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Calculation Notes for Surface Leak Resulting in Pool, TWRS FSAR Accident Analysis

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Abstract: This document includes the calculations performed to quantify the risk associated with the unmitigated and mitigated accident scenarios described in the TWRS FSAR for the accident analysis titled: "Surface Leaks Resulting in Pool."

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**CALCULATION NOTES FOR SURFACE LEAK RESULTING IN POOL,
TWRS FSAR ACCIDENT ANALYSIS**

Rev. 0

Safety Analysis and Nuclear Engineering

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1.0 INTRODUCTION

This document contains the calculation notes that support the accident analysis titled "Surface Leak Resulting in Pool" in the TWRS FSAR. The unmitigated accident analysis is presented first (Section 2), followed by the mitigated accident analysis (Section 3). The specific accident scenarios examined in the unmitigated and mitigated analyses are identified in Sections 2.1 and 3.1. The unmitigated and mitigated accident analyses include the data, assumptions, and calculations used to establish accident frequency categories (Sections 2.2 and 3.2), to estimate airborne aerosols releases and waste spill volumes (Sections 2.3 and 3.3), and to estimate radiological doses and toxicological exposures (Sections 2.4 and 3.4). The frequency and consequence estimates from the unmitigated accident analysis establishes the inherent risk" of the subject hazard should no controls be in place to prevent or mitigate the hazard. The mitigated accident analysis defines a set of controls to prevent or mitigate the accident and determines the reduction in risk provided by those controls.

Section 4.0 compares the unmitigated and mitigated accident consequences to the TWRS evaluation guidelines. The calculations in the document form the basis for the selection of safety class hardware and TSR controls to prevent and mitigate pool leaks throughout the TWRS waste transfer systems.

2.0 UNMITIGATED ACCIDENT ANALYSIS

2.1 SCENARIO DESCRIPTION

The bounding, representative accident selected for detailed analysis is an overflow of a process pit due to a misroute of waste through an open nozzle. This results in the highest potential leak rate and the largest surface pool of waste in the shortest period of time. Waste can also be spilled into pits due to transfer equipment leaks. Such leaks can overflow pits, but in a longer period of time than in the misroute scenario.

The waste is assumed to be misrouted through an open nozzle into a pit where the cover blocks have been removed and the valve pit drain is closed. The misroute is assumed to occur during a transfer of aging waste facility (AWF) waste. This results in conservative dose estimates because the unit liter dose (ULD) for aging waste solids is much higher than for SST or DST waste solids.

While the pit is filling with waste, aerosols are generated due to splatter and splashing, until the nozzle becomes submerged. After the nozzle becomes submerged, aerosols will continue to be resuspended off the surface of the liquid in the pit as the pit fills (due to eddy and convection currents). The waste eventually overflows the pit and forms a liquid pool on the ground. The pool continues to grow until the transfer pump runs out of waste or the transfer pump is shut off. For the purpose of this analysis, the transfer pump is assumed to be shut off within 12 hours. It is assumed the large leak produced will be detected in 12 hours and the transfer pump shutoff. While the surface pool is growing liquid aerosols are resuspended in wind blowing over the leak. After the transfer pump is shut off, the pool is assumed to soak into the ground, since the pool is no longer resupplied with liquid waste. It is also assumed that the leak occurs when the ambient temperature is below the saturation temperature of the waste. Dissolved salts crystallize out of solution while the pool soaks in leaving a surface layer of contamination. Entrained sludge particulates in the waste are also postulated to be filtered out and left on the surface of the soil. Particulate surface layer contamination is postulated to be resuspended as the soil dries up for an indefinite time period (until the leak site is remediated--sprayed with water to limit resuspension, covered with gravel and dug up for transport to a burial facility). Aerosols are resuspended off the surface of the liquid waste in the pit after the remaining spill volume has soaked into the soil for an indefinite time period (until the pit is drained, pumped, or covered).

2.2 FREQUENCY CATEGORY

Three general types of initiating events are postulated that can lead to overflows of transfer enclosures (e.g., valve pits, pump pits, sluice pits, etc): 1) misroutes through open nozzles, 2) leaks from transfer equipment inside pits (e.g., leaks due to gasket failures, misaligned jumpers, valve packing failures, pump seal failures, etc.), and 3) leaks from buried portions

of concrete or pipe encased transfer lines, where the leak drains back into the pit through the encasement drain.

All three type of initiators are considered to be anticipated events, based on Site experience. The Table in Appendix A lists the events from the occurrence reporting database (between 1972 and 1995) where waste has been misrouted into pits, where transfer equipment leaks inside pits have occurred, or where waste has drained back into pits via transfer line encasements. The occurrence reporting database contains five events between 1975 and 1977 where waste was misrouted through compromised paths and was spilled into pits. These events led to more stringent controls to prevent misroutes. In addition, the occurrence reporting database contains ten accounts between 1972 and 1995 where waste or flush water was found to have spilled into pits due to leaks from jumpers, valves or pump seals. Nine events are included in the database between 1972 and 1995 where waste leaked from primary transfer lines and drained back into pits or diversion boxes via concrete or pipe encasements.

2.3 SOURCE TERM DEVELOPMENT

2.3.1 Waste Inventory and Solids Content

The waste leaked is postulated to be AWF waste, as defined in WHC-SD-WM-SARR-037 (1996), consisting of 33 vol% solids. The radionuclide inventory of AWF waste, by solids and liquids fractions, is summarized in Table 2-1. The inhalation unit liter dose (ULD) values for the solids and liquids fractions are summarized in Table 2-2.

For this analysis, it is assumed that the waste being transported contains one-third (by volume) entrained solids. This is the maximum solids loading expected during tank waste transfers. This solids loading is conservative because it is above the upper operating limit of the 242-A evaporator (limit = 30 vol % solids), which handles the most concentrated waste transported in the tank farms.

2.3.2 Waste Flowrate

The flowrate into the pit depends on the transfer pump and the resistance of the line up to the nozzle. Depending on the length of the line, the number of fittings in the line between the pump and the open nozzle, and whether the misroute involves branch flow, the flowrate through the leak path can vary anywhere between a few gpm and the maximum capacity of the pump. Nominal flowrates in typical transfer routes are expected to be in the range of 50 to 100 gpm. A bounding flowrate through the open nozzle can be established based on pump performance curves. On complete runoff, DST and AWF transfer pumps are capable of flows up to 350 gpm (see information validation form in Appendix B). For this analysis, it is assumed the waste is misrouted into a pit a short distance from the transfer pump. It is assumed that the maximum flowrate through the open nozzle in this pit is 300 gpm. This

accounts for lift out of the tank and resistance provided by fittings and elbows in the transfer line up to the nozzle.

2.3.3 Time Required to Overflow Pit

The inside dimensions of valve pits and pump pits that might be used during DST waste transfers in the 200 East area are summarized in Appendix C. For the purposes of this analysis, the leak is assumed to occur in the A-A valve pit, the smallest valve pit. The AW feed pump pit is smaller and would overflow faster than the A-A valve pit, but is less likely to experience a misroute or a major leak. Diversion boxes are larger than valve pits or pump pits, with the exception of the AP valve pit. The dimensions of diversion boxes can be found in WHC-SD-WM-ISB-001 (1993).

