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Accident Consequence Calculations for Project W-058 Safety Analysis

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Abstract: This document describes the calculations performed to determine the accident consequences for the W-058 safety analysis. Project W-058 is the replacement cross site transfer system (RCSTS), which is designed to transport liquid waste between the 200 W and 200 E areas. Calculations for RCSTS safety analyses used the same methods as calculations for the Tank Waste Remediation System (TWRS) Basis for Interim Operation (BIO) and its supporting calculation notes. Revised analyses were performed for the spray and pool leak accidents since the RCSTS flows and pressures differ from those assumed in the TWRS BIO.

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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

Accident consequence analyses have been performed for Project W-058, the Replacement Cross Site Transfer System (RCSTS), using the assumption and analysis techniques developed for the Tank Remediation Waste System (TWRS) Basis for Interim Operation (BIO) (WHC, 1996). Most potential accident involving the RCSTS are bounded by the TWRS BIO analysis. However, the spray leak and pool leak scenarios require revised analyses since the RCSTS design utilizes larger diameter pipe and higher pressures than those analyzed in the TWRS BIO. Also the volume of diversion box and vent station are larger than that assumed for the valve pits in the TWRS BIO, which effects results of sprays or spills into the pits. The revised analysis for the spray leak is presented in Section 2, for the above ground spill in Section 3, for the subsurface spill forming a pool in Section 4, and for the subsurface pool remaining subsurface in Section 5. The conclusions from these sections are summarized below.

1.2 SUMMARY OF RESULTS

The events without controls all show risk guidelines are exceeded, which indicates controls are required. This is to be expected as the BIO reaches the same conclusion for these events. The radiological dose and toxic consequences with controls for accidents involving the RCSTS are summarized in Table 1-1 along with the results for the same accident scenarios given in the BIO.

The RCSTS accidents all show that risk guidelines are met with controls for events specifically analyzed for the RCSTS. Doses with controls are lower for sprays in the diversion box and vent station than the doses in similar BIO analyses due to closure of the doors and the presence of a HEPA filter.

There are efforts underway to refine the TWRS BIO and TWRS FSAR spray leak analysis which are expected to produce lower doses. These refinements will be incorporated into the RCSTS analysis as they are included in the BIO.

The analysis in the BIO for an underground leak producing an above ground spray conclude that the controls are effective in preventing this accident. The same conclusion applies to the RCSTS.

The above ground leak resulting in a pool for the RCSTS is modelled as a leak to the diversion box and vent station. These analyses produce doses under the risk guidelines for the RCSTS. The spill is assumed to form an aerosol within the box due to splashing. The results are similar to the spray. The fact the diversion box is sealed and most of the release will be through a HEPA filter reduces the RCSTS doses. Doses from pools in the valve pits or flush system are bounded by the TWRS BIO analysis.

The below ground spill forming an above ground pool is modelled in the BIO as a spill of SST liquids and solids at 50 gpm. The spill with the SST liquids is judged to be an "anticipated event" due to the age of the lines and the fact that the lines are in direct contact with the ground. The RCSTS spill is modelled using RCSTS flows (140 gpm) and the limiting ageing waste mix. The event was determined to be "extremely unlikely" in the RCSTS PSAR (WHC 1995). The doses with controls meet the risk guidelines for extremely unlikely events.

Table 1-1. Summary of Results - with Controls.

Accident	RCSTS	Risk guideline	TWRS BIO	Risk guideline
Spray Leak in Diversion Box				
Onsite Does (mSv)	5.1 E-01	5.0 E+00	4.1 E+01	5.0 E+00
Offsite Dose (mSv)	4.5 E-04	1.0 E+00	3.7 E-02	1.0 E+00
Toxic - Onsite	1.0 E-03	1.0 E+00	8.1 E-02	1.0 E+00
Toxic - Offsite	5.4 E-06	1.0 E+00	4.2 E-04	1.0 E+00
Spray Leak in Valve Pit - Results Are Identical to TWRS BIO Results				
Spray Leak in Vent Pit				
Onsite Dose (mSv)	2.1 E-01	5.0 E+00	4.1 E+01	5.0 E+00
Offsite Dose (mSv)	2.0 E-04	1.0 E+00	3.7 E-02	1.0 E+00
Toxic Onsite	3.5 E-04	1.0 E+00	8.1 E+00	1.0 E+00
Toxic Offsite	1.8 E-06	1.0 E+00	4.2 E-04	1.0 E+00
Spray Leak in Underground Piping - Controls Prevent Event From Occurring				
Above Ground Leak Leading to a Pool - Leak in Valve Pit Results are Enveloped by BIO analysis.				
Above Ground Leak Leading to a Pool - Leak in Diversion Box				
Onsite Dose (mSv)	9.3 E-01	5.0 E+01	2.3 E+00	5.0 E+00
Offsite Dose (mSv)	1.8 E-03	1.0 E+00	4.4 E-03	1.0 E+00
Toxic - Onsite	6.8 E-04	1.0 E+00	1.2 E-03	1.0 E+00
Toxic - Offsite	3.6 E-06	1.0 E+00	6.1 E-06	1.0 E+00
Above Ground Leak Leading to a Pool - Leak to Existing Vent Station Results are Enveloped by the TWRS BIO Analysis				
Above Ground Leak Leading to a Pool - Flush system Results are Enveloped by the TWRS BIO Analysis				
Subsurface Leak Leading to a Pool				
Onsite Dose (mSv)	5.2 E+01	1.0 E+02	4.2 E+00	5.0 E+00
Offsite Dose (mSv)	3.6 E+01	4.0 E+01	6.5 E-01	1.0 E+00
Toxic - Onsite	4.1 E-04	1.0 E+00	2.4 E-03	1.0 E+00
Toxic - Offsite	8.1 E-04	1.0 E+00	5.4 E-03	1.0 E+00
Subsurface Leak Remaining Subsurface				
Onsite Dose (mSv)	1.7 E+00	1.0 E+02	6.4 E-01	5.0 E+00
Offsite Dose	0.0	4.0 E+01	0.0	1.0 E+00
Toxic Onsite and Offsite	0.0	1.0 E+00	0.0	1.0 E+00

The subsurface leak remaining subsurface produces higher doses than the TWRS BIO since the RCSTS flow is higher than the flow modelled for the TWRS BIO, and the AWF mix, which contains higher radioactive inventories, is used for the RCSTS. The event is classified as "extremely unlikely" for the RCSTS. However, even the more restrictive "anticipated" event risk guidelines are met.

2.0 SPRAY LEAK FOR THE RCSTS SYSTEM

2.1 INTRODUCTION TO SPRAY LEAK ANALYSIS

Pressurized transfers of tank material have the potential that a leak could result in a spray. Spray leaks can produce large radiological doses since a spray is an effective means of producing aerosols that can transport radioactive material to a receptor. Spray leaks in structures are analyzed in Section 5.3.2.20 of the TWRS BIO (WHC,1996) and the supporting calculation note, WHC-SD-WM-CN-048, (Hall 1996a). Several of the conditions assumed in the TWRS BIO differ from those in the RCSTS. The significant differences relative to spray leaks are summarized in Table 2-1.

Table 2-1. Comparison of TWRS BIO and RCSTS Spray Leak Assumptions.

	TWRS BIO	RCSTS
Maximum pressure	2,068 kPa 300 psi	8,970 kPa (1,300 psi)
Maximum Pit/Diversion Box Volume	333 m^3	622 m^3
Pipe Diameter	5.08 cm (2 in.)	7.62 cm (3 in.)

The maximum pump pressure is taken from pump curves which are given in Appendix A. The peak head of 2,900 ft (1,257 psig) was rounded up to 1,300 psig for this analysis. Other data on the RCSTS in Table 2-1 was taken from the RCSTS PSAR (WHC, 1995).

The limiting TWRS BIO spray leak accident consequence analysis has been repeated with the RCSTS conditions given above. The evaluation methodology and assumption on source term, accident duration, etc, are the same as in the TWRS BIO. The only differences in the analysis assumptions are those listed in Table 2-1.

Two other spray leak conditions are also considered: a spray leak in an existing pump pit and spray leak outside a pit. The spray leak in the diversion box is discussed in Section 2.2 and the spray leak in an existing box in Section 2.3 and the spray leak outside the valve pits and diversion boxes in Section 2.4.

2.2 SPRAY LEAK IN THE DIVERSION BOX

2.2.1 Accident Analysis - No Controls

2.2.1.1. Release Quantities Assuming No Controls The SPRAY (Hey 1994) computer code was used to determine the flow rate and particle size distribution for the unmitigated event. SPRAY determines the total and respirable release rate based on the dimensions of the orifice or crack that is postulated to occur. The calculation performed in WHC-SD-WM-CN-048 (Hall 1996a) for the TWRS BIO was repeated with identical parameters except the pressure and pipe dimensions were used for the RCSTS. An equivalent crack depth of 0.549 cm (0.216 in), which is the thickness of 3 inch schedule

40 pipe, was assumed. The leak was assumed to occur at the maximum deadhead pressure of the RCSTS pump of 8,970 kpa (1300 psi). A crack length of 5.08 cm (2 inches) was assumed. SPRAY performs iterative calculations to determine the crack width that will produce the maximum respirable releases. The SPRAY output is shown in Appendix B.

The results indicate that the maximum respirable release (< 15 μm) is 2.83 x 10^{-5} m^3/s (0.449 gpm). Over a 12 hour time period (the exposure time for the onsite individual), the release is 1223 L. The release over a 24 hour time period (the exposure time for the offsite individual) is 2,446 L.

2.2.1.2 Dose and Toxic Calculation Methods The inhalation doses are given by:

$$D = Q \times X/Q' \times BR \times ULD_{inh} \quad (1)$$

where Q = Material released (L)
X/Q' = Atmospheric dispersion coefficient (s/m^3)
BR = Breathing rate (m^3/s)
ULD_{inh} = Inhalation unit liter dose (Sv/L)

The ingestion doses for the offsite receptor are given by

$$D = Q \times X/Q' \times ULD_{ing} \quad (2)$$

where Q = Material released (L)
X/Q' = Atmospheric dispersion coefficient (s/m^3)
ULD_{ing} = 24 hour ingestion unit liter dose (m^3-Sv/L-s)

The parameters used for the unmitigated analysis are taken from (WHC 1996a) and are shown in Table 2-2.

Table 2-2. Parameters Used in Dose Calculation.

X/Qs (s/m^3)	
onsite	5.54 x 10^{-3} (12 hour)
offsite	4.62 x 10^{-6} (24 hour)
Breathing rate	(m^3/s)
	3.3 x 10^{-4} light activity (onsite)
	2.7 x 10^{-4} 24 hour average (offsite)

ULD (inhalation) - 5.6 x 10^5 Sv/L (for 33% solid/67 %liquid AWF Mix)
ULD (ingestion) - 2.7 Sv-m^3/L-s(for 33%/67% liquid AWF mix)

ULDs are derived based on methods described in Van Keuren 1996a ULDS for this mix are taken from Hall 1996a.

Toxic release consequences are computed by multiplying the sum of fractions for the toxic mix times the release rates. Products less than or equal to 1 indicate risk guidelines are met. The sum of fraction (SOF) approach is derived in Van Keuren 1996b and SOFs are derived for this mix in Hall 1996a. SOFs depend on frequency category and are shown in Table 2-3 for the 33% solids/67% DST mix. AWF tanks are grouped with other DST tanks for toxic evaluations.

Table 2-3 Sum of Fraction of Risk Guidelines for Unit Releases of Toxic Chemicals for 33% Solids/67% Liquid DST Mix for Continuous Releases

Maximum Individual Location	Accident Frequency		
	10^{-2} to 1	10^{-4} to 10^{-2}	10^{-6} to 10^{-4}
Onsite	1.3 E+04	1.6 E+03	3.5 E+02
Offsite	6.8 E+01	1.1 E+01	1.3 E+00

2.2.1.3 Spray Leak Dose Calculation - No Controls The onsite dose from Equation 1 is:

$D = (1.22 \times 10^3 \text{ L}) (5.54 \times 10^{-3} \text{ s/m}^3) (3.3 \times 10^{-4} \text{ m}^3\text{/s}) (5.6 \times 10^5 \text{ Sv/L})$

$D = 1.25 \times 10^3 \text{ Sv}$

The offsite dose is the sum of the inhalation and ingestion doses. The inhalation dose is

$D_{inh} = (2.44 \times 10^3 \text{ L}) (4.62 \times 10^{-6} \text{ s/m}^3) (2.7 \times 10^{-4} \text{ m}^3\text{/s}) (5.6 \times 10^5 \text{ Sv/L})$

$D_{inh} = 1.70 \text{ Sv}$

The ingestion dose from Equation 2 is:

$D_{ing} = (2.44 \times 10^3 \text{ L}) (4.62 \times 10^{-6} \text{ s/m}^3) (2.7 \text{ Sv-m}^3\text{/L-s})$

$= 0.030 \text{ Sv}$

The total offsite dose is the sum of the inhalation and ingestion doses or

$D_{total} = 1.70 + 0.030 = 1.73 \text{ Sv} = 173 \text{ rem}.$

The event is classified as anticipated. The risk guidelines for anticipated events are 5 mSv (0.5 rem) onsite and 1 mSv (0.1 rem) offsite. Both doses exceed the risk acceptance guidelines, indicating that mitigation is required.

2.2.1.4 Toxic Release Evaluation - No Controls Toxic releases are evaluated in the same manner as was done in the TWRS BIO. The method is described in Van Keuren 1996b. The comparison to risk guidelines for toxic releases is calculated based on the release rate. The maximum respirable release rate is 0.028 L/s from Section 2.2.1.1. Non-respirable particles can cause skin and eye irritation but the respirable particles produce the dominant toxic effect. The toxic consequences are therefore evaluated based on the respirable release rate. The sum of fraction of the toxicological risk acceptance criteria for this mix is 1.3×10^4 s/L onsite and 68 s/L offsite.

