #625021	DM Hammond	GW Gault 7/27/98
RS 1	Replace Entire Rev. 0 document via ECN #605732	DA Himes 5/5/99	BE Key 5/5/99

A-7320-005 (10/97)

CONSEQUENCE ANALYSIS OF A LINER BREACH DUE TO STEAM UNDER THE LINER

Executive Summary:

If water is present under the bottom liner of a single shell tank, it is possible under certain conditions for the water under the liner to reach saturated conditions and to lift the liner against the hydrostatic pressure of the overlying sludge and supernate waste layers within the tank. Such a condition could cause a steam release from under the tank liner if sufficient localized deformation is produced in the liner to cause a failure (breach). Such a release of steam from under the liner would pass upward through the waste and inject entrained aerosol into the tank void volume. Some portion of the resulting aerosol suspended in the tank void volume could then be released through unfiltered pathways if the tank pressure exceeds atmospheric due to the added steam volume.

This document reports the results of an analysis of the potential for, and possible consequences of, a liner breach and possible steam/particulate release in Tank 241-C-106. The event is postulated to be due to leakage of water under the tank liner and subsequent vaporization of this water due to tank heating in connection with Project W-320 sluicing operations. The major conclusions of this analysis are as follows:

1. The bottom liner of the tank rests on a thick asphalt mat which, at the local prevailing temperature, will tend to flow and fill any local irregularities in the bottom liner, and on a larger scale the bottom liner will act like a thin diaphragm. Voids of any substantial size which could contain liquid at less than the local hydrostatic pressure are therefore not expected to be able to exist under the liner. It is therefore expected that, prior to tank dry-out, any substantial amount of liquid under the liner will have a greater temperature margin to saturation than the sludge above it in the tank. A high heat condition (or loss of cooling) will then initially lead to a steam bump before flashing of steam under the liner. A steam bump will have much greater consequences than a liner breach due to the larger amount of material involved and the lack of resistance to the release (i.e., the liner with a failed weld). The consequences of a liner breach will therefore not add significantly to the consequences of a steam bump, which are already unacceptable. The required controls to prevent the steam bump will also prevent a liner breach under wet conditions.

2. This accident is therefore only of concern after completion of sluicing operations when the sludge layer has been allowed to dry out and temperatures increase due to the loss of evaporative cooling. If such a liner breach event should occur at that point, the analysis shows the radiological and toxicological consequences to be well below the most restrictive guidelines for the unmitigated (i.e., unfiltered release) case. Moreover, the maximum tank pressure from this event was found to be much less than the pressure required to challenge the integrity of the ventilation HEPA filters.

CONSEQUENCE ANALYSIS OF A LINER BREACH DUE TO STEAM UNDER THE LINER

Purpose:

The objective of Project W-320 is to remove most of the soft sludge in Tank 241-C-106 by sluicing with supernate pumped from Tank 241-AY-102 and pumping the suspended sludge back to Tank 241-AY-102. Tank 241-C-106 is on the High Heat Watch List and water must be periodically added to maintain waste temperatures within allowable limits. The immediate goal of the project is to eliminate the need for continued water additions to Tank 241-C-106 and resolve the high-heat safety issue.

The purpose of this document is to analyze the potential for, and possible consequences of, a liner breach and possible steam/particulate release in Tank 241-C-106 due to leakage of water under the tank liner and subsequent vaporization of this water due to tank heating.

Introduction:

If water is present under the bottom liner of a single shell tank, it is possible under certain conditions for the water under the liner to reach saturated conditions and to lift the liner against the hydrostatic pressure of the overlying sludge and supernate waste layers within the tank. This condition occurred in Tank A-105 sometime prior to January 28, 1965 leading to a steam bump-like release on that date (Beard et. al., 1967) albeit at much higher waste temperatures than are envisioned for Tank 241-C-106. Such a condition can cause a release either by causing a failure (breach) in the tank liner with a release of steam from under the liner which passes upward through the sludge and supernate layers, or, if the liner is not breached, by mechanically disturbing the sludge. In either case, if saturated conditions exist in the sludge layer (prevented by controls to prevent steam bump), a steam bump could be triggered in addition to any release from under the liner. Because of the nature of the sluicing operation (i.e., agitation of the sludge and removal of material) Tank 241-C-106 will have to be cooled prior to the start of any sluicing operation so that none of the sludge layer can reach saturated conditions thus precluding a steam bump.