The inside dimensions of A-A valve pit are 10 ft by 12 ft by 4.9 ft deep. Assuming 10% of the pit volume is taken up by transfer equipment (e.g., jumpers, valves and piping), the holding capacity of this pit is

$$V = (10 \text{ ft})(12 \text{ ft})(4.9 \text{ ft})(0.9) = 530 \text{ ft}^3$$

This volume converts to 4000 gal or 15 m³.

The minimum amount of time required for the pit to overflow can be determined by dividing the pit holding capacity by the maximum transfer pump flowrate:

$$\text{Time required for pool to form} = 4000 \text{ gal} / 300 \text{ gpm} = 13 \text{ min.}$$

The above calculation is based on the assumption that the 3 in pit drain is closed. It should be noted that the maximum flowrate of 300 gpm will overwhelm the pit drain and cause an overflow of the pit, even if the pit drain is open. See Appendix D for the calculation showing the maximum drain rate of the pit.

2.3.4 Final Surface Pool Volume and Dimensions

At the maximum transfer pump flowrate of 300 gpm, the total leak volume over 12 hours is calculated as follows:

$$V(\text{final pool}) = (300 \text{ gal/min})(60 \text{ min/h})(12 \text{ h}) = 216,000 \text{ gal}$$

[To simplify the consequence analysis, line drainback into the pit after the transfer pump has been shut off is ignored. Drainback would add insignificantly to the pool volume above.]

The spread of the pool is dependent on the topography of the soil, the natural infiltration rate of the soil and chemistry considerations. In this analysis, the ambient temperature is assumed to be well below the saturation temperature of the waste at the time of the leak. This results in salts

crystallizing out of solution, forming a crust on the ground surface which limits penetration of the waste into the soil. This maximizes the spread of the pool creating the largest surface area for resuspension. Atlantic Richfield Hanford Company Occurrence report 73-78 and ARH-2977 RD (1974) describe an incident where an estimated 8600 gal of waste escaped from a tank riser to the soil surface in the S Tank Farm. The flow covered an irregularly shaped area with maximum dimensions of about 50 feet by 200 ft. The depth of penetration into the soil varied from about 2 inches to 18 inches. The penetration depth was limited by a crust of salts which crystallized out of solution. Dividing the surface area of soil effected by the estimated spill volume gives the "spreading factor" for the above incident:

$$\begin{aligned}\text{spreading factor} &= (50 \text{ ft})(200 \text{ ft}) / (8600 \text{ gal})(1 \text{ ft}^3 / 7.48 \text{ gal}) \\ &= 8.7 \text{ ft}^{-1}\end{aligned}$$

The volume of waste spilled to the soil surface in the unmitigated accident is 212,000 gal (216,000 gal - 4000 gal held contained in the valve pit). If it is assumed the 212,000 gal that overflows the pit spreads out with the same spreading factor as the incident reported in ARH-2977, the soil surface area effected in the unmitigated accident is:

$$A = (216,000 \text{ gal})(1 \text{ ft}^3 / 7.48 \text{ gal})(8.7 \text{ ft}^{-1}) = 2.51\text{E}+05 \text{ ft}^2$$

For the purposes of estimating shine and skyshine doses the soil area effected by the leak is assumed to be circular, with the pit at the center of the pool. The radius of the effected soil surface area is given by $r = [A/(\pi)]^{1/2}$:

$$r = [(2.51\text{E}+05 \text{ ft}^2) / (3.14)]^{1/2} = 283 \text{ ft} = 86 \text{ m}$$

2.3.5 Aerosol Release During Filling of the Pit

While the pit is filling with waste aerosols will be generated due to splatter (initially), splashing (after a layer of liquid has built up). Aerosols will also be resuspended off the surface of the waste in the pit away from the area where the splatter and splashing are occurring.

2.3.5.1 Release due to Splatter and Splashing. Waste flowing out the open nozzle will splatter off the floor of the pit, initially, but may also splatter off other equipment in the pit while falling to the floor (until that equipment becomes submerged). No release fraction could be found in the literature for liquids being poured into liquids. It would be expected that the splashing source term would be much smaller than a splatter source term. However, since splatter off other equipment could occur even after several inches of waste have built up in the bottom of the pit, a splatter release fraction is used to estimate the aerosol release until the nozzle becomes submerged.

DOE-HDBK-3010-94, Section 3.2.3.2, gives splatter release fractions for free fall spills of slurries (3 m fall distance). The bounding respirable

release fraction (RRF), based on the experiments summarized in DOE-HDBK-3010-94, is $4\text{E-}05$. The average release fraction is $1.6\text{E-}05$. It is assumed that the nozzle becomes submerged when the liquid fills the pit half full. The splatter RRF therefore applies to the first 2000 gal of waste spilled into the pit. Using the bounding RRF, the aerosol release due to splatter and splashing is

$$Q(\text{splatter, splashing}) = (2000 \text{ gal})(3.8 \text{ L/gal})(4\text{E-}05) = 0.30 \text{ L}$$

It is assumed that all the aerosols generated due to splatter are dispersed away from the pit at the same rate they are generated. No credit is taken for aerosol depletion due to agglomeration and rainout within the open pit. This release occurs in the first 6.7 minutes of the accident $[(2000 \text{ gal})/(300 \text{ gal/min})]$.

2.3.5.2 Resuspension Release from the Surface of the Waste in the Pit. The resuspension release from the surface of the waste in the pit while the pit fills is negligible in comparison to the splatter/splashing source term. The resuspension flux off large outdoor ponds is shown in the Section 2.3.6.1 to be less than $2\text{E-}10 \text{ kg/m}^2\text{-s}$. The estimated density of a slurry containing 33 vol % solids is 1.4 kg/L (based on the operating limit of the 242-A evaporator). Converting the mass resuspension flux to a volumetric basis, gives a resuspension flux of $1.4\text{E-}10 \text{ L/m}^2\text{-s}$. This resuspension flux includes the aerosol generating effects of ripples or waves on the surface of a large pond.

The cross sectional area of the pit is 120 ft^2 ($10' \times 12'$), or 11.1 m^2 . Using the conservative outdoor pool resuspension flux of $1.4\text{E-}10 \text{ L/m}^2\text{-s}$ to estimate the aerosol generation due to resuspension as the pit fills (which includes aerosol entrainment from welling and wave action within the pit) gives the following release rate:

$$Q'(\text{Resuspension during filling}) = (1.4\text{E-}10 \text{ L/m}^2\text{-s})(11.1 \text{ m}^2) = 1.55\text{E-}09 \text{ L/s}$$

Multiplying by the time period required to fill the pit (13 min, Section 2.3.3), gives a release volume of:

$$Q(\text{Resuspension during filling}) = 1.55\text{E-}09 \text{ L/s}(60 \text{ s/min})(13 \text{ min}) = 1.21\text{E-}06 \text{ L}$$

This release occurs during the first 13 minutes of the accident.

2.3.6 Resuspension Releases After the Pit Overflows

2.3.6.1 Resuspension Release from Surface Pool. After the pit overflows, the waste is postulated to form an expanding surface pool until the transfer pump is shutoff at 12 h. Aerosols will also be resuspended off the surface of the pool due to ripple/wave action.

The release from the growing liquid pool is estimated using a resuspension release flux of $2\text{E-}10 \text{ Kg/m}^2\text{-s}$. This resuspension flux was

estimated from Figure 3-8 in DOE-HDBK-3010-94, corresponding to the mass release for a pond with a 200 m fetch at wind speeds less than 5 m/s. This resuspension flux is conservative for this accident where the radius of the pool is 86 m and 99.5 percentile meteorology is assumed in performing dose calculations. 99.5 percentile meteorology corresponds to wind speeds less than 1 m/s.