The toxicological comparison to risk guidelines is:

Onsite 0.028 L/s x 1.3 x 10^4 s/L = 360
Offsite 0.028 L/s x 68 s/L = 1.9

Products higher than 1 indicate that risk guidelines are not met. The risk guidelines are therefore not met for the unmitigated releases of toxic materials from a spray leak.

2.2.2 Spray Leak In Diversion Box - With Controls

2.2.2.1 Release Quantities With Controls The mitigation feature is that the diversion box doors are closed and sealed. Leak testing will be performed to confirm the door seal. The flow path will be through a HEPA filter, which will reduce the release to the atmosphere. It is assumed that the maximum release of material from the diversion box occurs at a concentration of 100 mg/m^3. This is the maximum concentration of aerosol that the air will sustain for long periods under steady state conditions (ANSI, 1980). The release from the pit will occur in two stages:

1. Initially air containing aerosols is expelled from the pit due to the pit temperature and humidity increase from the spray.

2. The air containing aerosol will continue to be displaced due to liquid filling the box after equilibrium temperature and humidity conditions are reached.

Conditions are different for this scenario than those analyzed in the TWRS BIO in terms of temperature rise and the filtered release.

Initial conditions in the TWRS BIO for the valve pits was assumed to be 30 °F and 15% relative humidity. The spray was assumed to result in a peak temperature in the diversion box of 120 °F, and 100% relative humidity. The diversion box has a large volume, with significant volume below ground. The box also contains the booster pumps which will produce significant heat in the cell during pumping. An initial temperature of 60 °F is therefore assumed. Because of the large size of the box, a lower average post spray equilibrium temperature would be expected than in the valve pit. An equilibrium condition of 100 °F and 100% humidity is assumed. From psychometric tables (see WHC-SD-WM-CN-048), the specific volume of air at the initial conditions is 0.82 m^3/kg and is 0.95 m^3/kg at the equilibrium spray conditions. The fraction of the pit volume expelled due to increased temperature humidity is

$$\text{Volume expansion} = (0.95/0.82) - 1 = 0.16$$

Given a volume of the diversion box of 622 m^3, the volume of the release is

$$\text{Volume released} = (622\ m^3)\ (0.16) = 99\ m^3$$

The release due to the air density change is assumed to occur during the first hour of the accident.

The release due to displacement of air in the pit from the continued release of aerosols is assumed to occur at a rate of 20 gpm (4.6 m^3/h). The release rate will depend on the crack size, and liquid flow, and pressure, but 20 gpm is assumed in the TWRS BIO to be the maximum rate that will produce significant aerosol generation. A larger release rate would produce a liquid spill that will not contribute significantly to the generation of aerosols.

The solution sprayed is assumed to 'consist of a mixture 1/3 AWF solids and 2/3 AWF liquids, which produces the largest doses. The density of the solution is assumed to be 1.4×10^6 mg/L.

The onsite release is based on 12 hours maximum individual exposure, and the offsite release is based on a 24 hour maximum individual exposure. The total release is the release from the increase in temperature and humidity during the first hour plus the release due to displacement of the aerosol for the next 11 hours onsite or the next 23 hours offsite.

The majority of the release will be through the HEPA filter. The filter efficiency of a HEPA is 0.999. The presence of moisture can degrade filter performance and a study by Ricketts et al. 1986 indicated that a filter in high moisture can increase the penetration of aerosols by one order of magnitude. A filter efficiency of 0.99 is used in this analyses, i.e., 1% of the aerosol is passed through the filter.

The material released during the first hour is the air displaced times the aerosol density of 100 mg/m^3, or

$$Q\ (1st\ hr) = [99\ m^3 + (4.6\ m^3/h)(1\ h)][100\ mg/m^3][1/(1.4 \times 10^6\ mg/L)][0.01]$$

$$= 7.40 \times 10^{-5}\ L$$

The material released in the next 11 hours is the release rate after equilibrium conditions are reached times 11 hours, or

$$Q\ (11\ hrs) = (4.6\ m^3/h)\ (11\ hr)\ (100\ mg/m^3)\ (1/(1.4 \times 10^6\ mg/L)(0.01))$$

$$= 3.61 \times 10^{-5}\ L$$

For the offsite calculation, the total release is the release in the first hour plus the release in the next 23 hours. The release in the first hour is the same as above. The release for the next 23 hours is:

$$Q(23\ hrs) = (4.6\ m^3/h)\ (23\ hr)\ (100\ mg/m^3)\ (1/(1.4 \times 10^6\ mg/L))(0.01)$$

$$Q(23\ hrs) = 7.56 \times 10^{-5}\ L$$

Moisture can degrade filter performance to the point where filter failures occur. The total moisture absorbed in the filter can be computed by looking at the total displacement of aerosol in the pit. The total moisture reaching the filter is the release due to temperature and humidity change plus the release from displacement due to flow into the diversion box.

$$Moisture = [(99\ m^3 + (4.6\ m^3/h))\ (23\ h)\ 100\ mg/m^3/1.4 \times 10^6\ mg/L](0.99)$$
$$= 0.014\ L.$$

The total quantity of water absorbed on the filter is quite small. Filter testing for reactor loss of coolant accident conditions have indicated filters will operate with continuous high flows with significantly higher water absorption (Ricketts et al. 1986).

2.2.2.2 Dose Calculation Methods The doses are calculated using the same basic methodology as described for the unmitigated events, i.e., Equations 1, and 2.

The parameters used in the dose calculation, which are taken from WHC-SD-WM-CN-048 (Hall, 1996a), are shown in Table 2-4.

Table 2-4. Parameters for the Spray Leak Dose Calculation with Controls.

X/Qs (s/m^3)	
onsite	0.0341 (1 hour)
	5.74×10^{-3} (11 hours)
offsite	2.83×10^{-5} (1 hour)
	4.74×10^{-6} (23 hours)
Breathing rate (m^3/s)	
	3.3×10^{-4} light activity
	2.7×10^{-4} 24 hour average

ULD (inhalation) - 5.6×10^5 Sv/L (for 33% solids/67 %liquid AWF Mix)
ULD (ingestion) - 2.7 $Sv\text{-}m^3/L\text{-}s$

2.2.2.3 Dose Calculation With Controls The onsite inhalation dose is:

$$D(1\ hour) = (7.40 \times 10^{-5}\ L)\ (0.0341\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

$$= 4.66 \times 10^{-4}\ Sv$$

$$D(11\ h) = (3.61 \times 10^{-5}\ L)(5.74 \times 10^{-3}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(5.6 \times 10^5\ Sv/L)$$

$$= 3.83 \times 10^{-5}\ Sv$$

$$\text{Total onsite inhalation dose} = 4.66 \times 10^{-4} + 3.83 \times 10^{-5} = 5.0 \times 10^{-4}\ Sv$$

$$= 0.051\ rem$$

The offsite inhalation dose is:

$$D(1\ hour) = (7.40 \times 10^{-5}\ L)(2.83 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(5.6 \times 10^5\ Sv/L)$$

$$= 3.87 \times 10^{-7}\ Sv$$

$$D(23\ h) = (7.56 \times 10^{-5}\ L)(4.74 \times 10^{-6}\ s/m^3)(2.7 \times 10^{-4}\ m^3/s)(5.6 \times 10^5\ Sv/L)$$

$$= 5.41 \times 10^{-8}\ Sv$$

The offsite ingestion doses are given by

$$D(1\ hour) = (7.40 \times 10^{-5}\ L)(2.83 \times 10^{-5}\ s/m^3)(2.7\ m^3\text{-}Sv/L\text{-}s)$$

$$= 5.65 \times 10^{-9}\ Sv$$

$$D(23\ hr) = (7.56 \times 10^{-5}\ L)(4.74 \times 10^{-6}\ s/m^3)(2.7\ m^3\text{-}Sv/L\text{-}s)$$

$$= 9.66 \times 10^{-10}\ Sv$$

The total offsite dose is the sum of the offsite inhalation and ingestion doses.

Total Offsite Dose $= 4.5 \times 10^{-7}$ Sv $= 4.5 \times 10^{-5}$ rem

The event is classified as anticipated. The risk guidelines for anticipated events are 5 mSv (0.5 rem) onsite and 1 mSv (0.1 rem) offsite. Risk guidelines are met both offsite and onsite (see Chapter 3, Table 3-25).

2.2.2.4 Toxic Release Evaluation With Controls The maximum release rate occurs during the initial temperature and humidity increase in the diversion box. The toxic consequences are calculated based on a 15 minute peak average, which is the recommended method to compare to risk guidelines for prolonged releases with changing rates (Van Keuren 1996b). The release due to temperature and humidity increase is averaged over the first 15 minutes and the aerosol release due to displacement added. The total release is 99 m^3 due to thermal expansion plus the 4.6 m^3/hour times 15 minutes divided by 60 minutes. The release rate is multiplied by the effective filter transmission factor of 0.01. The release rate of the aerosol is therefore:

$$RR = \frac{[99\ m^3 + 4.6\ m^3/h(15 min/60\ min/h][100\ mg/m^3][1/(1.4 \times 10^6\ mg/L)][0.01]}{15\ min \times 60\ s/min}$$

$RR = 7.9 \times 10^{-8}$ L/s

Sum of fractions are given in Table 2-3
Onsite sum of fraction $= 1.3 \times 10^4$ s/L
Offsite sum of fractions = 68 s/L

$(7.9 \times 10^{-8}$ L/s) $(1.3 \times 10^4$ s/L) = 0.00103
$(7.9 \times 10^{-8}$ L/s) (68 s/L) $= 5.4 \times 10^{-6}$

Products less than one indicate that risk guidelines are met. The risk guidelines for the toxicological consequences for the mitigated event are therefore met.

2.3 SPRAY LEAK IN VALVE PIT

The spray leak due to a spray in the valve pit assumes that a spray from the line occurs in a smaller volume valve pit. A valve pit size of 15 m^3 (which is used in the TWRS BIO) will be used. RCSTS pressures and flows will be assumed.

2.3.1 Spray in Valve Pit - No Controls

The spray analysis with no controls presented in Section 2.2.1 took no credit for the diversion box or any other mitigating feature. The doses and toxic results are therefore the same for this case as presented in Section 2.2.1. The radiological doses are over the risk guidelines and controls are therefore required.

2.3.2 Spray in Valve Pit - With Controls

The analysis of spray leak will be the same as presented in Section 2.2.2 except the valve pit dimensions are different, and the releases do not pass through a HEPA filter. The analysis assumes an aerosol concentration of 100 mg/m^3. The release is initially due to the increase in temperature and humidity in the pit. Once equilibrium conditions are reached, aerosol is displaced by the liquid flow. The analysis assumptions are summarized in Table 2-5 below. The TWRS BIO assumptions are also summarized in the same table.

Table 2-5. Assumptions for Spray for RCSTS in Standard Valve Pit.

Assumption	RCSTS Analysis	TWRS BIO
Valve Pit Volume	15 m^3	15 m^3
Initial Conditions	30 °F and 15% humidity	30 °F and 15% humidity
Equilibrium Spray Conditions	120 °F and 100% humidity	120 °F and 100% Humidity
Maximum Spray producing aerosol	20 gpm	20 gpm
Limiting source term	33%/67% solids/liquids aging waste mix	33%/67% solids/liquids aging waste mix
Density of solution	1.4 kg/m^3	1.4 kg/m^3

The assumptions for the RCSTS in Table 2-5 are identical to the TWRS BIO assumptions. The pipe dimensions, pressures and flows do not affect the results since the pit is assumed to reach equilibrium conditions of 100 mg/m^3 and the maximum flow that will produce a spray is assumed to be 0.00126 m^3/s (20 gpm). The dose calculation for this accident would therefore be identical to that of the limiting case for the TWRS BIO.

2.4 SPRAY LEAK IN VENT STATION

The vent station design is similar to that of the diversion box including the sealed doors and HEPA filter except the volume is smaller and the vent station does not contain the booster pumps. The volume is 207 m^3.

2.4.1 Spray in Vent Station No Controls

The accident scenario described in Section 2.2.1 indicated no credit for pit dimensions. The consequences for a spray in a vent station with no controls are the same as the spray in the diversion box. The doses exceed risk guidelines. Controls are therefore required.

2.4.2 Spray in Vent Station With Controls

The controls are the same as for the diversion box, sealed doors and presence of a HEPA filter on the vent line. The quantity released is developed in the same manner as for the diversion box in Section 2.2.2.1.

Given a volume of the vent station of 207 m^3, the volume of the release due to temperature and humidity increase is

$$\text{Volume released} = (207\ m^3)\ (0.16) = 33\ m^3$$

The release due to the air density change is assumed to occur during the first hour of the accident.

The release due to displacement of air in the pit from the continued release of aerosols is assumed to occur at a rate of 20 gpm (4.6 m^3/h). The release rate will depend on the crack size, and liquid flow, and pressure, but 20 gpm is assumed in the TWRS BIO to be the maximum rate that will produce significant aerosol generation. A larger release rate would produce a liquid spill that will not contribute significantly to the generation of aerosols.