Since it is not expected that a significant amount of sludge (with attendant high heat generation rate) can get under the liner, the downward heat conduction path will be from the hottest part of the sludge layer through the liner and into the ground. In addition, the material under the liner will be under a greater hydrostatic pressure than the sludge hot spot above. This implies that any liquid under the liner will have a greater temperature margin to saturation than the hottest part of the sludge layer. Controls in place to prevent a steam bump during sluicing operations will therefore effectively prevent any steam formation under the liner. The only concern, therefore, is the period after sluicing operations are ended when the residual sludge layer is allowed to dry out and temperatures increase due to the loss of evaporative cooling.

Temperature conditions in Tank 241-C-106 were previously (in the 1970's) much more severe (with boiling of the waste) than they are now. It is therefore assumed that any water initially present under the liner has long since been evaporated and that there is presently no significant amount of water under the liner (Bander, et. Al., 1994). The present concern is that the sluice stream could strike the tank liner at a spot weakened by corrosion causing a penetration of the liner with consequent penetration of liquid behind the liner. Supernate could then make its way down to the base mat and possibly seep under the tank.

Dry-out of a residual sludge layer in the tank would then (a) decrease the hydrostatic pressure under the tank liner (thereby lowering the saturation temperature of any supernate under the liner) and (b) heat up due to the elimination of the primary evaporative cooling mode. Supernate, if present, under the liner could then flash to steam, deforming and possibly breaching the liner. Such a steam release through a breach in the liner could then entrain waste from the dry sludge layer and pressurize the tank with a resulting release to the environment.

Description of System:

Tank 241-C-106 is 23 m (75 ft) in diameter and is fabricated of reinforced concrete with a carbon steel liner on the bottom and sides. The bottom of the tank is dished 31 cm (12 in) deep at the center and rests on a 5 cm (2 in) layer of asphalt composition material which in turn rests on a reinforced concrete slab 15 cm (6 in) thick. The bottom liner and transition (between the bottom plate and side walls) are 0.95 cm (3/8) thick while the side walls vary from 0.95 to 0.64 cm (3/8 to 1/4 in) thick. The liner extends 5.5 m (18 ft) up the wall to the base of the dome which is unlined reinforced concrete 38 cm (15 in) thick. During construction, the outside wall of the liner was covered with an asphalt composition membrane and was then used as the inside form for the pouring of the concrete wall. Differential thermal expansion will expand the liner slightly more than the concrete and so will tend to compress the intervening waterproof membrane. It is expected, therefore, that the joint between the liner and the concrete will be very tight with little, if any, space for water intrusion. The top of the liner is covered with lead flashing to prevent moisture from entering any space between the liner and the concrete wall. The center of the dome (inside) rises 4.1 m (13 ft 7 in) above the top of the liner.

When sluicing is not in progress the tank is ventilated by the 296-P-16 ventilation system. For this project an inlet air chiller system has been installed which can provide inlet air flow at a constant 4.4°C (40°F). This system maintains confinement by providing a negative pressure on the tank and sweeps out any flammable gases in addition to providing cooling. It is expected that this system will be maintained in operation after the residual sludge layer is allowed to dry out upon completion of sluicing operations.

Scenario Development:

Because of the history of Tank 241-C-106, which includes periods when heat generation rate and waste temperatures were far higher than they are today, it is assumed that any water under the tank liner has long since been dissipated and no significant voids exist under the liner. The only identified potential source of water under the liner now is leakage down the outside of the liner caused by sluicing operations inside the tank. The sluicing nozzle is mechanically prevented from aiming sluicing fluid near the top of the liner so that the only remaining possibility is the impact of sluicing fluid against a weak spot on the liner wall which, for example, could have been thinned by corrosion. Supernate could then be forced, or leak, through the opening in the liner and seep down to the base mat where it could penetrate under the liner forcing a slight separation between the tank liner and the asphalt sealer. The pressure head required to force this separation would have to at least exceed the hydrostatic pressure under the liner since the liner would behave in this case like a thin, flexible diaphragm. The hydrostatic pressure under the liner is determined by the thickness of the sludge layer and the density of the sludge plus the thickness of the overlying supernate and the density of the supernate plus the weight of the liner per unit area.