The aerosol resuspension release rate from the surface of the growing pool varies with time, as the release rate is proportional to the surface area of the pool. The time integrated dose over the 0 to 12 hour time period can be estimated, however, by using the average resuspension release rate over the time period of interest. The average pool surface area is $1.26\text{E}+05 \text{ ft}^2$ (one half the final pool surface area reported in Section 2.3.4), or $1.17\text{E}+04 \text{ m}^2$. The resuspension release flux is converted to a volumetric basis using a waste density of 1.4 kg/L. This is the estimated density of waste slurry containing 1/3 vol fraction solids. The volumetric resuspension flux is $1.4\text{E}-10 \text{ L/m}^2\text{-s}$ ($2\text{E}-10/1.4$).

The average resuspension release rate while the surface pool is growing is therefore

$$\begin{aligned} Q'(\text{resuspension, surface pool}) &= (1.4\text{E}-10 \text{ L/m}^2\text{-s})(1.17\text{E}+04 \text{ m}^2) \\ &= 1.64\text{E}-6 \text{ L/s} \end{aligned}$$

Multiplying this average release rate by the time period the pool is growing gives the total release over this phase of the accident.

$$Q(\text{resuspension, surface pool}) = (1.64\text{E}-6 \text{ L/s})(3600 \text{ s/h})(12 \text{ h}) = 7.08\text{E}-2 \text{ L}$$

This release occurs after the pit overflows in the 13 minute to 12 hour time frame.

2.3.6.2 Resuspension Release from Contaminated Soil After Soaking In. After the transfer pump is shut off, the waste will soak into the soil, leaving salts and entrained solids behind as surface contamination. As the soil dries out, this surface contamination is subject to resuspension in wind blowing over the soil. As the waste soaks in, some aerosols may also be generated due to sparging as air is displaced upward from voids in the soil.

The release from the contaminated soil surface after the waste has soaked in is estimated using a respirable release fraction (RRF) of $8.4\text{E}-5$ over a 24 h time frame. This resuspension RRF comes from Section 3.2.4.4 of DOE-HDBK-3010-94 (1994) and is based on experiments with UNH solutions spilled on soil and dried under low wind speed conditions ($<2.5 \text{ mph}$). The UNH experiments involved 25 to 50 ml aliquots of solution spread thinly over the soil. The resuspension fractions measured in these experiments is conservative for large pooling releases where the soil remains damp longer and the becomes more heavily intermingled with the soil matrix.

Applying the RRF of $8.4\text{E-}5$ to the 212,000 gal that overflowed the pit, the resuspension release after the waste has soaked in is:

$$Q(\text{resuspension, soil}) = (212,000 \text{ gal})(3.79 \text{ L/gal})(8.4\text{E-}5) = 67.5 \text{ L}$$

This release occurs in the 12 to 36 h time frame.

The resuspension release rate is not constant with time. Resuspension experiments reported in BNWL-1732 (1973) indicate that most of the easily resuspended material can be expected to come off early. Figure 2-1, reproduced from BNWL-1732, shows measured resuspension rates as a function of time. Based on this figure 50 % of the contaminated soil resuspension release can be expected to occur over a 2 h time frame after the waste soaks in. Approximately 80 % of the total release can be expected to occur within 12 hours, and 99 % within 16 hours.

The above release estimate of 67.5 L assumes the soil is allowed to dry out, making the surface contamination highly susceptible to resuspension. The release would be substantially reduced if the surface pool were continually wetted after discovery or covered up.

2.3.6.3 Continued Resuspension Release from the Surface of Waste Contained in the Pit. Aerosols will continue to be resuspended off the surface of the waste contained in the pit even after the waste material outside the pit has soaked into the soil. The surface area of the waste in the pit is $(10 \text{ ft})(12 \text{ ft}) = 120 \text{ ft}^2$, or 11.1 m^2 . Using the conservative resuspension flux of $1.4\text{E-}10 \text{ L/m}^2\text{-s}$, the release rate from the surface of the waste in the pit is:

$$Q'(\text{resuspension, pit liquid}) = (1.4\text{E-}10 \text{ L/m}^2\text{-s})(11.1 \text{ m}^2) = 1.55\text{E-}9 \text{ L/s}$$

The release is constant and occurs after 12 hours. The release from the surface of the waste overflowing the pit in the 13 min to 12 hour time frame is included in the release reported in Section 2.3.6.1. The total release from the pit waste over the 12 to 36 h time frame is:

$$\begin{aligned} Q(\text{pit waste surface}) &= (1.55\text{E-}9 \text{ L/s})(24\text{h})(60 \text{ min/h})(60 \text{ s/min}) \\ &= 1.34\text{E-}4 \text{ L} \end{aligned}$$

2.3.7 Maximum Release Rates for Estimating Toxicological Exposures

Unlike dose estimates, which are time integrated, toxicological exposure risk is estimated based on a release rate (see Section 2.4.6). For accidents where the release varies over time, it is necessary to identify the maximum release rate to assess toxicological exposure risk.

The maximum release rate for the onsite receptor is different than the maximum release rate for the offsite receptor. For the onsite receptor, the maximum release rate occurs while the pit is filling, due to splatter and resuspension. Over the first 13 minutes of the accident the release volume

due to splatter and splashing is 0.30 L. This gives a maximum release rate for the onsite receptor of:

$$Q'(\text{max, on}) = (0.30 \text{ L}/13 \text{ min})(1 \text{ min}/60 \text{ s}) = 3.85\text{E-}04 \text{ L/s.}$$

For the offsite receptor, the maximum waste release rate occurs after the waste has soaked into the soil. The resuspension release rate from the contaminated soil surface is not constant with time. Based on the resuspension experiment results reported in BNWL-1732 (1973), most of the easily resuspended material can be expected to come off early. Figure 2-1, reproduced from BNWL-1732, shows measured resuspension rates as a function of time. Based on this figure 50 % of the contaminated soil resuspension release can be expected to occur over a 2 h time frame after the waste soaks in. The maximum waste release rate is therefore:

$$Q'(\text{max, off}) = (67.4 \text{ L})/(2)(2 \text{ h}) = 16.9 \text{ L/h or } 4.69\text{E-}3 \text{ L/s}$$

2.4 CONSEQUENCE ANALYSIS

The onsite receptor is assumed to be exposed for the first 12 hours of the accident. The onsite receptor is thus exposed to the aerosols released during filling of the pit and to aerosols released off the surface of the growing pool. In accordance with the methodology outlined in WHC-SD-WM-SARR-037 (1996), the offsite receptor is assumed to be subject to a 24-h uptake ingestion dose in addition to the inhalation dose. The onsite receptor will receive significant external dose due to direct shine and skyshine. The shine and skyshine dose from the pool and contaminated soil will be negligible to the offsite receptor due to the extreme distance to that receptor. Both receptors can be effected by the chemicals and heavy metals in the release as well as by the radioactive components of the waste.

The following sections estimate the dose and toxicological effects to the onsite and offsite receptors.