The material released during the first hour is one percent of the air displaced times the aerosol density of 100 mg/m^3, or

$$Q\ (1st\ hr)=[33\ m^3+(4.6\ m^3/h)(1\ h)][100\ mg/m^3][1/(1.4\times 10^6\ mg/L)](0.01)$$

$$= 2.69\times 10^{-5}\ L$$

The material released in the next 11 hours is the release rate after equilibrium conditions are reached times 11 hours times one percent, or

$$Q\ (11\ hrs) = (4.6\ m^3/h)\ (11\ hr)\ (100\ mg/m^3)\ (1/(1.4\times 10^6\ mg/L)(0.01))$$

$$= 3.61\times 10^{-5}\ L$$

For the offsite calculation, the total release is the release in the first hour plus the release in the next 23 hours. The release in the first hour is the same as calculated above. The release for the next 23 hours is:

$$Q(23\ hrs) = (4.6\ m^3/h)\ (23\ hr)\ (100\ mg/m^3)\ (1/(1.4\times 10^6\ mg/L))(0.01)$$

$$Q(23\ hrs) = 7.56\times 10^{-5}\ L$$

2.4.2.1 Dose Calculation With Controls The onsite inhalation dose is:

$$D(1\ hour) = (2.69\times 10^{-5}\ L)\ (0.0341\ s/m^3)\ (3.3\times 10^{-4}\ m^3/s)\ (5.6\times 10^5\ Sv/L)$$

$$= 1.7\times 10^{-4}\ Sv$$

$$D(11\ h)= (3.61\times 10^{-5}\ L)(5.74\times 10^{-3}\ s/m^3)(3.3\times 10^{-4}\ m^3/s)(5.6\times 10^5\ Sv/L)$$

$$= 3.83\times 10^{-5}\ Sv$$

Total onsite inhalation dose $= 1.70\times 10^{-4} + 3.83\times 10^{-5} = 2.1\times 10^{-4}$ Sv
$= 0.021$ rem

The offsite inhalation dose is:

$$D(1\ hour) = (2.69 \times 10^{-5}\ L)(2.83 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(5.6 \times 10^5\ Sv/L)$$

$$= 1.41 \times 10^{-7}\ Sv$$

$$D(23\ h) = (7.55 \times 10^{-5}\ L)(4.74 \times 10^{-6}\ s/m^3)(2.7 \times 10^{-4}\ m^3/s)(5.6 \times 10^5\ Sv/L)$$

$$= 5.41 \times 10^{-8}\ Sv$$

The offsite ingestion doses are given by

$$D(1\ hour) = (2.69 \times 10^{-5}\ L)(2.83 \times 10^{-5}\ s/m^3)(2.7\ m^3\text{-}Sv/L\text{-}s)$$

$$= 2.06 \times 10^{-9}\ Sv$$

$$D(23\ hr) = (7.55 \times 10^{-5}\ L)(4.74 \times 10^{-6}\ s/m^3)(2.7\ m^3\text{-}Sv/L\text{-}s)$$

$$= 9.66 \times 10^{-10}\ Sv$$

The total offsite dose is the sum of the offsite inhalation and ingestion doses.

Total Offsite Dose $= 2.0 \times 10^{-7}$ Sv $= 2.0 \times 10^{-5}$ rem

The event is classified as anticipated. The risk guidelines for anticipated events are 5 mSv (0.5 rem) onsite and 1 mSv (0.1 rem) offsite. Risk guidelines are met both offsite and onsite.

2.4.2.2 Toxic Release Evaluation With Controls The maximum release rate occurs during the initial temperature and humidity increase in the vent station. The toxic consequences are calculated based on a 15 minute peak average, which is the recommended method to compare to risk guidelines for prolonged releases with changing rates (Van Keuren 1996b). The release due to temperature and humidity increase is averaged over the first 15 minutes and the aerosol release due to displacement added. The total release is 33 m^3 due to thermal expansion plus the 4.6 m^3/hour times 15 minutes divided by 60 minutes. The release rate is multiplied by the effective filter efficiency of 0.01. The release rate of the aerosol is therefore:

$$RR = \frac{[33\ m^3 + 4.6\ m^3/h(15 min/60\ min/h][100\ mg/m^3][1/(1.4 \times 10^6\ mg/L)][0.01]}{15\ min \times 60\ s/min}$$

$$RR = 2.7 \times 10^{-8}\ L/s$$

Toxic sum of fractions are given in Table 2-3
Onsite sum of fraction = 1.3×10^4 s/L
Offsite sum of fractions = 68 s/L

$(2.7 \times 10^{-8}$ L/s$)(1.3 \times 10^{4}$ s/L$) = 3.52 \times 10^{-4}$
$(2.7 \times 10^{-8}$ L/s$)(68$ s/L$) = 1.8 \times 10^{-6}$

Products less than one indicate that risk guidelines are met. The risk guidelines for the toxicological consequences for the mitigated event are therefore met.

2.5 SPRAY LEAK IN THE LIFT STATION (244 A VALVE PIT)

2.5.1 No Controls

The results are the same as for the unmitigated diversion box accident. Controls are therefore required.

2.5.2 Controls

The spray accidents for the RCSTS are analyzed differently because of the high pressures and large volumes in the box. The lift station is not a large volume pit and the pit is at the end of the RCSTS line and will not experience high pressures during normal flow. In the event of the pump dead-heading into the line, there are rupture disks and pressure relief valves to relieve the pressure. Only a low pressure spray can occur in the Lift Station, and this scenario is enveloped by the analysis presented in the TWRS BIO.

2.6 SPRAY LEAK FROM UNDERGROUND PIPING

The TWRS BIO also considers a spray leak from underground piping outside valve pits and the diversion boxes in Section 5.3.2.21. A spray from a underground line requires both an uncovering of the line and a crack or hole in the line. An excavation accident is the most credible method of obtaining these conditions.

2.6.1 Spray Leak From Underground Piping - No Controls

The spray analysis with no controls presented in Section 2.2.1 took no credit for the diversion box or any other mitigating feature. The doses and toxic results are therefore the same for this case as presented in Section 2.2.1. The radiological doses are over the risk guidelines and controls are therefore required.

2.6.2 Spray Leak From Underground Piping - With Controls

Section 5.3.2.21 of the TWRS BIO indicates that controls will be effective in preventing a spray leak from an underground pipe due to an excavation accident. No consequences are therefore presented in the TWRS BIO. Controls to prevent a spray leak from underground piping are listed in the TWRS BIO and are summarized below.

1. An approved excavation permit is required when excavating where waste transfer lines exist.

2. Physical marking of surface is required where waste transfer line exist

3. Hand digging only is allowed within 5 ft of piping.

4. Waste transfer shall not be conducted in lines located within approximately 15 ft of ongoing excavation activities.

5. The excavation supervisor shall ensure that communication system are available at the job site and that the excavation crew knows how to contact tank farm operation immediately in the event of a leak or other abnormal situation.

6. Waste transfer through uncovered lines shall be prohibited unless approved radiation protection controls are established.

7. Mass balances shall be performed periodically.

The TWRS BIO should be consulted for more details.

3.0 SURFACE LEAK RESULTING IN A POOL

The bounding accident selected for an above ground spill to form a pool is an overflow of a process pit due to a misroute of waste through an open nozzle. This scenario results in the highest potential leak rate, and largest surface pool of all the potential surface leak accidents. Process pits considered are the valve pit, the diversion box, and the vent station.

The unmitigated surface spill accident is analyzed in Section 5.3.2.18 of the TWRS BIO and Hall, 1996b. The accident scenario assumes a leak of 300 gpm for 12 hours, producing a total spill of 216,000 gallons. The spill is assumed to overflow the pit. Doses are calculated from the splashing in the pit, resuspension from the surface of the pool, resuspension from the liquid surface in the pit, and resuspension of the contaminated soil after the liquid soaks in. Doses are calculated for direct shine from the pool, gamma scatter from the air and inhalation doses from material suspended in the air.

3.1 LEAK RESULTING IN A SPILL TO AN EXISTING VALVE PIT

The potential exists for an above ground spill to occur in the RCSTS system. However the maximum flow rate in the RCSTS is 0.0088 m^3/s (140 gpm). The maximum pool size is 100,800 gallons, which is smaller than the 216,000 gallons assumed in the TWRS BIO. The TWRS BIO assumed the limiting AWF source term. For the same pit volumes, the TWRS BIO analysis would bound the RCSTS spills. No further analysis of a spill to an existing valve pit will therefore be performed.

3.2 LEAK RESULTING IN A SPILL TO THE DIVERSION BOX

3.2.1 Spill With No Controls

The large volume of the diversion box effects the analysis results. The TWRS BIO analysis assumes an initial release due to splashing in the pit, a venting from the liquid pool in the pit after splashing stops, and a release from the liquid pool after the liquid overflows the pit and, finally, a resuspension from the ground after the pool liquid has soaked into the ground. The volume of the diversion box is 622 m^3, and a 12 hour leak at 0.0088 m^3/s will produce only a 380 m^3 spill volume. The spill will therefore not overflow the diversion box. The splashing may however continue for a longer period as the TWRS BIO scenario assumes the splashing stops after the pit is half full. The splashing is assumed to continue for the full period of the spill for this scenario. Analysis assumptions are shown in Table 3-1.

Table 3-1. Spill Analysis Assumptions.

Flow rate 0.0088 m^3/s (140 gpm)
Duration of spill 12 hours
Release contained within diversion box.
Splashing continues for the full 12 hours

The release fraction during the splashing phase of the accident is given in Hall 1996b as derived from Section 3.2.3.2 of the DOE handbook on release fractions (DOE 1994) as 4×10^{-5}. The quantity released is determined by multiplying the total amount spilled times this release fraction. The release from splashing in the pit is:

$$Q = (0.0088\ m^3/s)(12\ h)(3600\ s/h)\ (4 \times 10^{-5})$$

$$Q = 0.0152\ m^3 = 15.2\ L$$

A second contributor is the release from the surface of the pool. The release rate is a function of the pool surface area and is derived in Hall 1996b as 1.4×10^{-10} L/m^2-s. The surface area of the diversion box is 165 m^2. The release in 12 hours is 0.001 L, which is negligible compared to the release from splashing. The dose calculated in the TWRS BIO from the solution overflowing the pit is not applicable in this scenario, since the overflow does not occur.

3.2.1.1 Dose Calculation No Controls The onsite doses are calculated using the same methods as used for the spray leak, Equations 1 and 2 which are repeated below.

The inhalation doses are given by

$$D = Q \times X/Q' \times BR \times ULD_{inh} \quad (1)$$

where Q = Material released (L)
X/Q' = Atmospheric dispersion coefficient (s/m^3)
BR = Breathing rate (m^3/s)
ULD_{inh} = Inhalation unit liter dose (Sv/L)

The ingestion doses for the offsite receptor are given by

$$D = Q \times X/Q' \times ULD_{ing} \quad (2)$$

where Q = Material released (L)
X/Q' = Atmospheric dispersion coefficient (s/m^3)
ULD_{ing} = Ingestion unit liter dose (m^3-Sv/L-s)

The parameters used for the unmitigated analysis are taken from (WHC 1996) and are shown in Table 3-2.

Table 3-2 Parameters Used in Pool Dose Calculation.

X/Qs (s/3)	
onsite	5.54×10^{-3} (12 hour)
offsite	4.62×10^{-6} (24 hour)
	7.07×10^{-6} (12 hour)
Breathing rate (m^3/s)	
	3.3×10^{-4} light activity
	2.7×10^{-4} 24 hour average

ULD (inhalation) - 5.6×10^5 Sv/L (for 33% sold/67 %liquid AWF Mix)
ULD (ingestion) - 2.7 Sv-m^3/L-s

The doses for 15.2 L release over 12 hours are

$$D = (15.2\ L)\ (5.54 \times 10^{-3}\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

D = 15.6 Sv (1560 rem)

The offsite dose is the sum of the inhalation and ingestion doses. The inhalation dose is

$$D_{inh} = (15.2\ L)\ (7.07 \times 10^{-6}\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

D_{inh} = 0.020 Sv (2.0 rem)

The ingestion dose from Equation 2 is

$$D_{ing} = (15.2\ L)\ (4.62 \times 10^{-6}\ s/m^3)\ (2.7\ Sv\text{-}m^3/L\text{-}s)$$

$= 1.9 \times 10^{-4}$ Sv

The total offsite dose is the sum of the inhalation dose plus the ingestion dose or,

D_{total} = 0.020 Sv (2 rem)

The event is classified as anticipated. The risk guidelines for anticipated events are 5 mSv (0.5 rem) onsite and 1 mSv (0.1 rem) offsite. Risk guidelines are not met onsite or offsite.

The spill into the pit will produce a direct radiation dose due to gamma radiation from the liquid in the pit, and from air-scatter (skyshine) to the onsite receptor. The distance to the offsite receptor is over 8 km which is far enough that the direct dose to the offsite receptor will be negligible. The direct dose to the onsite receptor will be lower than that given in Hall 1996b since the spill area is smaller, and the spill is confined in the pit. The pit walls will provide some shielding. However, the dose from air-scatter will not be zero. The conclusions of the aerosol dose analysis is that mitigation is required. Including the doses from skyshine will increase the dose slightly and will not change the conclusion that mitigation is required.

3.2.1.2 Toxic Releases The release is 15.2 L in 12 hours which corresponds to a release rate of 3.5×10^{-4} L/s. The sum of fractions derived for the mixture of AWF solids and liquids is 1.3×10^{4} s/L onsite and 68 s/l offsite for anticipated events (See Table 2-3). The comparison to risk guidelines are

Onsite
$(3.5 \times 10^{-4}$ L/s) $(1.3 \times 10^{4}$ s/L) = 4.6

Offsite
$(3.5 \times 10^{-4}$ L/s) (68 s/L) = 2.4×10^{-2}

Products less than 1 indicate that risk guidelines are met. Risk guidelines are therefore met offsite but not onsite.

3.2.2 Spill To Diversion Box - Accident Consequence Calculation With Controls

Mitigation features for the surface pool dose are controls designed to prevent the accident including blocking off unused open nozzles, locking out pumps when they are not in use, and performing jumper leak tests. Controls which reduce the consequences are the presence of pit covers and pit leak detectors. The key assumptions in the TWRS BIO are:

1. Preventative controls are assumed to eliminate the flow through an open nozzle but a loose connection is credible. The maximum credible leak rate, given the preventative controls, is 0.00126 m^3/s (20 gpm).