In terms of an equivalent height of supernate (specific gravity = 1.2) the hydrostatic head under the liner is, for example, given by (0.3 m) + (1 m)(1.4/1.2) + (0.0095 m)(7.83/1.2) = 1.53 m for 0.3 m (about 1 ft) of supernate, 1 m of sludge (specific gravity = 1.4), and a 3/8 in (0.0095 m) liner assuming a density of 7.83 g/cm^3 for carbon steel. This compares to the corresponding waste height in the tank of 1.3 m. Thus in this example the liner penetration would have to be at least 22 cm (23 cm column minus 1 cm for the liner) above the top of the waste to provide a supernate column outside the liner just able to counter the hydrostatic pressure under the liner. As the sludge layer becomes thinner the required height above the top of the waste would become less until at zero sludge thickness (at the edge of the tank), the only difference would be due to the weight of the liner. Note, however, that in order to reach the center of the bottom liner, an additional 0.3 m (12 in) of sludge hydrostatic pressure must be overcome due to the dished bottom. This corresponds to an additional (0.3 m)(1.4./1.2) = 35 cm of supernate column.

Two possibilities exist for the position of the initiating penetration through the liner. First, the penetration could be above the liquid level in the tank. In such a case sufficient head could be available, if the penetration is high enough, to force liquid under the bottom of the liner. However only a relatively small amount of liquid could be introduced through the penetration since the only source would be the moving sluice stream itself. Second, the penetration could be below the liquid level in the tank, in which case supernate could continue to leak through the liner penetration, but there would not be sufficient head to force liquid under the liner. As the waste level in the tank is lowered during the sluicing operations, a liner penetration which was initially below the liquid level may rise above the liquid and a column of liquid behind the liner and below the penetration could become sufficient to cause penetration under the bottom liner as the tank level falls. The amount of penetration would still be severely limited, however, since no additional liquid could be introduced behind the liner except by direct impact of the sluice stream against the penetration.

There is no mechanism to inject a significant amount of sludge (with its attendant heat generation) under the liner so the liquid under the liner cannot be at a higher temperature than the adjacent sludge above it in the tank. In addition, since the bottom liner will behave as a diaphragm (at least away from the edge) the hydrostatic pressure below the liner will always be higher than in the sludge above it. While there is liquid in the tank, therefore, a saturation condition in any liquid below the liner implies supersaturated conditions in the sludge layer. Such a condition would be conducive to a tank bump concurrent with any steam release through a breach in the liner and would just add to the consequences of the tank bump. The consequences of a tank bump, alone, are unacceptable. The tank bump event is therefore prevented by controls which would also very effectively prevent a steam flash below the liner which could add to the consequences of a bump. The liner breach accident is therefore considered not to be a concern while there is still liquid In the tank and tank bump prevention controls are in affect.

After sluicing operations are concluded, the periodic water additions will stop and any residual sludge layer will be allowed to dry out and heat up. With the tank in this condition any liquid under the liner could reach saturated conditions and begin to form steam. This would cause a lifting of the liner only if the path by which the liquid entered the space under the liner had become blocked. Note that in this condition (dry sludge layer) lifting of the liner would not by itself decrease the pressure under the liner since the residual sludge layer would just lift with it. A steam flash would therefore occur only if the blocked path to the side of the tank suddenly opened or if the liner breached depressurizing the steam bubble under the liner. If neither event occurred and the steam could exit slowly as it was generated out along the edge of the tank and up along the side liner (considered most likely) or if the tank cooled and the steam recondensed, the bottom liner would be lowered (like a diaphragm) back to its initial position and there would be no significant release and no consequence.