2.4.1 Onsite and Offsite Receptor Inhalation Dose Estimates

The onsite and offsite receptor inhalation doses are calculated in accordance with the methodology outlined in WHC-SD-WM-SARR-016 (1996) and WHC-SD-WM-SARR-037 (1996). The inhalation doses are calculated using the following equation:

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

Where,

D_{inh} = dose, in Sv (50-yr CEDE)
 Q = respirable release volume, in equivalent L_v of waste
 X/Q' = atmospheric dispersion coefficient, in s/m^3
 BR = receptor breathing rate, in m^3/s
 ULD_{inh} = inhalation unit liter dose, in Sv/L

The respirable release volumes are determined in Section 2.3. The acute X/Q's for the onsite and offsite receptors from SARR-Q16 are reproduced in Table 2-3. The active man's breathing rate is $3.3\text{E-}4 \text{ m}^3/\text{s}$. The inhalation ULDs for each tank waste type, by solids and liquids fractions, are reproduced from SARR-037 in Table 2-2. The material released in this accident is AWF waste with an estimated maximum solids content of 33 vol %. The composite ULD_{inh} for the AWF slurry is estimated by combining the AWF ULDs for solids and liquids (from Table 2-2) in their appropriate volume ratios, as follows:

$$\begin{aligned}\text{ULD}_{\text{inh}}(\text{AWF slurry}) &= (0.67)(1.4\text{E}+03 \text{ Sv/L}) + (0.33)(1.7\text{E}+06 \text{ Sv/L}) \\ &= 5.6\text{E}5 \text{ Sv/L}\end{aligned}$$

The above dose model assumes gaussian dispersion. The X/Q's in Table 2-3 are not valid inside 100 m. The onsite receptor is normally assumed to be 100 m from the site of the release. The radius of the pool formed in this accident is 86 m. If it is assumed the onsite receptor is 100 m from the center of the valve pit, the onsite receptor is only 14 m from the edge of the pool, where gaussian dispersion estimates are unreliable. It is unlikely an individual would remain within 14 m of such a large visible surface pool of waste for a significant time period. To allow for an estimation of the onsite inhalation dose, the onsite receptor is assumed to be located 100 m from the edge of the pool.

2.4.1.1 Onsite Receptor Inhalation Dose. The onsite receptor is assumed to be exposed for the first 12 hours of the release. This receptor is assumed to be evacuated after the leak is detected and the transfer pump is shut off. The receptor is exposed to aerosols from splatter/splashing and resuspension during the first 13 minutes of the accident and to aerosols resuspended from the expanding surface pool as the pump continues to operate up to 12 hours. From Sections 2.3.5.1, 2.3.5.2 and 2.3.6.1, the total aerosol release is 0.37 L. The acute X/Q', without plume meander, from Table 2-3 is used to estimate the dose. The acute X/Q' without plume meander is used because the release varies with time, with the majority of the release occurring in the first 13 minutes. The inhalation dose to the maximally exposed onsite receptor is:

$$\begin{aligned}D(\text{on, inh}) &= (0.37 \text{ L})(3.41\text{E-}2 \text{ s/m}^3)(3.3\text{E-}4 \text{ m}^3/\text{s})(5.6\text{E}+05 \text{ Sv/L}) \\ &= 2.3 \text{ Sv (230 rem)}\end{aligned}$$

[Note: this consequence analysis assumed the transfer pump is not shutoff until 12 h and that the pool does not soak into the ground while the pump is running. This maximizes the total spill volume and the offsite inhalation dose. Since the resuspension of surface contamination is much higher than off a pool surface, it should be noted that the onsite inhalation dose is underestimated for cases where smaller spill volumes are involved that could soak into the soil and dry out within the 12 onsite receptor's exposure period.]

2.4.1.2 Offsite Receptor Inhalation Dose. The offsite receptor is exposed for the duration of the accident. The release is modelled in Section

2.3 to last for 36 hours. Summing up the releases quantified in Section 2.3, the total release is 67.9 L. Using the acute offsite X/Q' , without plume meander, the inhalation dose to the offsite receptor is:

$$\begin{aligned} D(\text{off, inh}) &= (67.9 \text{ L})(2.83\text{E-}5 \text{ s/m}^3)(3.3\text{E-}4 \text{ m}^3/\text{s})(5.6\text{E+}05 \text{ Sv/L}) \\ &= 0.355 \text{ Sv (35.5 rem)} \end{aligned}$$

2.4.2 Offsite Receptor Ingestion Dose Estimate

The offsite receptor is assumed to be exposed to a 24 h uptake ingestion dose as well as to an inhalation dose. This is in accordance with SARR-037. The dose effect due to ingestion is estimated with the following equation:

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

Where,

$$\begin{aligned} D_{\text{ing}} &= 24\text{-h uptake ingestion dose, in Sv (50-yr CEDE)} \\ Q &= \text{respirable release volume, in equivalent } L \text{ of waste} \\ X/Q' &= \text{atmospheric dispersion coefficient, in } \text{s/m}^3 \\ ULD_{\text{ing}} &= \text{inhalation unit liter dose, in } \text{Sv-m}^3/\text{s-L} \end{aligned}$$

The material released in this accident is AWF waste with an estimated maximum solids content of 33 vol %. The composite ULD_{ing} for the AWF slurry is estimated by combining the SST ULDs for solids and liquids (from Table 2-2) in their appropriate volume ratios, as follows:

$$\begin{aligned} ULD_{\text{ing}}(\text{AWF slurry}) &= (0.67)(0.992 \text{ Sv-m}^3/\text{s-L}) + (0.33)(8.1 \text{ Sv-m}^3/\text{s-L}) \\ &= 2.7 \text{ Sv-m}^3/\text{s-L} \end{aligned}$$

This ULD_{ing} includes external exposure due to shine from particles deposited on the ground around the receptor. The offsite X/Q and the total resuspension release volume are the same as used previously. The ingestion dose to the offsite receptor is:

$$\begin{aligned} D(\text{ing, off}) &= (67.8 \text{ L})(2.83\text{E-}5 \text{ s/m}^3)(2.7 \text{ Sv-m}^3/\text{s-L}) \\ &= 5.2\text{E-}3 \text{ Sv (5.2E-1 rem)} \end{aligned}$$

2.4.3 Direct Shine Dose to Onsite Receptor

The direct shine dose to the onsite receptor varies over his 12 h of exposure. The shine dose increases as the pool grows and encroaches closer to the receptor. To simplify the calculation, the dose to the onsite receptor is conservatively estimated based on the maximum dose rate for the fully formed pool, when the edge of the pool is closest to the receptor and the pool activity is maximized.

The MICROSHIELD computer program (Grove 1992) is used to estimate the shine dose. WHC-SD-WM-SARR-016 (1996) contains a description of the calculational methods used in this code. Two MICROSHIELD runs are performed.

The first run is made to calculate the dose contribution from the important gamma emitters. The second run is made to calculate the dose contribution from bremsstrahlung radiation produced by scattering of beta particles in the pool.

2.4.3.1 Shine Dose Due to Gamma Emitters. The shine dose at the receptor location is dependent on the source geometry, the location of the receptor with respect to the source volume, the activity of gamma emitters in the source volume, and the source and shield material characteristics and densities.

Source Geometry. As discussed previously, the fully formed pool is postulated to assume a circular shape with a radius of 282 ft (86 m). The source volume is therefore modelled as a cylinder 86 m in radius. It is conservatively assumed that none of the waste soaks into the soil while the pump is running. The depth of the pool (cylinder) is 1.4 in (3.5 cm), based on the spreading value reported in Section 2.3.4.

Onsite Receptor Location. The onsite receptor is assumed to be 100 m from the edge of the pool. The receptor is therefore 186 m from the center of the pool. The dose rate is calculated for a point 1.5 m off the ground to determine effects to the trunk of the receptor.