2. The waste is 33% AWF solids, 67% AWF liquids.

3. The pit drain is assumed to be plugged.

4. The pit leak detector is assumed to respond after 0.051 m (2 in) of waste accumulates in the pit

5. Twenty percent of the line hold up in a 10,000 ft long, 3 inch line is assumed to gravity drain back into the pit.

6. The operators are assumed to respond by stopping the flow in 30 minutes following the leak detector.

Assumption 5 is different for the RCSTS since the RCSTS length is longer. The maximum drain volume is 27.4 m^3 based on a 18,800 ft drain of 3 inch schedule 40 piping. The drain volume of 27.4 m^3 is used in this analysis. The leak detectors in the diversion box are not safety class and are therefore not credited as a mitigating feature in this analysis. The leak will be assumed to be detected 2 hours due to mass balance and flow is assumed to be halted within a additional 30 minutes. The additional assumption for the RCSTS is that credit will be taken for the fact that the major flow path is through the HEPA. The amount of material released is a factor of 100 lower due to the HEPA. (See section 2.2.2.1).

3.2.2.1 Release Quantities With Controls Liquid is assumed to leak into the diversion box for 2 hours at the full flow of 0.0088 m^3/s (140 gpm). The operators are assumed to respond by stopping the flow in 30 minutes following detection of the leak by mass balance. The pumped flow duration is 150 minutes total. During this 150 minutes, the flow volume (v) into the pit is:

$$v = (150 \text{ minutes})(8.8 \times 10^{-3}\ m^3/s)(60\ s/m)$$

$$= 79.4\ m^3.$$

The back flow following pump shutoff is 27.4 m^3. The total flow into the pit is 79.4 + 27.4 = 106.8 m^3. The fraction of the pit volume filled is about 17%. The diversion box doors are sealed, but aerosol will be expelled through the HEPA filter.

Aerosol would be released from the pit due to displacement, expansion of the air plus normal breathing of the pit. Hall 1996b calculates doses conservatively based on an exchange of 100% of the volume of the pit. The material is assumed to be released with a maximum concentration of 100 mg/m^3. The HEPA filter will reduce the quantity of aerosol released by a factor of 100. The amount of material released is

$$Q = (622\ m^3)\ (100\ mg/m^3)\ (1/(1.4 \times 10^6\ mg/L)\ (0.01)$$

$$Q = 4.44 \times 10^{-4}\ L$$

3.2.2.2 Dose Calculation With Controls The dose is calculated based on the X/Qs with plume meander for a two hour period (1.13 x 10^{-2} s/m^3 onsite and 2.12 x 10^{-5} s/m^3 offsite from Van Keuren 1996a).

Onsite

$$D_{inh} = (4.44 \times 10^{-4}\ L)\ (1.13 \times 10^{-2}\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

$$D_{inh} = 9.28 \times 10^{-4}\ Sv\ (0.093\ rem)$$

The offsite dose is the sum of the inhalation and ingestion doses. The inhalation dose is

$$D_{inh} = (4.44 \times 10^{-4}\ L)\ (2.12 \times 10^{-5}\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

$$D_{inh} = 1.7 \times 10^{-6}\ Sv\ \ (1.7 \times 10^{-4}\ rem)$$

The offsite ingestion dose from equation 2 is

$$D_{ing} = (4.44 \times 10^{-4}\ L)\ (2.12 \times 10^{-5}\ s/m^3)\ (2.7\ Sv\text{-}m^3/L\text{-}s)$$

$$= 2.5 \times 10^{-8}\ Sv$$

The total offsite dose is

$$D_{total} = 1.8 \times 10^{-6}\ Sv\ (1.8 \times 10^{-4}\ rem)$$

The event is classified as anticipated. The risk guidelines for anticipated events are 5 mSv (0.5 rem) onsite and 1 mSv (0.1 rem) offsite. Risk guidelines are met both offsite and onsite.

The pit cover and doors will be an effective mitigator against air-scatter and direct shine dose. These doses will be negligible.

3.2.2.3 Toxic Releases With Controls The release from the pit is 4.44×10^{-4} L in 141 minutes. The release rate is assumed to be constant which produces a release rate of 5.2×10^{-8} L/s. The comparison to the risk guidelines is (Sum of fractions are taken from Table 2-3):

$$(5.2 \times 10^{-8}\ L/s)\ (1.3 \times 10^4\ s/L) = 6.8 \times 10^{-4}$$

$$(5.2 \times 10^{-8}\ L/s)\ (68\ s/L) = 3.6 \times 10^{-6}$$

Toxic risk guidelines are met for the mitigated accident since both products are less than 1.0.

3.3 POOL SPILL IN VENT STATION

3.3.1 Pool Spill In Vent Station - No Controls

The pool spill will overflow the vent station in about 6 hours at a flow of 0.0088 m^3/s (140 gpm). The dose due to splashing in 6 hours will be about one-half of the 12 hour dose calculated for the diversion box pool spill without controls. This dose will exceed both the onsite and offsite risk guidelines. The conclusion of the pool leak analysis without controls for the vent station will therefore be the same as for the diversion box spill, i.e., controls are required.

3.3.2 Pool Spill In Vent Station - With Controls

The mitigated results may be determined using the same methods as for the diversion box pool. The flow and time to detect the leak will be the same as for the diversion box. The diversion box spill assumed a 27.4 m^3 volume drained back from the lines. The vent station is at the high point of the line, so there will be no drain back from the line. The pool spill will have a total spill volume of 79.4 m^3 versus 106.8 m^3 for the diversion box pool. The volume of the vent station is 207 m^3, so the spill will not overflow the vent station. Since the vent station has the same HEPA filter design, and the same requirement that the doors be sealed, the doses from the pool spill in the vent station are enveloped by the diversion box spill.

3.4 POOL FORMED DUE TO FLUSH SYSTEM ACCIDENT

A flush system allows cleanout of the line. The potential for a backflow through the system results in radioactive waste being introduced into the flush tank and possibly overflowing and forming a pool.

3.4.1 No Controls

The analyses in the preceding sections have indicated that pool leaks without controls produce doses in excess of the risk guidelines. Controls are therefore necessary.

3.4.2 With Controls

There are several lines of defense to prevent a backflow through the flush system. Administrative controls require that at least 2 valves be closed when radioactive material is being transferred through the line. Back flow preventers are placed in the line to prevent reverse flow. In addition an interlock and pressure sensor will prevent pump operation if the flush system lines are open.

The controls are adequate to prevent a backflow into the flush system when the pumps are operating. It is possible due to a combination of administrative errors that a backflow could occur after the pumps are shutoff. However, the maximum backflow as discussed in the previous section is about 27.4 m^3 (7240 gallons). The flush tank volume is 151 m^3 (40,000 gallons). If it is postulated that the tank is empty, the backflow would be contained in the tank, and would be only a facility worker problem. If the tank is full, overflow would occur, but the waste would be diluted and the maximum release would be 27.4 m^3 (7240 gallons). Pool spills of larger quantities than would occur due to the drain of the line are analyzed in the TWRS BIO and in Section 4 of this report, and are shown to meet risk guidelines, even neglecting dilution effects. The spill through the flush system is therefore bounded by other accidents.

4.0 SUBSURFACE LEAK LEADING TO A SURFACE POOL

This section covers leaks from buried transfer lines as potential initiator of surface pools of waste. Transfer line leaks at high flow rates can result in surface pools because the soil beneath the leak can become supersaturated with liquid.

A subsurface leak is evaluated in Section 5.3.2.19 of the TWRS BIO and Hall 1996c. The TWRS BIO considers a subsurface leak for SST lines as the limiting case since these un-encased lines are older, in direct contact with the soil, and more prone to failure than the newer double walled lines. The event is considered an anticipated event because of the age of the lines and the fact the lines have only a single wall. The RCSTS system is a modern, double walled system and it is clear that the probability of a line failure leading to a pool is lower for this event. An evaluation of the RCSTS failures will be performed using the RCSTS flows. The assumptions that are different are as follows:

1. The RCSTS flow is 140 gpm while the TWRS BIO analysis is based on a 50 gpm transfer rate.

2. The TWRS BIO assumes a drain from the piping of 400 gal. The RCSTS line is significantly longer. A drain from 5730 m of 3 inch schedule 40 pipe is assumed in this analysis (27.4 m^3 or 7190 gallons).

3. The TWRS BIO analysis is based on a line break during SST transfers and therefore assumes SST solids, and liquids to determine a unit liter does. The unit liter dose for AWF solids and liquids, which is the limiting mixture is assumed in this evaluation.

4. The TWRS BIO considers the pipe break event as "anticipated". "Extremely Unlikely" criteria will be used for this RCSTS pipe break with controls event since the RCSTS is a modern, double walled line. Extremely unlikely was the frequency category determined for the subsurface leak from the RCSTS in the RCSTS PSAR (WHC 1995). The pipe break without controls is evaluated as an anticipated event.

4.1 ACCIDENT CONSEQUENCE - NO CONTROLS

4.1.1 Release Quantity With No Controls

The TWRS BIO assumes as an unmitigated event a leak of 50 gpm over a 12.5 hour period which produces a pool volume of 37,500 gallons. A 50 gpm flow is bounding for SST transfers. A leak at the maximum RCSTS flow for the same time period will be evaluated for the RCSTS. In 12.5 hours at a transfer rate of 140 gpm, the release would be 105,000 gallons, or 397 m^3. An additional back flow from the piping of 27.4 m^3 is assumed, as was done for the surface leak. The total flow into the pool is 424 m^3. A pool depth of 1 inch was assumed in the TWRS BIO and the same depth is assumed in this analysis. The pool diameter is 146 m and the surface area is 1.67 x 10^4 m^2. Releases from the pool will occur in two segments. The first is the suspension from the evaporation from the pool liquid surface, and the second will occur from the resuspension of radioactive material on the ground after the liquid has soaked into the ground.

The suspension from the pool is estimated based on the pool surface area using DOE Handbook on release fractions (DOE, 1994) data. A release fraction of 1.4×10^{-10} L/m^2-s is used in the TWRS BIO (Hall 1996c). The release from the pool is therefore:

$$Q(pool) = (1.4 \times 10^{-10}\ L/m^2\text{-}s)\ (1.67 \times 10^4\ m^2/2)\ (750\ min)(60\ s/min)$$

$$Q(pool) = 0.053\ L$$

The pool area is divided by two since the average surface area is used for this calculation. The pool is assumed to remain on the surface for 12.5 hours (750 minutes) prior to soaking into the ground.

The resuspension from the pool material soaking into the ground is derived from DOE 1994. A release fraction of the total spill volume of 8.4×10^{-5} is used in the TWRS BIO based on data from Section 3.2.4.4 of DOE (1994). The release due to resuspension is:

$$Q(resus) = (424\ m^3)\ (8.4 \times 10^{-5})\ (1000\ L/m^3)$$

$$Q(resus) = 35.6\ L$$

4.1.2 Dose Consequences

4.1.2.1 Airborne Releases The accident scenario described in Hall 1996c assumes that the pool forms for 12.5 hours. At the end of the 12.5 hours, the pool soaks into the ground essentially instantaneously and resuspension from the ground occurs over the next 24 hours. The onsite release receptor is exposed for only 12 hours since that is the maximum work shift duration. The release during the first 12 hours after the liquid soaks into the ground is assumed to be 80% of the total.

The inhalation doses are given by

$$D = Q \times X/Q' \times BR \times ULD_{inh} \tag{1}$$

where Q = Material released (L)
X/Q' = Atmospheric dispersion coefficient (s/m^3)
BR = Breathing rate (m^3/s)
ULD_{inh} = Inhalation unit liter dose (Sv/L)

The ingestion doses for the offsite receptor are given by

$$D = Q \times X/Q' \times ULD_{ing} \tag{2}$$

where Q = Material released (L)
X/Q' = Atmospheric dispersion coefficient (s/m^3)
ULD_{ing} = Ingestion unit liter dose (m^3-Sv/L-s)

The parameters used for the unmitigated analysis are taken from

(WHC 1996c) and are shown in Table 4-2.

Table 4-2. Parameters Used in the Pool Dose Calculation.

X/Qs (s/m3)		
onsite	1.13×10^{-2}	(2 hour X/Q)
offsite	2.12×10^{-5}	(plume meander)
Breathing rate (m^3/s)		
	3.3×10^{-4}	light activity
	2.7×10^{-4}	24 hour average

ULD (inhalation) - 5.6×10^5 Sv/L (for 33% sold/67 %liquid AWF Mix)
ULD (ingestion) - 2.7 Sv-m^3/L-s

A X/Q with plume meander is used since this is a relatively long duration release. The X/Qs however are not averaged over the 12 hour duration since there are non-linearities in the release rate. The 2 hour X/Q is conservatively used for this evaluation.

The dose during the second 12 hours of the accident is higher than the dose during the first 12 hours since the dose rate is higher after the pool dries. The offsite receptor is therefore assumed to receive a dose from the material released for 12 hours after the liquid soaks into the ground. Hall 1996c indicates that 80% of the material that is released will be released in the first 12 hours. The dose for a 80% release of 35.6 L over 12 hours is

$$D = (35.6)(0.8)\ (1.13 \times 10^{-2}\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

$$D = 59.5\ Sv\ (5950\ rem)$$

The offsite dose is the sum of the inhalation and ingestion doses. The receptor is assumed to remain in-place during the 12 hour spill and the 12 hours of resuspension. The inhalation dose is

$$D_{inh} = [(0.8)(35.6)L+0.05\ L](2.12 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(5.6 \times 10^5\ Sv/L)$$

$$D_{inh} = 0.11\ Sv\ \ (11\ rem)$$

The ingestion dose from Equation 2 is

$$D_{ing} = [(0.8)(35.6)\ L + 0.05\ L]\ (2.12 \times 10^{-5}\ s/m^3)\ (2.7\ Sv\text{-}m^3/L\text{-}s)$$

$$= 1.6 \times 10^{-3}\ Sv\ (0.16\ rem)$$

The total offsite dose is the sum of the inhalation dose plus the ingestion doses or

$$D_{total} = 0.11\ Sv\ \ (11\ rem)$$

4.1.2.2 Direct Shine and Skyshine Dose A calculation is given in Hall 1996b for a pool with a diameter of 172 m. The pool in Hall 1996b envelopes the pool formed in this case. The direct plus the skyshine dose for the pool over 12 hours was 1 Sv to the onsite receptor. The dose to the offsite receptor was negligible.