In the unlikely event that the liquid entrance path had become sealed and sufficient liquid was available to produce enough steam to severely strain the liner, the liner could breach. In this case a substantial stream release could occur through the dry sludge layer and possibly challenge the ventilation exhaust HEPA filter due to over-pressure. This is the worst-case unmitigated release identified for this scenario. A structural analysis (Bander, et al., 1994) has shown that the steam produced by vaporizing about 26 L (7 gal) of water could generate about 22 kPa (3.2 psi) differential pressure across the liner forming a blister with a volume of roughly 40 m^3 for the conditions postulated in his analysis. It was calculated that if this blister occurred adjacent to the weld joining the liner bottom to the transition at the side of the tank it could breach the liner at the weld. Note, however that this location places the blister away from the center (high temperature region) of the tank.

Major Assumptions:

1. Due to the high-heat history of Tank 241-C-106, it is assumed that any water which was initially under the tank liner has long since dissipated, and that there is now no significant amount of water or voids under the liner.

2. Despite the compression stress on the liner-asphalt membrane-wall interface and the required position of the liner failure above the waste liquid level, it is assumed that 30.5 L (8.1 gal) of liquid are able to penetrate under the liner below the tank. This is the minimum amount calculated to be necessary to be able to cause a liner breach near the bottom-wall

transition given the final sludge depth assumed in this analysis. The assumption of no more than 30.5 L of liquid under the liner is considered conservative in view of the difficulty of injecting liquid behind the liner to the depth necessary to float the liner and provide space for liquid ingress. The consequences of the liner breach would be roughly proportional to the amount of liquid reaching saturated conditions under the liner.

3. In order for the steam release to occur, it is assumed that dry waste temperatures near the edge of the tank are sufficient to vaporize water under the liner even though the waste will be thinner and, therefore, much cooler at that location than near the middle where the waste is thicker due to the dished bottom of the tank. It is considered much less likely that liquid could reach the hotter area near the center of the liner due to the higher hydrostatic pressure there. In addition, there is no mechanism to breach the liner at locations far from the bottom-wall transition.

4. A maximum sludge depth of 0.914 m (3 ft) at the end of sluicing operations was assumed for this analysis. Increasing the final sludge depth would increase the hydrostatic pressure under the liner leading to a slight increase in the mass of saturated steam necessary to fail the liner. In addition, the tank headspace volume would decrease slightly causing a small increase in the aerosol concentration in the headspace air. Overall, the consequences of the release are relatively insensitive to the final sludge depth. Increasing the sludge depth from 0.792 m (2.6 ft) to 0.914 m (3.0 ft), for example produced no change in the event consequences to two significant figures.

Release Calculation:

The maximum amount of sludge which could be left in the tank after completion of sluicing operations was calculated to be 0.79 m (2.6 ft) in a thermal analysis by Bander, et al. (1996) based on worst-case heating conditions. Without ventilation this amount of dry sludge could result in temperatures above saturation. In reality the amount of dry sludge left in the tank will likely be much less. For purposes of this analysis, however, a final sludge depth of 0.914 (3.0 ft) was conservatively assumed. Based on the assumed maximum of 0.792 m (2.6 ft) of dry sludge left in the tank, the pressure under the tank liner can be determined as follows:

$$p_t = \rho\, g\, h(1kPa/1000Pa) + p_{atm}$$

Where:

p_t	= pressure at bottom of sludge layer (kPa)
p_{atm}	= Atmospheric pressure (101 kPa [14.7 psi])
ρ	= bulk density of dry solid waste (kg/m^3)
g	= acceleration of gravity (9.81 m/s^2)
h	= depth of residual sludge layer (m).

Assuming the wet sludge to have a density of about 1.4E+3 kg/m^3 (Brevick 1996), with a conservatively estimated interstitial liquid content of about 0.3, implies that the dry sludge (at the same bulk volume with the water removed only from the interstitial spaces leaving any dissolved material) would have a density of about 1.4E+3 kg/m^3 – (0.3)(1.0E+3 kg/m^3) = 1.1E+3 kg/m^3. During the drying process the depth of the sludge layer would probably shrink, but the weight per unit area on the tank bottom would be the same. The resulting pressure at the bottom of the dried sludge layer is 111 kPa (16.1 psi). Adding the 22 kPa (3.2 psi) differential pressure required to breach the liner yields 133 kPa (19.3 psi) in the steam blister under the liner.