Source Activities. The SST radionuclide inventories from Table 2-1 are used to define the gamma emitter activities in the source volume. For the composite AWF material containing 33 vol % solids, the following activities are estimated by multiplying the solids and liquids concentrations by the appropriate volume fraction. The daughter Ba-137m is in equilibrium with its parent Cs-137 at a 0.946 ratio. The source volume activities for the important gamma emitters are as follows:

$$\text{Cs-137 activity} = [(9.8\text{E}+10 \text{ Bq/L})(0.33) + (8.84\text{E}10 \text{ Bq/L})(0.67)] \\ \times (212,000 \text{ gal})(3.79 \text{ L/gal}) = 7.4\text{E}16 \text{ Bq}$$

$$\text{Ba-137m activity} = (0.946)(\text{Cs-137 activity}) = 7.0\text{E}16 \text{ Bq}$$

$$\text{Co-60 activity} = [(4.9\text{E}+08 \text{ Bq/L})(0.33) + (7.71\text{E}5 \text{ Bq/L})(0.67)] \\ \times (212,000 \text{ gal})(3.79 \text{ L/gal}) = 1.3\text{E}14 \text{ Bq}$$

$$\text{Eu-154 activity} = (1.11\text{E}+10 \text{ Bq/L})(0.33)(212,000 \text{ gal})(3.79 \text{ L/gal}) \\ = 2.94\text{E}+15 \text{ Bq}$$

The activity of the waste in the pit is ignored, due to its distance from the receptor and the shielding provided by the soil between the pit and the receptor.

Shield Materials. The waste is modelled as water with a density of 1.4 g/cc (the estimated density of a waste slurry containing 33 vol % solids). The soil between the edge of the pool and the receptor is modelled as a side clad shield consisting a concrete with an overall density of 1.6 g/cc.

2.4.3.1.2 MICROSHIELD Results. The input and output file from the MICROSHIELD run are included in Appendix E, as Case 1. The cylindrical source was divided into 10 radial, 10 circumferential, and 10 axial kernels or segments.

The total exposure rate, with buildup, was found to be 619 mR/h. Exposure in Roentgen is conservatively converted to effective dose equivalent, in rem, using a conversion factor of 1. Multiplying the maximum exposure rate by the exposure duration of 12 h gives a conservative total shine dose, due to gamma emitters, of:

$$\begin{aligned} D(\text{on, shine, gamma}) &= (619 \text{ mR/h})(12 \text{ h})(1 \text{ rem/R}) \\ &= 7430 \text{ mrem (74.3 mSv)}. \end{aligned}$$

2.4.3.2 Shine Dose Due to Bremsstrahlung Radiation. The shine dose due to brehmstrahlung radiation was estimated with MICROSHIELD using the same geometry and shield material densities used to estimate the direct shine dose.

Appendix F includes output generated by BREMCALC (Rittmann 1992) of the photon production rates for 1 Ci (3.7E10 Bq) of Sr-90/Y-90, in both water and concrete. The source term in this scenario is made up of a mixture of concrete (to simulate soil) and water. It is conservative to use the photon production rate values for concrete since they are higher than those of water.

The photon production rates in the source pool can be estimated by scaling up the photon production rates for concrete in Appendix F by the total activity of Sr-90/Y-90 in the source volume. From Table 2-1, the activity concentration of Sr-90/Y-90 in the solids phase of AWF waste is 2.9E12 Bq/L. In the liquids phase of AWF waste, the Sr-90/Y-90 concentration is 5.6E09 Bq/L. Multiplying by the appropriate solids and liquids fractions and the total spill quantity gives the total activity of Sr-90/Y-90 in the source volume:

$$\begin{aligned} \text{Sr-90/Y-90 Activity} &= [(2.9\text{E}12 \text{ Bq/L})(0.33) + (5.6\text{E}+09 \text{ Bq/L})(0.67)] \\ &= \times (212,000 \text{ gal})(3.79 \text{ L/gal}) \\ &= 7.7\text{E}+17 \text{ Bq (2.1E}+07 \text{ Ci)} \end{aligned}$$

To estimate the photon production rate of the contaminated soil, the photon production rates for concrete, from Appendix F, were scaled up by a factor of 2.1E+07. The photon production rates entered into the code, for each of the energies bins of concern, are summarized in Table 2-5.

The MICROSHIELD output file is contained in Appendix E, Case 2. From the output file, the estimated exposure rate is 86.8 mR/h, with buildup in air. Over a 12 h time period, the total dose (EDE) is:

$$\begin{aligned} D(\text{on, shine, bremsstrahlung}) &= (86.8 \text{ mR/h})(12 \text{ h})(1 \text{ rem/R}) \\ &= 1040 \text{ mrem, or 10.4 mSv} \end{aligned}$$

2.4.4 Skyshine Dose to Onsite Receptor

The skyshine dose from the contaminated soil is estimated using the MICROSKYSHINE computer code (Grove 1987). WHC-SD-WM-SARR-016 contains a description of the calculational methods used in this code. Again, the dose due to gamma emitters and brehmsstrahlung effect are calculated separately.

2.4.4.1 Skyshine Dose Due to Gamma Emitters. For the skyshine calculation the pool is modelled as a vertical cylinder behind a hypothetical shield wall. The wall height is selected to be just high enough to preclude line of sight dose to the onsite receptor. This is necessary to avoid double counting the direct shine dose. The radius and depth of the cylinder are the same as in the direct shine calculations. The dose to the receptor is calculated for a point 1.5 m off the ground 100 m from the edge of the pool. To model the self shielding provided by the pool, the pool is modelled to have the shielding properties of water with a density of 1.4, as in the direct shine calculation.

The geometrical parameters that must be entered into the MICROSKYSHINE code are depicted in Figure 2-2. For this analysis, the hypothetical shield wall was arbitrarily located 1 m from the edge of the pool (the location of the wall is not important as long as it precludes line of sight radiation but is not too high to mask skyshine). The radius of the pool, W, is 86 m (Section 2.3.1). The distance from the center of the pool to the hypothetical shield wall, parameter R1 in figure 2-2, is 87 m. The distance from the hypothetical shield wall to the receptor location, parameter X from Figure 2-2 is = 99 m. The depth of the pool, L, is 3.5 cm. The dose is modelled at a point 1.5 m off the ground (Section 2.4.3.1). Therefore, $-H = 1.5 - Y$. The parameter Y was determined using similar triangles, with the following equation:

$$Y/(W+R1) = -1.5/(W+R1+X)$$

Rearranging and solving gives $Y = 0.956$ m and $H = -0.544$ m.

The results of the MICROSKYSHINE run are included in Appendix G as Case 1. The estimated exposure rate is 6.16 R/h. Multiplying the maximum exposure rate by the 12 h exposure duration and converting to absorbed dose, using a conservative conversion factor of 1 (R to rem), gives a total dose:

$$D(\text{on, skyshine, gamma}) = (6.16 \text{ R/h})(12 \text{ h})(1 \text{ rem/R}) = 74 \text{ rem } (0.74 \text{ Sv})$$

2.4.4.2 Skyshine Dose Due to Bremsstrahlung Radiation. The skyshine dose due to brehmsstrahlung radiation is measured using the same geometrical parameters as in the previous section. The photon production rates and energy groups entered into the code are the same as those used for the direct shine doses in Section 2.4.3.3.