4.1.2.3 Total Doses The total onsite dose is therefore 59.5 + 1 = 60.5 Sv = (6050 rem)

The total offsite is 0.11 Sv (11 rem).

The risk guidelines for extremely unlikely events are 0.10 Sv onsite and 0.04 Sv offsite. These guidelines are exceeded, controls are therefore required.

4.1.3 Toxic Releases

Hall 1996c indicates that half of the resuspension from liquids that have soaked into the ground will occur during a 2 hour period (based on DOE 1994 data). The maximum release rate will occur during this period. The maximum release rate is:

$(35.6 \text{ L} \times 0.5)/(2 \text{ hr} \times 3600 \text{ s/hr}) = 2.47 \times 10^{-3} \text{ L/s}$

The sum of fraction for a 33% DST solids and 67% liquids aging waste mix for extremely unlikely events is 3.5×10^{2} s/L for onsite and 1.3 s/L offsite (See Table 2-3). The comparison to risk guidelines are:

Onsite $(2.47 \times 10^{-3} \text{ L/s})(3.5 \times 10^{2} \text{ s/L}) = 0.87$

Offsite $(2.47 \times 10^{-3} \text{ L/s})(1.3 \text{ s/L}) = 0.0032$

Toxicological release risk guidelines are met both offsite and onsite.

4.2 *SUBSURFACE LEAK LEADING TO A POOL CONSEQUENCES WITH CONTROLS*

In the scenario with controls, operator action is credited with limiting the duration and the volume of the material spilled. The leak will be detected within 2 hours, either due to mass balance calculations or the pipe annulus leak detectors. It assumed that it takes 30 minutes to shutdown the pump after the leak is detected. The pumped flow therefore continues for a total time of 2.5 hours after the leak. It is also assumed that emergency response procedures will be implemented within 2.5 hours to evacuate onsite workers in the vicinity of the leak. The offsite individual is assumed to remain in place for a full 24 hours. The frequency category with controls is extremely unlikely.

4.2.1 Release Quantity With Controls

The pumped release quantity during the pumped flow is 140 gpm x 150 min = 21,000 gal = 79.5 m^3. The liquid in the pipes will drain releasing an additional 27.4 m^3. The total releases is 106.9 m^3. The pool diameter and surface area are 73.2 m and 4209 m^2, respectively, assuming a pool depth of 0.025 m (1 inch).

The onsite receptor is assumed to be evacuated within 2.5 hours after the start of the leak. The release used for the onsite dose calculation therefore considers only the pumped release during the 2.5 hours. As discussed for the unmitigated event, the release fraction from the liquid pool surface is 1.4×10^{-10} L/m^2-s. The release from the pool is therefore:

$$Q(pool) = (1.4 \times 10^{-10}\ L/m^2\text{-}s)\ (4209\ m^2/2)\ (150\ min)(60\ s/min)$$

$$Q(pool) = 5.30 \times 10^{-3}\ L$$

The peak pool surface area is divided by two since the pool surface area is increasing linearly during pumping. The average surface area is used for the onsite calculation.

The offsite release quantity is computed based on a 2.5 hour pumping time plus the drain from the lines. The resuspension from the material soaking into the ground is derived from Section 3.2.4.4 of DOE (1994) in Hall 1996c. The release fraction is 8.4×10^{-5}. The release due to resuspension from the ground is:

$$Q(resus) = (106.9\ m^3)\ (8.4 \times 10^{-5})\ (1000\ L/m^3)$$

$$Q(resus) = 9.0\ L$$

The release due to resuspension will dominate the offsite release.

4.2.2 Dose Consequences

4.2.2.1 Airborne Releases The onsite receptor is exposed for only 2.5 hours since emergency response is assumed to evacuate the onsite receptor after 2.5 hours.

The onsite dose for 5.30×10^{-3} L release over 2.5 hours is

$$D = (5.30 \times 10^{-3}\ L)\ (1.13 \times 10^{-2}\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

$$D = 0.011\ Sv\ (1.1\ rem)$$

The offsite dose is the sum of the inhalation and ingestion doses. The receptor is assumed to remain in-place for 24 hours. The X/Qs however are not averaged over the 24 hour duration since there are non-linearities in the release rate. The inhalation dose is

$$D_{inh} = (9\ L)\ (2.12 \times 10^{-5}\ s/m^3)\ (3.3 \times 10^{-4}\ m^3/s)\ (5.6 \times 10^5\ Sv/L)$$

$$D_{inh} = 0.035\ Sv\ \ (3.5\ rem)$$

The ingestion dose from Equation 2 is

$$D_{ing} = (9\ L)\ (2.12 \times 10^{-5}\ s/m^3)\ (2.7\ Sv\text{-}m^3/L\text{-}s)$$

$$= 5.2 \times 10^{-4}\ Sv$$

The total offsite dose is the sum of the inhalation dose plus the ingestion doses or

inhalation and ingestion $D_{total} = 0.036$ Sv (3.6 rem)

4.2.2.2 Direct Shine and Skyshine Dose In addition to the inhalation dose, the onsite receptor will be subjected to gamma radiation from the pool release. The dose from the pool was computed using the MICROSHIELD[1] code and MICROSKYSHINE[2] code in a similar manner to that of the TWRS BIO. The receptor is assumed to remain 100 m from the edge of the pool for 1 hour. The onsite does calculation is based on 106.9 m^3 pool. The source terms are derived based on a 33% solid, 67% liquid mixture. Concentrations are taken from Van Keuren, 1996a. The source term is the concentration times the volume. The source term is shown in Table 4-3.

Table 4-3. Gamma Ray Source Term for 106.9 m^3 Pool.

Isotope	AWF Solids (Bq/L)	AWF Liquids (Bq/L)	33% Solids 67% Liquids Mix Bq/L	Activity for 106.9 m^3 of mix (Ci)	Activity for 59.2 m3 of mix (Ci)
^{137}Cs	9.80 E+10	8.84 E+10	9.16 E+10	2.65 E+05	1.47 E+05
^{137m}Ba	9.27 E+10	8.36 E+10	8.67 E+10	2.50 E+05	1.39 E+05
^{154}Eu	1.11 E+10	0.00	3.66 E+09	1.05 E+04	5.86 E+03
^{60}Co	4.85 E+08	7.71 E+05	1.61 E+08	4.63 E+02	2.57 E+02
$^{90}Sr/^{90}Y$	2.88 E+12	5.60 E+09	9.54 E+11	2.76 E+06	1.53 E+06

^{90}Sr and ^{90}Y contribute to the dose due to bremstrahlung from the beta radiation. A calculation was performed in Van Keuren 1996a which shows the bremstrahlung production for 1 Ci of ^{90}Sr and ^{90}Y in various materials. The calculation for concrete, which is used to simulate dirt, is multiplied by the number of Ci for this isotope. The calculation shows the photons/s generated in the pool as function of energy. The photons/s are entered directly into the MICROSHIELD and MICROSKYSHINE codes. The energies and photon/s for both the 59.2 m^3 and the 106.9 m^3 pools are shown in Table 4-4.

[1] & [2] Microshield and Microskyshine are trademarks of Grove Engineering, Inc.

Table 4-4. Bremstrahlung Source Term for 59.2 m^3 and 106.9 m^3 Pool.

Midpoint Energy (Mev)	Photon/s for 1 Ci of $^{90}Sr/^{90}Y$	Photons/s for 59.2 m^3 Pool	Photon/s for 106.9 m^3 Pool
0.015	1.24 E+09	1.89 E+15	3.42 E+15
0.025	6.26 E+08	9.55 E+14	1.73 E+15
0.035	3.99 E+08	6.09 E+14	1.10 E+15
0.045	2.83 E+08	4.32 E+14	7.81 E+14
0.055	2.14 E+08	3.26 E+14	5.91 E+14
0.065	1.69 E+08	2.58 E+14	4.66 E+14
0.075	1.37 E+08	2.09 E+14	3.78 E+14
0.085	1.14 E+08	1.74 E+14	3.15 E+14
0.095	9.61 E+07	1.47 E+13	2.65 E+14
0.15	5.03 E+08	7.67 E+14	1.39 E+14
0.25	1.95 E+08	2.97 E+14	5.38 E+14
0.35	9.98 E+07	1.53 E+14	2.75 E+14
0.475	7.84 E+07	1.20 E+14	2.16 E+14
0.65	4.89 E+07	7.46 E+13	1.35 E+14
0.825	1.82 E+07	2.78 E+13	5.02 E+13
1.00	1.28 E+07	1.95 E+13	3.53 E+13
1.225	6.95 E+06	1.06 E+13	1.92 E+13
1.475	2.46 E+06	3.75 E+12	6.79 E+12
1.70	6.12 E+05	9.33 E+11	1.69 E+12
1.90	1.51 E+05	2.30 E+11	4.17 E+11
2.10	1.59 E+04	2.42 E+10	4.92 E+10
2.70	8.51 E+01	1.30 E+08	2.35 E+08

The MICROSHIELD and MICROSKYSHINE cases are shown in Appendix C.

The dose rates for the inventories given above are shown in Table 4-5. During the 2.5 hours accident the pool size will grow from zero to full size. The dose rates will change as a function of time. A calculation has also been performed for a 59.2 m^3 pool and Hall 1996c gives doses rates for a 12.9 m^3 pool. The dose rate for the 12.9 m^3 pool volume is also shown in Table 4-5.

Table 4-5. Dose Rate As Function of Pool Volume.

	Dose rate (Sv/h)		
Pool Volume m^3	12.9	59.2	106.9
Direct dose - gamma	8.8 E-04	2.9 E-03	1.0 E-02
Direct dose-bremstrahlung	1.3 E-04	4.5 E-04	1.8 E-03
Skyshine - gamma	2.2 E-03	1.0 E-02	2.2 E-02
Skyshine-bremstrahlung	6.5 E-04	2.9 E-03	6.7 E-03
Totals	3.8 E-03	1.6 E-02	4.1 E-02

The total dose to an onsite receptor 100 m from the pipe during the pool growth is computed by integrating the dose over the 2.5 hour in 30 minute intervals. The pool size is assumed to grow linearly, with drain from the line assumed to be spread uniformly over the time of the release. The doses are summed in Table 4-6.

Table 4-6. Total Dose During Pool Growth.

Time Interval (minutes)	Average Pool Size (m^3)	Dose rate (mr/h)	Dose for Interval(Sv)
0 -30	10.7	340	1.7 E-03
30 - 60	32.1	800	4.0 E-03
60 - 90	53.5	1400	7.0 E-03
90 - 120	74.8	2200	1.1 E-02
120-150	96.4	3400	1.7 E-02
Total			4.1 E-02

The total direct dose is added to the inhalation doses to determine a total onsite dose.

4.2.2.3 Total Doses (With Controls) The total onsite (direct inhalation) dose is 0.041 Sv + 0.011 Sv = 0.052 Sv = (5.2 rem)

The dose from the direct radiation from the pool will be negligible offsite. The total offsite dose is 0.036 Sv (3.6 rem).

The risk guideline for extremely unlikely events is 0.10 Sv onsite and 0.04 Sv offsite. These guidelines are met.

The onsite dose is normally much higher than the offsite dose. The onsite and offsite dose are nearly equal in this case due to the assumption that the onsite receptor is evacuated after 2.5 hours while the offsite receptor remains in place for 24 hours.

4.2.3 Comparison To Toxic Risk Guidelines

The toxic consequences onsite are evaluated assuming a release of 5.3×10^{-3} L over 2.5 hour. The release rate varies as pool surface area, which increases linearly. The peak release rate is twice the average. The peak release rate is $(5.3 \times 10^{-3}\ \text{L})(2)/(2.5)(3600\ \text{s}) = 1.18 \times 10^{-6}$ L/s. The offsite consequences are evaluated based on a 50% release of 9.0 L in 2 hours. The release rate offsite is 6.25×10^{-4} L/s. The sum of fraction for a 33% DST solids and 67% liquids aging waste mix for extremely unlikely events is 3.5×10^{2} s/L for onsite and 1.3 s/L offsite (See Table 2-3). The releases are compared to risk guidelines as follows:

$$(1.18 \times 10^{-6})(3.5 \times 10^{2}) = 4.1 \times 10^{-4}$$

$$(6.25 \times 10^{-4})(1.3) = 8.1 \times 10^{-4}$$

The toxic risk guidelines for an extremely unlikely event are met both onsite and offsite.

5.0 SUBSURFACE LEAK REMAINING SUBSURFACE

5.1 SCENARIO DESCRIPTION

An analysis of subsurface leak is presented in Section 5.3.2.7 of the TWRS BIO, and in Ryan (1996). The TWRS BIO assumes a leak in a single walled buried pipe at a maximum flow rate of 379 L/min (100 gpm). A release of 5% of the flow for 24 hours is assumed to occur forming a subsurface plume. The leak volume of 5% and the maximum flow rate was based on engineering judgement. Larger leak volumes are assumed to form a surface plume, which would be detected. The subsurface plume was assumed to be 15.24 cm (6 inches) below the surface. A soil cover of 6 inches was assumed because a spill with less covering would be likely to be detected, and more covering would decrease the dose. Radiological exposure is assumed to occur from gamma and bremstrahlung radiation from both direct exposure and scatter from the air (skyshine).