The temperature and specific volume of saturated steam at this pressure can be derived from standard steam tables. For a saturation pressure of 133 kPa (19.3 psi) the corresponding temperature is 108°C (226°F) and the vapor specific volume is 1.30 m^3/kg (20.8 ft^3/lb). In order to produce a 40 m^3 blister, and hence the strain which could fail the transition weld, (40 m^3)/(1.30 m^3/kg) = 30.8 kg of steam under the liner (corresponding to 30.8 L [8.1 gal] of initial liquid water) would be necessary in this case. When the liner breaches, the steam is assumed to vent directly through the dried sludge layer allowing the blister to initially depressurize to essentially 1 atmosphere. The specific volume of steam at 1 atmosphere is 1.67 m^3/kg (26.8 ft^3/lb). The steam is assumed to expand adiabatically (i.e., at constant specific entropy) into the tank void space (while remaining saturated) to a specific volume of 1.67 m^3/kg (26.8 ft^3/lb) while cooling to 100°C (212°F). A look at a Mollier chart shows that about 1.5% of the steam will condense during the isentropic expansion from 133 kPa (19.3 psi) to 1 atmosphere. This condensed moisture will form a water aerosol which will be entrained in the steam flow. The effect of this small amount of condensation is considered insignificant and was ignored. The total volume of the steam expelled at 1 atmosphere is then (1.67 m^3/kg)(30.8 kg) = 51.4 m^3.

As the steam is vented from the 40 m^3 blister under the liner, it is expected that the liner would collapse back to its initial position against the concrete base since the only force supporting the liner was the pressure of the steam and since, at least away from the edge of the tank, the liner would act like a thin diaphragm. Near the edge of the tank, however, a residual cavity could remain under the liner due to yielding of the liner near the transition. Since, however, the volume of the blister under the liner is exactly compensated for by a reduction in the tank void volume due to the displacement of the dried sludge layer, the void volume under the liner plus the tank void volume is a constant equal to the tank void volume with no liner displacement. In either case, therefore, the net addition to the tank void volume would be only 51 m^3 – 40 m^3 = 11 m^3 of steam.

The internal height of the tank wall is 5.5 m so that the assumed residual dried sludge depth of 0.91 m leaves 4.6 m of free space plus the volume of the dome. Using the standard formula for the volume of a cylinder and the tank radius of 11.5 m (37.5 ft), the free space below the dome is 1910 m^3. Assuming the dome to be a section of a sphere, the volume is given by :

$$V = \frac{1}{6}\pi h\left(h^2 + 3r^2\right)$$

Where h and r are the height and radius of the dome, respectively. For h= 4.1 m and a tank radius of 11.5 m, the resulting volume is 1030 m^3. The resulting tank free volume is 2940 m^3. This does not include any interstitial void volume within the dried sludge layer since this volume may not be fully accessible from the tank void space. No allowance was made for any volume associated with a residual void volume under the liner since this would be exactly compensated for by the corresponding reduction in the tank void volume.

Assuming the bounding case where the steam release occurs very rapidly, the net 11 m^3 volume addition to the tank void space increases the pressure by a factor (2940 m^3 + 11 m^3)/(2940 m^3) = 1.00374. Assuming the tank void to be at essentially atmospheric pressure, the tank pressure would increase by 0.00374 atm or 38 Pa (1.5 in WG). Note that this is an extremely conservative bounding case since the steam would have to enter the tank void space through a relatively small penetration in the tank liner. The penetration would most likely be a narrow crack along a few inches of weld permitting only a slow escape rate of the steam into the tank so that no noticeable pressurization would occur. The minimum static pressure loading required to fail a standard HEPA filter is about 9.0 kPa (36 in WG) (DOE 1994). In cases like this, however, it is usual to assume that the HEPA filter could fail at 2.5 kPa (10 in WG) to conservatively allow for dynamic loading effects. Even the bounding case of a very rapid steam release would produce only a small fraction of this value. Conversely, a steam release from about 200 L (54 gal) of water under the liner would be required to challenge the HEPA filters even under the worst possible conditions. Because of the considerations already discussed, the presence of 200 L of liquid under the tank liner is not considered credible in this case.