The output file from the MICROSKYSHINE run are included in Appendix G as Case 2. The estimated exposure rate is 1.39 R/h. Multiplying by the 12 h exposure period, using a conservative conversion factor of 1 (R to rem), gives a total dose of:

$$\begin{aligned} D(\text{on, skyshine, bremsstrahlung}) &= (1.39 \text{ R/h})(12 \text{ h})(1 \text{ rem/R}) \\ &= 17 \text{ rem } (0.17 \text{ Sv}) \end{aligned}$$

2.4.5 Summary of Dose Estimates, by Pathway

Table 2-5 provides a summary of the onsite and offsite dose estimates, by pathway, for the unmitigated accident scenario. The shine and skyshine dose estimates in the table are the combined total from gamma emitters and bremsstrahlung radiation. The total dose to the onsite receptor due to the inhalation, shine, and skyshine pathways is 3300 mSv (330 rem). The total dose to the offsite receptor from the inhalation and ingestion pathways is 360 mSv (36 rem).

2.4.6 Toxicological Exposure Estimates for the Onsite and Offsite Receptors

Onsite and offsite toxicological exposures are assessed using the sum-of-fractions methodology outlined in WHC-CM-SARR-011 (1996). Table 2-6 gives the unit liter sum-of-fractions multipliers for the various waste types, broken into liquids values and solids values. Toxicological exposure is assessed by multiplying the release rate by the appropriate sum-of-fractions multiplier from Table 2-6. (Note that the sum-of-fraction multipliers are dependent on accident frequency). Products less than one are considered to indicate acceptable risk (i.e., indicate exposures below evaluation guidelines).

The sum of fractions multipliers for DST waste containing 33 vol % solids is estimated by combining the DST solids and liquids values from Table 2-6. For the Anticipated frequency range, the sum of the fraction multiplier for the onsite receptor is $1.3\text{E}+04 \text{ s/L} [(0.33)(1.8\text{E}+04 \text{ s/L}) + (0.67)(1.0\text{E}+04)]$. For the offsite receptor and the Anticipated frequency category, the sum of the fraction multiplier for DST waste containing 33 vol % solids is $68 \text{ s/L} [(0.33)(190) + (0.67)(8.4)]$.

Toxicological exposures are assessed using the maximum release rate. From Section 2.3.8, the maximum release rate for the onsite receptor is $3.8\text{E}-04 \text{ L/s}$. The maximum release rate for the offsite receptor is $4.7\text{E}-03 \text{ L/s}$. The onsite and offsite sum of fractions results are therefore:

$$\text{Onsite sum of fractions} = (3.85\text{E}-4 \text{ L/s})(1.3\text{E}+04 \text{ s/L}) = 5.0$$

$$\text{Offsite sum of fractions} = (4.69\text{E}-03 \text{ L/s})(68 \text{ s/L}) = 0.32$$

3.0 MITIGATED ACCIDENT ANALYSIS

3.1 SCENARIO DESCRIPTION

The following controls were selected to prevent and mitigate the valve pit overflow accident:

Preventative Controls

- Waste transfer controls were selected to prevent misroutes through open nozzles. These controls consist of configuration management of transfer routings and independent verification of valve lineups prior to transfers.
- Open nozzles in all pits that could overflow in a misroute scenario will be blanked off.
- Transfer pumps will be locked out when not in use to prevent inadvertent pump startups.
- Jumper leak tests will be performed following jumper changes to ensure the jumpers have been installed properly. This will minimize the potential for catastrophic leaks at jumper connections.

Mitigative Controls

- For transfer equipment leaks (i.e., gasket failures, valve packing failures, pump seal failures, pipe failures, etc), pit leak detectors and their alarms will be relied on to limit the total volume of liquid spilled.
- Operator response to pit leak detectors will be required to ensure transfer pumps are shutdown within 30 minutes of indication of a leak.
- The pit covers will be required to be installed during transfers to limit shine and skyshine doses to facility workers and to mitigate the release of aerosols from the pit generated due to splatter while the pit is filling.

The preventative controls above are relied on to prevent high volume flowrates into pits (i.e., misroutes through open nozzles, jumpers falling off during transfers). High flowrate leaks can overflow the pit despite the mitigative controls listed above, since 30 minute may be required for operator response to a pit leak detector alarm. Flowrates in excess of 295 gpm can overflow the pit even if the pit drain is open (see calculation in Appendix D), so requiring that pit drains be open and free of debris may not preclude pit overflows in misroute accidents.

Taking credit for the preventative controls, only small flowrate leaks into the pit are expected (e.g., leaks caused by gasket failures, valve packing failures, corrosion failures in pipes, etc.). The mitigative controls above will detect the small flowrate leaks from transfer equipment inside the pit and will prevent the pit from overflowing.

The mitigated accident scenario is as follows:

- An equipment leak inside the A-A pit causes a low volume flowrate leak.
- As in the unmitigated analysis, the pit drain is assumed to be closed.
- The pit leak detector is assumed to alarm after 2 inches of waste have built up in the bottom of the pit. The assumed 2 inch activation level provides safety margin since the pit leak detectors are normally set to alarm at 1 inch.
- Flow is assumed to continue for 30 minutes, allowing time for operators to respond to the alarm and to shut off the appropriate transfer pump.
- Aerosols are generated inside the pit while the pump is running due to splatter and sloshing.
- Convection currents in the pit are assumed to keep some aerosols in suspension after the transfer pump is shutoff.
- Aerosols are expelled through gaps in the cover block due to liquid displacement and natural pit breathing. The pit is postulated to breathe due to wind effects, the heat load inside the pit, and atmospheric temperature and pressure changes.

3.2 FREQUENCY CATEGORY

The frequency category of the mitigated accident is anticipated. Leaks from transfer equipment inside pits is anticipated based on site experience. See Section 2.2.

3.3 SOURCE TERM DEVELOPMENT

3.3.1 Spill Volume

The total volume of waste spilled to the pit includes the volume of waste necessary to activate the pit leak detector, the volume of waste spilled during the 30 minutes required for operator action to shutoff the transfer pump, and the volume of waste that may drain back through the transfer line after the transfer pump is shut off due the slope and length of the transfer line.

The cross sectional area of the A-A valve pit is 120 ft^2 [(12 ft)(10 ft)]. It is assumed that the pit leak detector will alarm when waste has built up to 2 in. The spill volume necessary to activate the leak detector is

$$V(\text{LD}) = (120 \text{ ft}^2)(2 \text{ in})(1 \text{ ft}/12 \text{ in})(7.48 \text{ gal}/\text{ft}^3) = 150 \text{ gal}$$

The volume of waste spilled after the leak detector alarms until the transfer pump is manually shutdown determined based on the leak rate and the duration necessary to perform the manual shutdown. Given the controls to prevent high flowrate leaks into the pit, the maximum leak rate into the pit is assumed to be 20 gal/min from piping. This flowrate is judged to be conservative for leaks from jumper gaskets, valve packing, and pipe. The nominal flowrate through transfer lines ranges from 75 to 100 gpm, so the assumed leak rate corresponds to greater than 20 % of the nominal flowrate.