There are three differences in this accident scenario for the RCSTS:

1. The flow rate for the RCSTS is 140 gpm. Assuming a 5% leak flow, the maximum flow volume is 38,200 L. This is larger than the 27,250 L assumed in the TWRS BIO.

2. The TWRS BIO calculation assumes a SST 33% solid and 67% liquid mixture. This calculation assumes the more limiting AWF 33% solids and 67% liquids mixture.

3. Because of the modern design of the RCSTS, the accident frequency category of this event with controls is judged to be "extremely unlikely."

The doses in Ryan (1996) were calculated for three subsurface geometries: a horizontal cylinder, a vertical cylinder, and a sphere. The horizontal cylinder produced the largest dose at 100 m from the pipe. Only this case will be considered here. The pipe is assumed to be 1 m below the ground and the spill is assumed to remain 15.2 cm (6 inches) below the ground. The spill is assumed to extend equal distances above and below the pipe, giving a cylinder diameter of 2(100-15.24) = 169.5 cm. The spill volume is 38.2 m^3. The void fraction of the ground is assumed to be 0.4, giving an effective volume of the plume of 38.2/0.4 = 95.5 m^3. The length of the cylinder is given by

$$L = (4V)/(\pi d^2)$$

$$L = (4)(95.5\ m^3)/[\pi(1.695\ m)^2] =$$

$$L = 42.3\ m$$

5.2 DOSE CALCULATION

The doses were calculated to a receptor 100 m from the center of the pool. The pipe is assumed to be at the center of the pool. The doses are calculated as the sum of four components:

1. The dose from gamma decay of isotopes due to the direct transmission of gamma radiation.

2. The dose from bremstrahlung radiation from beta decay due to transmission.

3. The dose from scatter from the gamma radiation air (skyshine) due to direct gamma decay.

4. The dose from skyshine of bremstrahlung radiation from beta decay.

The first two cases were calculated using the MICROSHIELD code (Grove 1992) and the second two were calculated using the MICROSKYSHINE code (Grove 1987). The computer code outputs are given in Appendix C. Gamma decay doses were calculated based on ^{137}Cs/^{137m}Ba, ^{60}Co and ^{154}Eu, which are the principal gamma emitters (Van Keuren 1996a). Activity concentrations were calculated based on a AWF mix of 33% solids and 67% liquids. The source terms are derived based on a 33% solids, 67% liquids AWF mixture. Concentrations are taken from Van Keuren, 1996a. The total source term is the concentration times the volume. The source term is shown in Table 5-1.

Table 5-1. Gamma Ray Source Term for 38.2 m^3 Spill.

Isotope	AWF Solids Concentration (Bq/L)	AWF Liquids Concentration(Bq/L)	33% solids 67% Liquids Mix Bq/L	Activity for 38.2 m^3 of mix (Ci)
^{137}Cs	9.80 E+10	8.84 E+10	9.16 E+10	9.45 E+04
^{137m}Ba	9.27 E+10	8.36 E+10	8.67 E+10	8.94 E+04
^{154}Eu	1.11 E+10	0.00	3.66 E+09	3.78 E+03
^{60}Co	4.85 E+08	7.71 E+05	1.62 E+08	1.66 E+02
^{90}Sr/^{90}Y	2.88 E+12	5.60 E+09	9.54 E+11	9.85 E+05

^{90}Sr and ^{90}Y contribute to the dose due to bremstrahlung from the beta radiation. A calculation was documented in Van Keuren 1996a which shows the Bremstrahlung production for 1 Ci of ^{90}Sr and ^{90}Y in various materials. The calculation for concrete, which is used to simulate dirt, is multiplied by the 9.68 x 10^{-5} of Ci for this isotope. The calculation shows the photons/s as function of energy. The calculations are entered directly into the MICROSHIELD and MICROSKYSHINE codes. The energies are shown in Table 5-2.

Table 5-2. Bremstrahlung Source Term for 38.2 m^3 Pool.

Midpoint Energy (Mev)	Photon/s for 1 Ci of $^{90}Sr/^{90}Y$	Photon/s for 38.2 m^3 Pool
0.015	1.24 E+09	1.22 E+15
0.025	6.26 E+08	6.16 E+14
0.035	3.99 E+08	3.93 E+14
0.045	2.83 E+08	2.78 E+14
0.055	2.14 E+08	2.11 E+14
0.065	1.69 E+08	1.66 E+14
0.075	1.37 E+08	1.35 E+14
0.085	1.14 E+08	1.12 E+14
0.095	9.61 E+07	9.46 E+14
0.15	5.03 E+08	4.95 E+14
0.25	1.95 E+08	1.92 E+14
0.35	9.98 E+07	9.82 E+13
0.475	7.84 E+07	7.71 E+13
0.65	4.89 E+07	4.81 E+13
0.825	1.82 E+07	1.79 E+13
1.00	1.28 E+07	1.26 E+13
1.225	6.95 E+06	6.84 E+12
1.475	2.46 E+06	2.42 E+12
1.70	6.12 E+05	6.02 E+11
1.90	1.51 E+05	1.49 E+11
2.10	1.59 E+04	1.56 E+10
2.30	8.51 E+01	8.37 E+07

The MICROSHIELD and MICROSKYSHINE cases are shown in Appendix C. Other assumptions used in the code are the same as given in Ryan, 1996. The results are summarized in Table 5-3.

Table 5-3. Dose Consequences of Subsurface Pool Remaining Subsurface.

Case	Dose Rate (mr/hr)	Dose for 12 hrs (Sv)
Gamma decay direct dose	1.85 E-20	2.22 E-24
Bremstrahlung, direct dose	4.71 E-21	5.65 E-25
Gamma decay, skyshine	1.23 E+01	1.47 E-03
Bremstrahlung, skyshine	1.47 E+00	1.77 E-04
Total	1.38 E+01	1.65 E-03

The doses without controls are less than the risk guideline of 0.005 Sv for anticipated events. There are no toxic consequences for this event since the plume is assumed to not reach the surface, or any ground water. There is no significant offsite dose since the distance to the site boundary is over 8 km, and the direct dose will be negligible at this distance. The risk guidelines are therefore met. Additional controls are however imposed to protect facility workers.

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APPENDIX A PUMP PERFORMANCE CURVES FOR RCSTS

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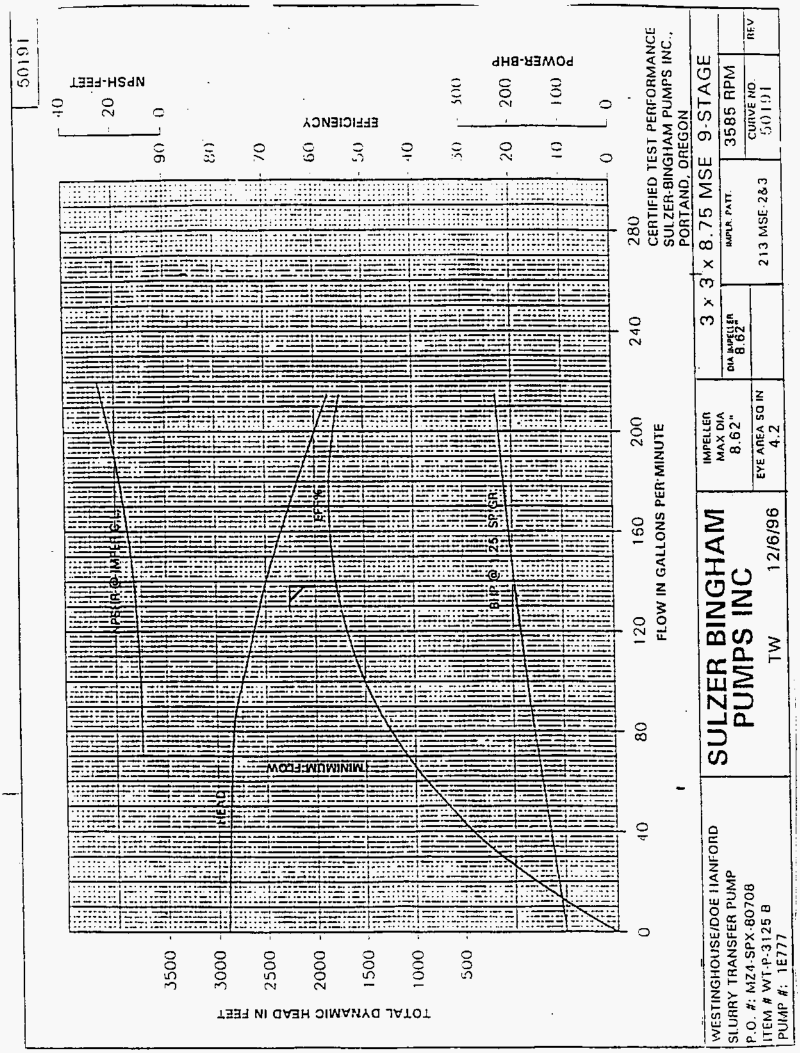
50191
CERTIFIED TEST PERFORMANCE
SULZER-BINGHAM PUMPS INC.,
PORTLAND, OREGON
3 x 3 x 8.75 MSE 9-STAGE
3585 RPM
REV
CURVE NO. 50191
IMPLR. PATT. 213 MSE-2&3
DIA IMPELLER 8.62"
IMPELLER MAX DIA 8.62"
EYE AREA SQ IN 4.2
SULZER BINGHAM PUMPS INC
TW 12/6/96
WESTINGHOUSE/DOE HANFORD
SLURRY TRANSFER PUMP
P.O. #: MZ4-SPX-80708
ITEM # WT-P-3125 B
PUMP #: 1E777
NPSH-FEET
40 20 0
EFFICIENCY
90 80 70 60 50 40 30 20 10 0
POWER-BHP
300 200 100 0
FLOW IN GALLONS PER MINUTE
0 40 80 120 160 200 240 280
TOTAL DYNAMIC HEAD IN FEET
3500 3000 2500 2000 1500 1000 500
HEAD
MINIMUM FLOW
EFF %
BHP @ 1.25 SP.GR.
NPSHR @ IMPLR C.L.

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APPENDIX B SPRAY COMPUTER CODE OUTPUT FILE

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SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

Run Date = 12/18/96/
Run Time = 14:00:39.78

```
INPUT ECHO:
c SPRAY RCSTS spray 1300 psi 2 inch slit 3inch schedule 40 pipe Input Deck
c   mode iflow iopt
   2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or
turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
   1.97000E-02     2.00000E+00     2.16000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98   for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98   for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82   for square edge orifice
c   ___________     ____________    ____________    ______________________________
   1.30000E+03     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (µm)            (q)
```

c

1.40000E+00	1.00000E+00	1.50000E+01	2.40000E+00

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:

Liquid Velocity =	1.80E+02 ft/s	5.50E+01 m/s	
Reynolds Number =	2.12E+04 Turbulent Flow		
Sauter Mean Diameter =	2.87E+01 μm		
Optimum Slit Width =	5.44E-03 in	1.38E-04 m	
Respirable Fraction =	7.34E-02		
Total Leak Rate =	6.12E+00 gpm	3.86E-04 m3/s	5.40E+02 g/s
Respirable Leak Rate =	4.49E-01 gpm	2.83E-05 m3/s	3.97E+01 g/s

APPENDIX C MICROSHIELD AND MICROSKYSHINE OUTPUT FILES

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MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1
DOS File: POOL1.MS4
Run Date: February 11, 1997
Run Time: 3:20 p.m. Tuesday
Duration: 0:00:38

File Ref: ________
Date: ___/___/___
By: ________
Checked: ________

Case Title: 106.9 m3 pool AWF liquids/solids case rcsts01

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	and inches
Dose point coordinate X:	6340.0	208.0	.1
Dose point coordinate Y:	164.0	5.0	4.6
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	14.0	0.0	5.5
Cylinder radius:	3660.0	120.0	.9
Side Clad:	2680.0	87.0	11.1

Source Volume: 5.89169e+8 cm^3   20806.3 cu ft.   3.59533e+7 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Transition Shield	Side Clad Shield	Immersion Shield
Air		0.00122		0.00122
Concrete			1.6	
Water	1.4			

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE NUCLIDES

Nuclide	curies	μCi/cm^3	Nuclide	curies	μCi/cm^3
Ba-137m	2.5000e+005	4.2433e+002	Co-60	4.6362e+002	7.8690e-001
Cs-137	2.6518e+005	4.5010e+002	Eu-154	1.0571e+004	1.7943e+001

Page : 2
DOS File: POOL1.MS4
Run Date: February 11, 1997
Run Time: 3:20 p.m. Tuesday
Title : 106.9 m3 pool AWF liquids/solids case rcsts01

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.1	1.583e+014	1.349e+002	2.026e+003	2.064e-001	3.100e+000
0.2	2.671e+013	6.880e+001	6.014e+002	1.214e-001	1.062e+000
0.4	2.791e+012	2.229e+001	1.078e+002	4.342e-002	2.101e-001
0.5	8.469e+011	9.771e+000	4.042e+001	1.918e-002	7.935e-002
0.6	8.355e+015	1.304e+005	4.809e+005	2.544e+002	9.387e+002
0.8	1.525e+014	3.843e+003	1.201e+004	7.309e+000	2.284e+001
1.0	1.375e+014	5.032e+003	1.409e+004	9.275e+000	2.596e+001
1.5	1.698e+014	1.230e+004	2.889e+004	2.069e+001	4.861e+001
TOTAL:	9.003e+015	1.518e+005	5.387e+005	2.921e+002	1.041e+003