In this event, therefore, the HEPA filter would not be challenged and there would be no significant release. One of the initiators for this type of event, however, could be a loss of ventilation where the tank void space could actually be pressurized to slightly greater than atmospheric. Since the pit cover blocks and other penetrations into the tank are not airtight, some release could occur through these penetrations instead of the HEPA filters and some aerosols could be carried along The maximum sustainable (quasi-stable) aerosol concentration in air after several minutes is usually assumed to be 100 mg/m^3 (NRC 1982, ANSI 1981, BNWL 1975). In short-time transient situations, however, 10 times this concentration, or 1 g/m^3, is normally assumed. This is very conservative in this situation since the pressure of the venting steam is relatively low. If the entire 51 m^3 of depressurized steam vents through the dry sludge layer (i.e., the void space under the liner collapses), and picks up a maximum transient loading of 1 g/m^3 which then mixes uniformly with the air in the tank void, the resulting concentration in the void space would be (51 g)/(2940 m^3) = 1.7E-2 g/m^3. It is further assumed that the entire 11 m^3 net release from the tank exits by way of unfiltered pathways carrying this aerosol load. The total release under the worst conditions is then (11 m^3)(1.7E-2 g/m^3) = 0.19 g or of SST solids. The corresponding volume of reconstituted sludge is just (0.19 g)/(1.1E+3 g/L) = 1.7E-4 L.

If the tank ventilation system is operating, this event would not be expected to be able to pressurize the tank above 1 atm since the tank is normally maintained at approximately –1.5 in WG and the steam release from under the liner would take place over some period of time and not instantaneously. If, however, the tank were to be momentarily pressurized above 1 atm, there could be some unfiltered release and the consequences would be intermediate between the filtered and unfiltered release cases. For the filtered release, the 1.7E-4 L of SST solids estimated above would be reduced by the transmission fraction of two HEPA filters in series, i.e., 1E-5 (Elder, et al. 1986, ANSI 1981) for a filtered release of 1.7E-9 L of SST solids.

These are extremely conservative estimates because the venting through the dried sludge layer occurs near the bottom of the tank while the release pathways are near the top of the tank. Complete mixing in the large head space would therefore be unlikely before the venting of gas from the tank was complete. The concentration of material in the gas vented from the tank would therefore be less than in the vapor vented through the sludge layer. Note that this event would be far less energetic than a steam bump and no bulk movement of sludge into the risers would occur.

This unfiltered release scenario is exactly equivalent to the event without HEPA filtration, and so can be used to test the importance of the HEPA filters as an unmitigated release.

Consequence Calculations:

Radiological and toxicological consequences of the mitigated (filtered) and unmitigated (unfiltered) releases were calculated using the methodology described in WHC-SD-WM-SARR-16, Rev. 2, Tank Waste Compositions and Atmospheric Dispersion Coefficients for Use in Safety Analysis Consequence Assessments (Van Keuren, 1996a). Doses calculated are 50-year committed effective dose equivalents (CEDE). Ingestion doses are for a 24-hour uptake period by the offsite receptor before evacuation and/or interdiction of food supplies. Inhalation doses (onsite or offsite) are given by:

$$D_{inh} = (Q)(X/Q')(BR)(ULD_{inh})$$

where

D_{inh} = inhalation dose (Sv)
Q = release in terms of liters of waste (L)
X/Q' = atmospheric dispersion coefficient (s/m^3)
BR = receptor breathing rate (m^3/s)
ULD_{inh} = inhalation unit liter dose (Sv/L).

The offsite ingestion dose is given by:

$$D_{ing} = (Q)(X/Q')(ULD_{ing})$$

where

D_{ing} = ingestion dose (Sv)
ULD_{ing} = ingestion unit liter dose (Sv•m^3/s•L).