30 minutes is allowed for manual shutdown of the transfer pump. The leak volume during this 30 minutes is

$$V(30 \text{ min}) = (20 \text{ gal}/\text{min})(30 \text{ min}) = 600 \text{ gal}.$$

Drain back is estimated by assuming that 20 % of the holdup in a 10,000 ft line drains back into the pit after the transfer pump is shut off. Transfers are made through 2 in or 3 in schedule 40 lines. To maximize drain back, it is assumed the transfer is made through a 3 in line. The volume due to drain back is estimated with the following equation:

$$V(\text{drainback}) = f(\pi)(d)^2(L)/(4)$$

where: f is fraction of holdup drained through the leakage path instead of to the source or receipt tank, $\pi = 3.14$, L = length of pipe, d = pipe diameter. The inner diameter of a 3 in schedule 40 pipe is 3.068 in. Plugging in the appropriate values gives:

$$V(\text{drainback}) = (0.2)(3.14)(3.068/12 \text{ ft})^2(10,000 \text{ ft})/4 = 103 \text{ ft}^3$$

The drainback volume converts to 770 gal [(103 ft^3)(7.48 gal/ ft^3)].

The total volume of waste leaked to the pit over the course of the accident is 150 gal + 600 gal + 770 = 1520 gal. The holding capacity of the pit is 4000 gal (Section 2.3.3). The waste therefore fills the pit approximately 38 % full (1520/4000).

3.3.2 Aerosol Release from the Pit

Aerosols are produced due to splatter and splashing while waste is spilling into the pit. Aerosols may also be resuspended off the surface of the waste due to convection currents in the pit. After the transfer pump shuts off, these convection currents may continue to maintain suspension of a fraction of the aerosols that were generated while the pump was running.

The quantity of aerosols generated due to splatter and splashing while the waste is flowing is estimated using a respirable release fraction RRF of 4E-05. This RRF is based on experiments with viscous slurries spilled from heights up to 3 m. The results of the experiments are summarized in Section 3.2.3.3 of DOE HDBK-3010-94 (1994). The density of the 33 vol% solids waste slurry is assumed to be 1.4 g/cc (the upper operating limit of the 242-A evaporator at 30 vol% solids). Using the splatter RRF, the assumed maximum leak rate of 20 gpm, and the assumed waste slurry density of 1.4 kg/L, gives the following splatter aerosol production rate:

$$Q'(\text{splatter}) = (20 \text{ gal/min})(3.8 \text{ L/gal})(4\text{E}-05)(1400 \text{ g/L}) = 2.1 \text{ g/min}$$

The quasi-stable aerosol loading limit of air is 100 mg/m^3 (PNL-4154, Section 2.4.14). The volume of the A-A valve pit is approximately 530 ft^3 or 15 m^3 (Section 2.3.3). The pit air volume will therefore could reach the quasi-stable aerosol loading limit in as fast as 0.34 min [$(100 \text{ mg/m}^3)(15 \text{ m}^3)/4300 \text{ mg/min}$]. Aerosols will agglomerate and settle out after reaching the quasi-stable limit.

Air is expelled from the pit due to liquid displacement, heat load, wind effects, and atmospheric pressure and temperature fluctuations. Approximately 40% the pit air volume (1520 gal) is displaced by the liquid spilling into the pit. A leak rate of 20 gpm, the air is expelled over $1520 \text{ gal}/20 \text{ gpm} = 76$ minutes. The pit will breathe indefinitely thereafter. The equivalent mass of waste released as aerosol from the pit can be conservatively estimated by assuming 1 pit volume of air is expelled at the quasi-stable aerosol loading limit of 100 mg/m^3 . At a conservative pit breathing rate of 0.1 volume exchanges/h, the majority of the aerosols in the pit vapor space after the transfer pump has been shut off and the line holdup has drained back into the pit will be displaced over a 10 h time frame, conservatively assuming none of the aerosol condenses or settles out of the pit vapor space.

The 100 mg/m^3 aerosol loading value is the same aerosol loading used in the unmitigated analysis where the pit covers are assumed to be off during the leak. The mitigated analysis is therefore conservative as no decontamination factor is applied to the pit covers. It is expected that the airborne aerosol concentration would be reduced as the air passed through the tortuous cover block gaps.

The holding capacity of the pit is 4000 gal or 15 m^3 . The respirable aerosol release from the pit, converting to a volumetric basis using the assumed waste density of 1.4 g/cc, is:

$$Q(\text{aerosol release}) = (15 \text{ m}^3)(100 \text{ mg/m}^3)(1 \text{ L}/1.4\text{E6 mg/L}) = 1.1\text{E}-03 \text{ L}$$

3.4 CONSEQUENCE ANALYSIS

The onsite and offsite receptors are exposed to the entire aerosol release quantity estimated in the previous section. The onsite receptor

receives an inhalation dose. The offsite receptor receives both an inhalation dose and a 24 h uptake ingestion dose.

3.4.1 Onsite Receptor Inhalation Dose Estimate

The release volume is $1.1\text{E-}03$ L. The acute X/Q' with plume meander from Table 2-3 is used to model atmospheric dispersion. Using the AWF composite slurry ULD_{inh} developed earlier, and the active receptor breathing rate, the dose to the onsite receptor is:

$$\begin{aligned} D(on, inh) &= (1.1\text{E-}03 \text{ L})(1.13\text{E-}02 \text{ s/m}^3)(3.3\text{E-}4 \text{ m}^3/\text{s})(5.6\text{E+}05 \text{ Sv/L}) \\ &= 2.3\text{E-}03 \text{ Sv } (0.23 \text{ rem}) \end{aligned}$$

3.4.2 Offsite Receptor Inhalation Dose Estimate

Using the acute offsite X/Q' , with plume meander, from Table 2-3, the active man's breathing rate, and the AWF composite slurry ULD_{inh} , the offsite receptor dose is:

$$\begin{aligned} D(off, inh) &= (1.1\text{E-}3 \text{ L})(2.12\text{E-}5 \text{ s/m}^3)(3.3\text{E-}4 \text{ m}^3/\text{s})(5.6\text{E+}05 \text{ Sv/L}) \\ &= 4.3\text{E-}06 \text{ Sv } (4.3\text{E-}04 \text{ rem}) \end{aligned}$$

3.4.3 Offsite Receptor Ingestion Dose Estimate

From Section 2.4.2, the ULD_{ing} for an AWF composite slurry containing 33 vol % solids is $2.7 \text{ Sv-m}^3/\text{s-L}$. Using the acute offsite X/Q' , with plume meander, the offsite receptor dose to 24-h uptake of his own fruits and vegetables is:

$$\begin{aligned} D(off, ing) &= (1.1\text{E-}03 \text{ L})(2.12\text{E-}5 \text{ s/m}^3)(2.7 \text{ Sv-m}^3/\text{s-L}) \\ &= 6.3\text{E-}8 \text{ Sv } (6.3\text{E-}6 \text{ rem}) \end{aligned}$$

3.4.4 Shine and Skyshine Doses to the Onsite Receptor

The direct shine and skyshine doses to the onsite receptor, located 100 m from the pit, will be negligible in comparison to the inhalation dose due to the shielding provided by the concrete pit cover block (1'8" deep), the pit walls (1' thick), and the soil between the pit and the receptor.