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1
DOS File: RCSTS02.MS4
Run Date: February 11, 1997
Run Time: 3:24 p.m. Tuesday
Duration: 0:01:35

File Ref: ________
Date: __/__/__
By: ________
Checked: ________

Case Title: 106.9 m3 pool AWF liquids/solids bremstrhlung rcsts02

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	and inches
Dose point coordinate X:	6340.0	208.0	.1
Dose point coordinate Y:	164.0	5.0	4.6
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	14.0	0.0	5.5
Cylinder radius:	3660.0	120.0	.9
Air Gap:	20.0	0.0	7.9
Side Clad:	2660.0	87.0	3.2

Source Volume: 5.89169e+8 cm^3   20806.3 cu ft.   3.59533e+7 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Transition Shield	Air Gap	Side Clad Shield	Immersion Shield
Air		0.00122	0.00122		0.00122
Concrete				1.6	
Water	1.4				

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE WAS ENTERED AS ENERGIES ONLY

Page : 2
DOS File: RCSTS02.MS4
Run Date: February 11, 1997
Run Time: 3:24 p.m. Tuesday
Title : 106.9 m3 pool AWF liquids/solids bremstrhlung rcsts02

================================ RESULTS ================================

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.015	3.409e+015	6.026e-004	9.955e-004	5.168e-005	8.539e-005
0.025	1.723e+015	1.277e+001	4.329e+001	2.203e-001	7.466e-001
0.035	1.099e+015	8.037e+001	5.332e+002	5.091e-001	3.378e+000
0.045	7.793e+014	1.398e+002	1.517e+003	4.648e-001	5.044e+000
0.055	5.881e+014	1.727e+002	2.473e+003	3.887e-001	5.566e+000
0.065	4.654e+014	1.910e+002	3.091e+003	3.467e-001	5.612e+000
0.075	3.770e+014	1.999e+002	3.330e+003	3.258e-001	5.428e+000
0.085	3.139e+014	2.055e+002	3.345e+003	3.192e-001	5.197e+000
0.095	2.652e+014	2.081e+002	3.222e+003	3.185e-001	4.931e+000
0.15	1.384e+015	2.251e+003	2.483e+004	3.706e+000	4.089e+001
0.25	5.358e+014	1.980e+003	1.405e+004	3.653e+000	2.592e+001
0.35	2.742e+014	1.758e+003	9.364e+003	3.390e+000	1.806e+001
0.475	2.165e+014	2.295e+003	9.829e+003	4.503e+000	1.929e+001
0.65	1.346e+014	2.398e+003	8.432e+003	4.656e+000	1.637e+001
0.825	5.015e+013	1.330e+003	4.091e+003	2.520e+000	7.752e+000
1.0	3.518e+013	1.287e+003	3.604e+003	2.373e+000	6.644e+000
1.225	1.912e+013	9.847e+002	2.514e+003	1.743e+000	4.449e+000
1.475	6.765e+012	4.764e+002	1.126e+003	8.052e-001	1.903e+000
1.7	1.683e+012	1.505e+002	3.378e+002	2.445e-001	5.487e-001
1.9	4.149e+011	4.475e+001	9.670e+001	7.030e-002	1.519e-001
2.1	4.366e+010	5.570e+000	1.165e+001	8.482e-003	1.774e-002
2.3	2.345e+008	3.485e-002	7.085e-002	5.154e-005	1.048e-004
TOTAL:	1.168e+016	1.617e+004	9.584e+004	3.057e+001	1.779e+002

MicroSkyshine
=============
(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1 File Ref: ________
File: POOLG.SKY Date: ___/___/___
Run: 3:23 p.m. By: ________
: March 19, 1997 Checked: ________

CASE: 106.9 m3 pool 1/3 awf solids 2/3 liquids gammas rcsts03

GEOMETRY: Vertical cylinder area source behind a wall

DIMENSIONS (meters):

Distance between wall and detector...........	X	25.8
Depth of source behind wall..................	Y	1.1
Offset of detector...........................	Z	0.
Depth of dose point..........................	H	-0.38
Distance between center of source and wall...	R1	37.6
Thickness of cover slab......................	T1	0.
Thickness of second shield...................	T2	0.
Radius of source.............................	W	36.6
Height of source.............................	L	0.14

INTEGRATION PARAMETERS:

Number of Radial Segments....................	M	5
Number of Circumferential Segments...........	N	5
Number of Vertical Segments..................	C	5
Quadrature Order..........................		16

MATERIAL DENSITIES (g/cc):

Ambient air: .0012

Material	Cover Slab	Lower Shield	Volume Source
Air			
Water			0.56
Concrete			1.6
Iron			
Lead			
Zirconium			
Urania			

Buildup factor based on: AIR.

CASE: 106.9 m3 pool 1/3 awf solids 2/3 liquids gammas rcsts03

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	2.5000e+05	Co-60	4.6400e+02
Cs-137	2.6500e+05	Eu-154	1.0570e+04

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.30	1.738e+14	5.607e-20	4.018e+01
2	1.03	1.302e+14	5.894e-20	3.165e+01
3	.84	7.181e+13	5.686e-20	1.684e+01
4	.66	8.438e+15	6.086e-20	2.117e+03
5	.48	3.817e+12	6.489e-20	1.021e+00
6	.40	8.190e+11	6.275e-20	2.119e-01
7	.24	2.582e+13	6.665e-20	7.096e+00
8	.20	8.884e+11	6.566e-20	2.405e-01
9	.12	1.583e+14	5.237e-20	3.417e+01
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	9.003e+15		2.249e+03

MicroSkyshine
=============

(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1	File Ref: ________
File: POOLB.SKY	Date: __/__/__
Run: 3:34 p.m.	By: ________
: March 19, 1997	Checked: ________

CASE: 106.9 m3 pool awf solids 2/3 liquids bremstrahlung rcsts04

GEOMETRY: Vertical cylinder area source behind a wall

DIMENSIONS (meters):

Distance between wall and detector...........	X	25.8
Depth of source behind wall..................	Y	1.1
Offset of detector...........................	Z	0.
Depth of dose point..........................	H	0.38
Distance between center of source and wall...	R1	37.6
Thickness of cover slab......................	T1	0.
Thickness of second shield...................	T2	0.
Radius of source.............................	W	36.6
Height of source.............................	L	0.14

INTEGRATION PARAMETERS:

Number of Radial Segments....................	M	5
Number of Circumferential Segments...........	N	5
Number of Vertical Segments..................	C	5
Quadrature Order.........................		16

MATERIAL DENSITIES (g/cc):

Ambient air: .0012

Material	Cover Slab	Lower Shield	Volume Source
Air			
Water			0.56
Concrete			1.6
Iron			
Lead			
Zirconium			
Urania			

Buildup factor based on: AIR.

CASE: 106.9 m3 pool awf solids 2/3 liquids bremstrahlung rcsts04

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	1.3800e+05	Co-60	2.5900e+02
Cs-137	1.4600e+05	Eu-154	5.9200e+03

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.90	4.150e+11	4.920e-20	8.419e-02
2	1.70	1.680e+12	4.875e-20	3.377e-01
3	1.48	6.770e+12	4.815e-20	1.344e+00
4	1.23	1.912e+13	5.561e-20	4.384e+00
5	1.00	3.520e+13	5.678e-20	8.241e+00
6	.82	5.020e+13	5.466e-20	1.132e+01
7	.65	1.350e+14	5.984e-20	3.331e+01
8	.47	2.165e+14	6.322e-20	5.644e+01
9	.35	2.740e+14	5.920e-20	6.689e+01
10	.25	5.360e+14	6.512e-20	1.439e+02
11	.15	1.380e+15	5.984e-20	3.405e+02
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	2.655e+15		6.668e+02

WHC-SD-WM-CN-111, Rev 0

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

e : 1
File: RCSTS05.MS4
Date: February 11, 1997
Time: 4:01 p.m. Tuesday
ation: 0:01:38

File Ref: ________
Date: __/__/__
By: ________
Checked: ________

Case Title: 58.2 m3 pool AWF liquids/solids bremstrhlung rcsts05

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and inches	
Dose point coordinate X:	7275.0	238.0	8.2
Dose point coordinate Y:	164.0	5.0	4.6
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	14.0	0.0	5.5
Cylinder radius:	2725.0	89.0	4.8
Side Clad:	4550.0	149.0	3.3

Source Volume: 3.26596e+8 cm^3 11533.6 cu ft. 1.99301e+7 cu in.

MATERIAL DENSITIES (g/cm^3)

terial	Source Shield	Transition Shield	Side Clad Shield	Immersion Shield
r		0.00122		0.00122
ncrete			1.6	
ter	1.4			

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE WAS ENTERED AS ENERGIES ONLY

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	________
DOS File:	RCSTS06.MS4	Date:	__/__/__
Run Date:	February 11, 1997	By:	________
Run Time:	4:10 p.m. Tuesday	Checked:	________
Duration:	0:00:46		

Case Title: 59.2 m3 pool AWF liquids/solids case rcsts06

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and	inches
Dose point coordinate X:	7275.0	238.0	8.2
Dose point coordinate Y:	164.0	5.0	4.6
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	14.0	0.0	5.5
Cylinder radius:	2725.0	89.0	4.8
Side Clad:	4550.0	149.0	3.3

Source Volume: 3.26596e+8 cm^3   11533.6 cu ft.   1.99301e+7 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Transition Shield	Side Clad Shield	Immersion Shield
Air		0.00122		0.00122
Concrete			1.6	
Water	1.4			

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE NUCLIDES

Nuclide	curies	μCi/cm^3	Nuclide	curies	μCi/cm^3
Ba-137m	1.3900e+005	4.2560e+002	Co-60	2.5700e+002	7.8690e-001
Cs-137	1.4700e+005	4.5010e+002	Eu-154	5.8600e+003	1.7943e+001

-WT-SD-W[illegible]-11, Rev 0

Page : 2
DOS File: RCSTS06.MS4
Run Date: February 11, 1997
Run Time: 4:10 p.m. Tuesday
Title : 59.2 m3 pool AWF liquids/solids case rcsts06

============================== RESULTS ==============================

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0494	5.175e+014	2.809e+001	5.490e+002	7.674e-002	1.500e+000
0.246	1.481e+013	1.921e+001	1.827e+002	3.535e-002	3.362e-001
0.4426	2.016e+012	7.526e+000	4.019e+001	1.474e-002	7.870e-002
0.5907	1.351e+013	8.432e+001	3.584e+002	1.647e-001	7.002e-001
0.6625	4.688e+015	3.585e+004	1.404e+005	6.948e+001	2.721e+002
0.8723	3.042e+013	3.785e+002	1.241e+003	7.122e-001	2.334e+000
1.0024	6.164e+013	9.799e+002	2.971e+003	1.806e+000	5.474e+000
1.2614	8.975e+013	2.139e+003	5.754e+003	3.760e+000	1.012e+001
1.3325	9.509e+012	2.496e+002	6.537e+002	4.330e-001	1.134e+000
1.5767	7.642e+012	2.693e+002	6.542e+002	4.469e-001	1.086e+000
TOTAL:	5.434e+015	4.000e+004	1.528e+005	7.693e+001	2.949e+002

MicroSkyshine
=============
(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1 File Ref: ________
File: RCSTS07.SKY Date: ___/___/___
Run: 3:54 p.m. By: ________
: March 19, 1997 Checked: ________

CASE: 59.2 m3 pool 1/3 awf solids 2/3 liquids gammas rcsts07

GEOMETRY: Vertical cylinder area source behind a wall

DIMENSIONS (meters):

Distance between wall and detector...........	X	44.5
Depth of source behind wall..................	Y	0.832
Offset of detector...........................	Z	0.
Depth of dose point..........................	H	-0.667
Distance between center of source and wall...	R1	28.25
Thickness of cover slab......................	T1	0.
Thickness of second shield...................	T2	0.
Radius of source.............................	W	27.25
Height of source.............................	L	0.14

INTEGRATION PARAMETERS:

Number of Radial Segments....................	M	5
Number of Circumferential Segments...........	N	5
Number of Vertical Segments..................	C	5
Quadrature Order...........................		16

MATERIAL DENSITIES (g/cc):

Ambient air: .0012

Material	Cover Slab	Lower Shield	Volume Source
Air			
Water			0.56
Concrete			1.6
Iron			
Lead			
Zirconium			
Urania			

Buildup factor based on: AIR.

CASE: 59.2 m3 pool 1/3 awf solids 2/3 liquids gammas rcsts07

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	1.3900e+05	Co-60	2.5700e+02
Cs-137	1.4700e+05	Eu-154	5.8600e+03

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.30	9.634e+13	4.611e-20	1.832e+01
2	1.03	7.219e+13	4.836e-20	1.440e+01
3	.84	3.981e+13	4.662e-20	7.652e+00
4	.66	4.691e+15	4.960e-20	9.594e+02
5	.48	2.116e+12	5.252e-20	4.584e-01
6	.40	4.541e+11	5.069e-20	9.492e-02
7	.24	1.431e+13	5.209e-20	3.075e+00
8	.20	4.925e+11	5.074e-20	1.031e-01
9	.12	8.773e+13	3.994e-20	1.445e+01
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	5.005e+15		1.018e+03

MicroSkyshine
=============

(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1 File Ref: ________
File: RCSTS08.SKY Date: __/__/__
Run: 4:11 p.m. By: ________
: March 19, 1997 Checked: ________

CASE: 59.2 m3 pool 1/3 awf solids 2/3 liquids brem rcsts08

GEOMETRY: Vertical cylinder area source behind a wall

DIMENSIONS (meters):

Distance between wall and detector...........	X	44.5
Depth of source behind wall..................	Y	0.832
Offset of detector...........................	Z	0.
Depth of dose point..........................	H	-0.667
Distance between center of source and wall...	R1	28.25
Thickness of cover slab......................	T1	0.
Thickness of second shield...................	T2	0.
Radius of source.............................	W	27.25
Height of source.............................	L	0.14

INTEGRATION PARAMETERS:

Number of Radial Segments.....................	M	5
Number of Circumferential Segments............	N	5
Number of Vertical Segments...................	C	5
Quadrature Order..........................		16

MATERIAL DENSITIES (g/cc):

Ambient air: .0012

Material	Cover Slab	Lower Shield	Volume Source
Air			
Water			0.56
Concrete			1.6
Iron			
Lead			
Zirconium			
Urania			

Buildup factor based on: AIR.