For short duration ground level releases, the atmospheric dispersion coefficients (X/Q') are 3.41E-2 s/m^3 and 2.83E-5 s/m^3 for the onsite and offsite receptor, respectively. The breathing rate is the light activity breathing rate equal to 3.3E-4 m^3/s. The inhalation and ingestion unit liter doses were obtained from WHC-SD-WM-SARR-037, Rev. 0, Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations (Cowley 1996). For SST solids the ULDs are 2.2E+5 Sv/L and 4.1E+0 Sv•m^3/s•L for inhalation and ingestion, respectively.

The toxicological consequences are calculated in terms of a sum of fractions (SOF) of all the toxic components of the mix. (Each "fraction" is the ratio of the component concentration at the receptor to the concentration limit for that component for the given accident frequency.) In a manner analogous to unit liter doses, unit release (rate) SOFs have been calculated for various tank waste mixes for each accident frequency and receptor location. Such unit release (rate) SOFs come in two varieties: "puff" SOFs intended for essentially instantaneous releases such as explosions and "continuous release" SOFs for releases with durations of more than about 10 seconds. In this case the release is expected to have a duration of more than 10 seconds so the use of continuous release SOFs is appropriate. To obtain the SOF for a given release, the unit release rate SOF for the particular mix, receptor and accident frequency is simply multiplied by the source release rate. For a short duration release (i.e., less than 15 minutes) of concentration sensitive (as opposed to dose sensitive) toxins, the total release is averaged over 15 minutes to obtain the release rate. The time-averaged release rates for the filtered and unfiltered cases are then 1.9E-12 L/s and 1.9E-7 L/s, respectively.

The unit release rate SOFs for SST solids were obtained from WHC-SD-WM-SARR-011, Rev 2, Toxic Chemical Considerations for Tank Farm Releases (Van Keuren 1996b). The continuous release SST solids SOFs for Anticipated Frequency Class (1 – 10^{-2}/y) are 4.0E+4 s/L and 9.4E+1 s/L for the onsite and offsite receptor, respectively.

Results:

The resulting radiological doses and SOFs (Anticipated Frequency Class) for the unfiltered release (i.e., no ventilation or ventilation with no filtration) were calculated as follows:

Onsite dose:

Inhalation → (1.7E-4 L)(3.41E-2 s/m^3)(3.3E-4 m3/s)(2.2E+5 Sv/L) = 4.2E-4 Sv (4.2E-2 rem)

Offsite dose:

Inhalation → (1.7E-4 L)(2.83E-5 s/m^3)(3.3E-4 m^3/s)(2.2E+5 Sv/L) = 3.5E-7 Sv (3.5E-5 rem)

Ingestion → (1.7E-4 L)(2.83E-5 s/m^3)(4.1E+0 Sv•m^3/s•L) = 2.0E-8 Sv (2.0E-6 rem)

Total → 3.7E-7 Sv (3.7E-5 rem)

Onsite SOF:

→ (1.9E-7 L/s)(4.0E+4 s/L) = 7.6E-3

Offsite SOF:

→ (1.9E-7 L/s)(9.4E+1 s/L) = 1.8E-5

The results for the filtered case would just be less than the unfiltered case above by a factor equal to the transmission fraction of the HEPA filters (1E-5).

Results:

The results of the unmitigated liner breach with a maximum depth dried sludge layer are as follows:

Table 1: Consequences of Unmitigated Liner Breach in Tank 241-C-106

Hazard	Receptor	Dose/Exposure	Evaluation Guideline (Anticipated)
Radiological	Onsite	4.2E-1 mSv	5 mSv
	Offsite	3.4E-4 mSv	1 mSv
Toxicological	Onsite	7.6E-3	1
	Offsite	1.8E-5	1

Note that the consequences were compared to evaluation guidelines for Anticipated Frequency Class because they are most restrictive. The frequency of this event has not been quantified, but is qualitatively expected to be in the Extremely Unlikely (F1) Frequency Class based on the extreme assumptions necessary to allow the event to occur.