CASE: 59.2 m3 pool 1/3 awf solids 2/3 liquids brem rcsts08

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	1.3900e+05	Co-60	2.5700e+02
Cs-137	1.4700e+05	Eu-154	5.8600e+03

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.90	2.300e+11	4.244e-20	4.025e-02
2	1.70	9.330e+11	4.200e-20	1.616e-01
3	1.48	3.750e+12	4.138e-20	6.399e-01
4	1.23	1.060e+13	4.742e-20	2.073e+00
5	1.00	1.950e+13	4.821e-20	3.877e+00
6	.82	2.780e+13	4.631e-20	5.309e+00
7	.65	7.460e+13	5.016e-20	1.543e+01
8	.47	1.200e+14	5.248e-20	2.597e+01
9	.35	1.520e+14	4.893e-20	3.067e+01
10	.25	2.970e+14	5.202e-20	6.370e+01
11	.15	7.670e+14	4.665e-20	1.475e+02
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	1.473e+15		2.954e+02

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1
DOS File: SUBHCYLG.MS4
Run Date: January 15, 1997
Run Time: 2:17 p.m. Wednesday
Duration: 0:00:58

File Ref: ______
Date: __/__/__
By: ______
Checked: ______

Case Title: RSCTS SUBSURFACE HORIONTAL CYL GAMMAS RCSTS059

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and	inches
Dose point coordinate X:	250.0	8.0	2.4
Dose point coordinate Y:	2113.0	69.0	3.9
Dose point coordinate Z:	10000.0	328.0	1.0
Cylinder height:	4227.0	138.0	8.2
Cylinder radius:	84.76	2.0	9.4
Transition:	15.24	0.0	6.0
Air Gap:	150.0	4.0	11.1

Source Volume: 9.54034e+7 cm^3 3369.14 cu ft. 5.82187e+6 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Transition Shield	Air Gap
Air			0.00122
Concrete	1.6	1.6	
Water	0.56		

BUILDUP
Method: Buildup Factor Tables
The material reference is Transition

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE NUCLIDES

Nuclide	curies	μCi/cm^3	Nuclide	curies	μCi/cm^3
Ba-137m	8.9400e+004	9.3707e+002	Co-60	1.6600e+002	1.7400e+000
Cs-137	9.4500e+004	9.9053e+002	Eu-154	3.7800e+003	3.9621e+001

Page : 2
DOS File: SUBHCYLG.MS4
Run Date: January 15, 1997
Run Time: 2:17 p.m. Wednesday
Title : RSCTS SUBSURFACE HORIONTAL CYL GAMMAS RCSTS059

================================ RESULTS ================================

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.1	5.659e+013	3.811e-119	1.540e-020	5.830e-122	2.356e-023
0.2	9.551e+012	6.155e-088	3.311e-020	1.086e-090	5.844e-023
0.4	9.978e+011	4.481e-068	4.175e-021	8.731e-071	8.134e-024
0.5	3.028e+011	1.415e-062	1.058e-021	2.777e-065	2.078e-024
0.6	2.988e+015	7.002e-054	9.124e-018	1.367e-056	1.781e-020
0.8	5.454e+013	1.502e-048	1.294e-019	2.857e-051	2.462e-022
1.0	4.917e+013	1.857e-043	8.983e-020	3.423e-046	1.656e-022
1.5	6.071e+013	7.041e-035	8.490e-020	1.185e-037	1.428e-022
TOTAL:	3.220e+015	7.041e-035	9.481e-018	1.185e-037	1.846e-020

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1 File Ref: ______
DOS File: RCTSHCYB.MS4 Date: __/__/__
Run Date: January 15, 1997 By: ______
Run Time: 2:24 p.m. Wednesday Checked: ______
Duration: 0:02:27

Case Title: RSCTS SUBSURFACE HORIONTAL CYL BREM RCSTS010

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and	inches
Dose point coordinate X:	250.0	8.0	2.4
Dose point coordinate Y:	2113.0	69.0	3.9
Dose point coordinate Z:	10000.0	328.0	1.0
Cylinder height:	4227.0	138.0	8.2
Cylinder radius:	84.76	2.0	9.4
Transition:	15.24	0.0	6.0
Air Gap:	150.0	4.0	11.1

Source Volume: 9.54034e+7 cm^3 3369.14 cu ft. 5.82187e+6 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Transition Shield	Air Gap
Air			0.00122
Concrete	1.6	1.6	
Water	0.56		

BUILDUP
Method: Buildup Factor Tables
The material reference is Transition

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE WAS ENTERED AS ENERGIES ONLY

Page : 2
DOS File: RCTSHCYB.MS4
Run Date: January 15, 1997
Run Time: 2:24 p.m. Wednesday
Title : RSCTS SUBSURFACE HORIONTAL CYL BREM RCSTS06 10

=============================== RESULTS ===============================

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.015	1.220e+015	0.000e+000	1.394e-022	0.000e+000	1.196e-023
0.025	6.160e+014	0.000e+000	1.598e-022	0.000e+000	2.756e-024
0.035	3.930e+014	0.000e+000	2.592e-022	0.000e+000	1.642e-024
0.045	2.780e+014	0.000e+000	4.598e-022	0.000e+000	1.529e-024
0.055	2.110e+014	2.758e-217	2.122e-021	6.207e-220	4.775e-024
0.065	1.660e+014	8.866e-173	6.320e-021	1.609e-175	1.147e-023
0.075	1.350e+014	3.787e-148	6.643e-021	6.172e-151	1.083e-023
0.085	1.120e+014	5.367e-133	9.114e-021	8.337e-136	1.416e-023
0.095	9.460e+013	7.230e-123	1.757e-020	1.106e-125	2.688e-023
0.15	4.950e+014	1.197e-096	7.380e-019	1.972e-099	1.215e-021
0.25	1.920e+014	1.629e-079	8.641e-019	3.006e-082	1.594e-021
0.35	9.820e+013	7.647e-070	4.368e-019	1.475e-072	8.427e-022
0.475	7.710e+013	1.589e-061	2.814e-019	3.119e-064	5.520e-022
0.65	4.810e+013	1.161e-053	1.383e-019	2.254e-056	2.686e-022
0.825	1.790e+013	2.626e-048	4.100e-020	4.977e-051	7.770e-023
1.0	1.260e+013	4.759e-044	2.302e-020	8.772e-047	4.243e-023
1.225	6.840e+012	6.630e-040	1.068e-020	1.173e-042	1.891e-023
1.475	2.420e+012	1.330e-036	3.416e-021	2.247e-039	5.774e-024
1.7	6.020e+011	1.503e-034	7.813e-022	2.441e-037	1.269e-024
1.9	1.490e+011	3.342e-033	1.825e-022	5.251e-036	2.868e-025
2.1	1.560e+010	1.619e-032	1.854e-023	2.466e-035	2.823e-026
2.3	8.370e+007	2.382e-033	9.828e-026	3.523e-036	1.453e-028
TOTAL:	4.177e+015	2.207e-032	2.581e-018	3.368e-035	4.705e-021

MicroSkyshine
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(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1
File: SUBHCYL.SKY
Run: 4:02 p.m.
: January 15, 1997

File Ref: ________
Date: __/__/__
By: ________
Checked: ________

CASE: RCSTS HORIZONTAL CYL SUBSURFACE GAMMA RCSTS07 11

GEOMETRY: Horizontal cylinder source behind a wall

DIMENSIONS (meters):

Distance between wall and detector...........	X	100.
Depth of source behind wall..................	Y	1.01
Offset of detector...........................	Z	-21.14
Depth of dose point..........................	H	-1.5
Distance between source and wall.............	R1	0.01
Distance between near source edge and wall...	R2	1.6952
Thickness of cover slab......................	T1	0.
Thickness of second shield...................	T2	0.1524
Radius of source.............................	W	0.8476
Length of source.............................	L	42.27

INTEGRATION PARAMETERS:

Number of Radial Segments....................	M	5
Number of Circumferential Segments...........	N	5
Number of Length Segments....................	C	5
Quadrature Order...........................		16

MATERIAL DENSITIES (g/cc):

Ambient air: .0012

Material	Cover Slab	Lower Shield	Volume Source
Air			
Water			0.56
Concrete		1.6	1.6
Iron			
Lead			
Zirconium			
Urania			

Buildup factor based on: AIR.

CASE: RCSTS HORIZONTAL CYL SUBSURFACE GAMMA RCSTS011

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	8.9400e+04	Co-60	1.6600e+02
Cs-137	9.4500e+04	Eu-154	3.7800e+03

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.30	6.215e+13	1.381e-21	3.539e-01
2	1.03	4.658e+13	1.241e-21	2.384e-01
3	.84	2.568e+13	1.030e-21	1.091e-01
4	.66	3.017e+15	9.276e-22	1.154e+01
5	.48	1.365e+12	7.583e-22	4.269e-03
6	.40	2.929e+11	6.187e-22	7.473e-04
7	.24	9.234e+12	3.691e-22	1.405e-02
8	.20	3.177e+11	2.733e-22	3.580e-04
9	.12	5.659e+13	7.671e-23	1.790e-02
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.220e+15		1.228e+01

MicroSkyshine
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(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1
File: RCSTS12.SKY
Run: 4:53 p.m.
: May 15, 1997

File Ref: ________
Date: ___/___/___
By: ________
Checked: ________

CASE: RCSTS HORIZONTAL CYL SUBSURFACE BREM RCSTS12

GEOMETRY: Horizontal cylinder source behind a wall

DIMENSIONS (meters):

Distance between wall and detector...........	X	100.
Depth of source behind wall..................	Y	1.01
Offset of detector...........................	Z	-21.14
Depth of dose point..........................	H	-1.5
Distance between source and wall.............	R1	0.01
Distance between near source edge and wall...	R2	1.6952
Thickness of cover slab......................	T1	0.
Thickness of second shield...................	T2	0.1524
Radius of source.............................	W	0.8476
Length of source.............................	L	42.27

INTEGRATION PARAMETERS:

Number of Radial Segments....................	M	5
Number of Circumferential Segments...........	N	5
Number of Length Segments....................	C	5
Quadrature Order.............................		16

MATERIAL DENSITIES (g/cc):

Ambient air: .0012

Material	Cover Slab	Lower Shield	Volume Source
Air			
Water			0.56
Concrete		1.6	1.6
Iron			
Lead			
Zirconium			
Urania			

Buildup factor based on: AIR.

HNF-SD-WM-CN-111, Rev 0

CASE: RCSTS HORIZONTAL CYL SUBSURFACE BREM RCSTS12

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	8.9400e+04	Co-60	1.6600e+02
Cs-137	9.4500e+04	Eu-154	3.7800e+03

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	2.30	8.370e+07	1.623e-21	5.603e-07
2	2.10	1.560e+10	1.616e-21	1.039e-04
3	1.90	1.490e+11	1.553e-21	9.544e-04
4	1.70	6.020e+11	1.443e-21	3.581e-03
5	1.48	2.420e+12	1.305e-21	1.302e-02
6	1.23	6.840e+12	1.372e-21	3.870e-02
7	1.00	1.260e+13	1.211e-21	6.294e-02
8	.82	1.790e+13	1.007e-21	7.435e-02
9	.65	4.810e+13	9.232e-22	1.831e-01
10	.47	7.710e+13	7.498e-22	2.384e-01
11	.35	9.820e+13	5.295e-22	2.144e-01
12	.25	1.920e+14	3.830e-22	3.032e-01
13	.15	4.950e+14	1.671e-22	3.412e-01
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	9.509e+14		1.474e+00

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APPENDIX D PEER AND HEDOP REVIEW CHECKLISTS

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PEER REVIEW CHECKLIST

Document Reviewed: HNF-SD-WM-CN-111, REV 0, ACCIDENT CONSEQUENCE CALCULATIONS FOR THE W-058 SAFETY ANALYSIS
Author: J. C. VAN KEUREN
Date: MAY 1997
Scope of Review: ENTIRE DOCUMENT

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

[X] [ ] [ ] Document approved.

C. H. Huang Chin-Hua Huang — 5/22/97
Reviewer (Printed Name and Signature) — Date

HEDOP REVIEW CHECKLIST

Document Reviewed: HNF-SD-WM-CN-111, REV 0, ACCIDENT CONSEQUENCE CALCULATIONS FOR THE W-058 SAFETY ANALYSIS
Author: J. C. VAN KEUREN
Date: MAY 1997
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. Himes [signature] 5/23/97
HEDOP-Approved Reviewer (Printed Name and Signature) Date

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

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	J. C. Van Keuren	Date 5/28/97
Project Title/Work Order: Accident Consequence Calculations for Project W-058 Safety Analysis		EDT No. 621241
		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
D. J. Braun	A3-34	X			
S. E. Chalk	A2-25	X			
J. L. Gilbert	R3-47	X			
T. G. Goetz	R2-38	X			
B. E. Hey	A3-34	X			
C. Huang	A3-34	X			
L. E. Johnson	A2-25	X			
R. J. Kidder	A2-25	X			
J. C. Van Keuren (2)	A3-34	X			
Central Files (Original + 1)	A3-88	X			