Conclusions:

The development of the scenario and consequences for this accident revealed the following conclusions:

1. The bottom liner of the tank rests on a thick asphalt mat which, at the local prevailing temperature, will tend to flow and fill any local irregularities in the bottom liner, and on a larger scale the bottom liner will act like a thin diaphragm. Voids of any substantial size which could contain liquid at less than the local hydrostatic pressure are therefore not expected to be able to exist under the liner. It is therefore expected that, prior to tank dry-out, any substantial amount of liquid under the liner will have a greater temperature margin

to saturation than the sludge above it in the tank. A high heat condition (or loss of cooling) will then initially lead to a steam bump before flashing of steam under the liner. A steam bump will have much greater consequences than a liner breach due to the larger amount of material involved and the lack of resistance to the release (i.e., the liner with a failed weld). The consequences of a liner breach will therefore not add significantly to the consequences of a steam bump, which are already unacceptable. The required controls to prevent the steam bump will also prevent a liner breach under wet conditions.

2. Because the side wall of the tank liner was covered by an asphalt composition membrane and used as the inside form for pouring the concrete wall, and since subsequent tank heat-up has caused the liner to thermally expand against the concrete tank wall, the joint between the liner and the tank wall is expected to be very tight with little or no room for water to enter.

3. If water does penetrate between the liner and the tank wall, the point of penetration must be well above the liquid level in the tank to provide sufficient head to cause liquid to be forced under the bottom liner. The amount of liquid which can make its way through the liner is then severely restricted to that caused by direct impingement of the sluice stream on the liner penetration. Given the required location of the penetration and the tightness of the liner-wall joint, it is considered unlikely that a significant amount of liquid could enter by this path.

4. The minimum amount of liquid under the liner bottom necessary to breach the liner was calculated to be about 30 L (8 gal) (a very large amount in view of the above conclusions). The mechanism for the liner breach under such conditions is a failure of the weld at the wall-bottom transition, which implies formation of the blister well away from the center of the tank where temperatures would be much lower than in the center of the tank. Such a blister in the high heat location near the center would not fail the liner, which at that location would behave like a thin, flexible membrane.

5. This accident is only of concern after completion of sluicing operations when the sludge layer has been allowed to dry out and temperatures increase due to the loss of evaporative cooling. If such a liner breach event should occur at that point, the analysis shows the radiological and toxicological consequences to be well below the most restrictive guidelines for the unmitigated (i.e., unfiltered release) case. Moreover, the maximum tank pressure from this event was found to be much less than the pressure required to challenge the integrity of the ventilation HEPA filters.

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FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: HNF-SD-W320-CN-004, REV1
Title: CONSEQUENCE ANALYSIS OF A LINER BREACH DUE TO STEAM UNDER THE LINER
Author: D. A. HIMES
Date: MAY 1999
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 applicable guides or other standards.
[ ]		[✓] **	Review calculations, comments, and/or notes are attached.
[✓]	[ ]	[ ]	Traceability → Document will be placed in document control
[✓]	[ ]	[ ]	Document approved (for example, the reviewer affirms the technical accuracy of the document).

T.B. McCALL   T.B. McCall   5/5/99
Reviewer (printed name and signature)   Date

* All "no" responses must be explained below or on an additional sheet.

** 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.

FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

HEDOP REVIEW CHECKLIST

Document Reviewed: HNF-SD-W320-CN-004, Rev 1
Title: Consequence Analysis of a Liner Breach Due to Steam Under the Liner
Author: D.A. Himes
Date: May 1999
Scope of Review: entire document

Yes	No*	NA		
[✓]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[✓]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[ ]	[ ]	[✓]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[✓]	4.	Receptor locations were selected according to HEDOP recommendations.
[✓]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[✓]	[ ]	[ ]	6.	Hanford site data were used.
[✓]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[ ]	[ ]	[✓]	8.	The analysis is consistent with HEDOP recommendations.
[ ]	[ ]	[✓]	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.)
[✓]	[ ]	[ ]	10.	Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "no" responses must be explained below or on an additional sheet.

Brit E. Hey [signature] — HEDOP-Approved Reviewer (printed name and signature)

5/5/99 — Date

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