3.4.5 Toxicological Exposure Estimates

The maximum aerosol release rate occurs while the transfer pump is running and the pit is filling with waste. The displacement rate of air from the pit is equivalent to the waste leak rate--20 gal/min. Converting to more convenient metric units, the displacement rate is $(20 \text{ gal/min})(3.79 \text{ L/gal})(\text{m}^3/1000 \text{ L})(\text{min}/60 \text{ s}) = 1.26\text{E-}3 \text{ m}^3/\text{s}$. At the quasi-stable aerosol loading limit of 100 mg/m^3 , the maximum aerosol release rate, converting units to equivalent L of waste using the assumed waste density of 1.4 g/cc , is:

$$Q'(\text{max}) = (1.26\text{E-}3 \text{ m}^3/\text{s})(100 \text{ mg/m}^3)(1 \text{ L}/1.4\text{E}06 \text{ mg}) = 9.0\text{E-}08 \text{ L/s}$$

From Section 2.4.6, the onsite sum-of-fractions multiplier for DST waste containing 33 vol % solids, for the 'anticipated' frequency category, is $1.3\text{E}04$ s/L. The offsite sum-of-fractions multiplier for DST waste containing 33 vol % solids is 68 s/L.

Toxicological exposure is assessed by multiplying the release rate by the sum-of-fractions multiplier. Multiplying the maximum release rate by the onsite sum-of-fractions multiplier gives a product of $(9.0\text{E}-08 \text{ L/s})(1.2\text{E}+04 \text{ s/L}) = 1.1\text{E}-04$.

Multiplying the maximum release rate by the offsite sum-of-fractions multiplier gives a product of $(9.0\text{E}-08 \text{ L/s})(68 \text{ s/L}) = 6.1\text{E}-06$.

4.0 COMPARISON TO EVALUATION GUIDELINES

Table 4-1 summarizes the results of the consequence analyses above and compares the consequences with the TWRS evaluation guidelines. Table 4-1 shows that the unmitigated accident produces onsite and offsite dose consequences in excess of the evaluation guideline for the Anticipated frequency category. The unmitigated onsite toxicological exposure is also shown to be above the evaluation guideline for the Anticipated frequency category. The offsite toxicological consequences are shown to be below the evaluation guideline for the Anticipated frequency category.

Table 4-1 shows that the controls selected to mitigate the consequences of the accident are sufficient to keep onsite and offsite radiological and toxicological exposures below the evaluation guidelines for the Anticipated frequency category.

5.0 SUMMARY OF KEY ASSUMPTIONS

This section summarizes the key assumptions used in the unmitigated and mitigated accident analyses.

5.1 KEY ASSUMPTIONS, UNMITIGATED ACCIDENT ANALYSIS

- The waste leaked is assumed to be aging waste facility (AWF) waste containing 33 vol % entrained solids ($SpG = 1.4$).
- The maximum waste flowrate into the pit is assumed to be 300 gpm.
- The valve pit drain is assumed to be plugged at the time of the leak.
- Mass balances and visual observations are assumed to not be performed or to detect the pool leak for a period of 12 h.
- The transfer pump is assumed to be shutoff at 12 h.
- The waste is assumed to spread out over the soil surface to an average depth of 1.4 in.
- The onsite receptor is assumed to be located 100 m from the edge of the pool.
- For shine and skyshine calculations for the onsite receptor, the pool is assumed to be circular.
- After the transfer pump is shutoff and the liquid waste soaks into the soil, it is assumed that the contaminated soil surface is not sprayed with water or covered up to limit resuspension.
- The onsite receptor is assumed to be evacuated 12 h after the start of the leak.
- The offsite receptor is assumed to be exposed for a 36 hour time period.

5.2 KEY ASSUMPTIONS, MITIGATED ACCIDENT ANALYSIS

- The controls selected to prevent misroutes through open nozzles into pits and to prevent bad jumper connections are assumed to preclude high flowrate leaks into the pit.
- The maximum leak rate into the pit, given the preventative controls, is assumed to be 20 gpm from a degraded jumper gasket.
- The waste leaked is assumed to be AWF waste containing 33 vol % solids ($SpG = 1.4$).

- The leak is assumed to occur in the A-A valve pit, the smallest east area valve pit.
- The pit drain is assumed to be plugged at the time of the leak.
- The pit leak detector alarm is assumed to go off after 2 in of waste has built up in the pit.
- 30 minutes is assumed for operator action to shut down the appropriate transfer pump after the leak detector alarm goes off.
- 20% of the line holdup in a 10,000 ft long, 3 in (diameter) transfer line is assumed to gravity drain back through the leakage path after the transfer pump is shut off.
- One pit volume of air is assumed to be expelled from the pit at the quasi-stable aerosol loading limit of 100 mg/m^3 due to liquid displacement and natural breathing. The aerosols are produced during the leak due to splatter and splashing.

6.0 MINIMUM POOL SIZE REQUIRED TO EXCEED OFFSITE GUIDELINES

The large pool evaluated in the unmitigated accident analysis in Section 2 produces dose consequences that are well in excess of the offsite evaluation guidelines. For such a large pool to be formed, mass balances routinely performed during transfers (every 2 hours) would have to be skipped for 12 hours and operators would have to be absent from the area along the transfer route where the leak occurred or fail to visually observe the surface pool for a period of 12 hours. These failures would have to occur in addition to the failure of an engineered feature, the pit leak detector. This section calculates the minimum pool size required to exceed the offsite guidelines to provide a better perspective on risk.

Section 2.3.7 shows that the overwhelming majority of waste released in the accident occurs after the waste has soaked into the soil. In soaking into the soil the pool leaves behind surface contamination that is especially susceptible to resuspension as the soil surface dries out. The respirable release fraction for resuspension of the deposited contamination on the soil is shown in Section 2.3.7 to be $8.4\text{E-}5$ over 24 hours. This release fraction assumes the waste is spread thinly over the soil before soaking in. The airborne release quantity is directly proportional to the volume of waste spilled. This allows for the maximum acceptable surface pool volume (minimum surface pool volume necessary to exceed offsite guidelines) to be easily approximated. The maximum acceptable surface pool volume is given by:

$$V(\text{max. accept}) = D / (\text{ULD}_{\text{inh}}) (\text{RRF}) (X/Q') (\text{BR})$$

where V = maximum acceptable pool size, D = evaluation guideline dose limit = 1 mSv for the Anticipated frequency category, ULD_{inh} = unit liter dose factor for inhalation = $5.6\text{E}+05 \text{ Sv/L}$ (Section 2.4.1), RRF = respirable release fraction = $8.4\text{E-}4$, and X/Q' = offsite acute X/Q' (with plume meander) = $2.12\text{E-}5 \text{ s/m}^3$ (Table 2-3), and BR = receptor breathing rate = $3.3\text{E-}04 \text{ m}^3/\text{s}$.

Solving gives:

$$V(\text{max, accept}) = (1\text{E-}03 \text{ Sv}) / [(5.6\text{E}+05 \text{ Sv/L})(8.4\text{E-}05)(2.12\text{E-}05 \text{ s/m}^3)(3.3\text{E-}04 \text{ m}^3/\text{s})] \\ = 3000 \text{ L}$$

This converts to 800 gal. Adding in the holding capacity of the pit, which is 4000 gal, gives a total allowable leak volume of in this case of 4800 gal. At the maximum transfer pump flowrate of 300 gpm, the total leak volume is reached in 16 minutes (4800/300). The controls selected for the mitigated accident were developed to ensure that the process pit would not overflow. The calculation above demonstrates that moderate sized surface pools can create a significant offsite hazard.

The consequences of surface pool leaks can be substantially reduced if the soil surface is sprayed to keep it damp or if it is covered up with gravel. Such emergency response to the soil spill was also not assumed in the unmitigated accident scenario.

7.0 PEER REVIEW

Appendix H contains the signed off peer review checklists for this document.

8.0 REFERENCES

- ARH-2977 RD, 1974, *Report On the Cleanup Activities Following the 241-S Tank Farm Contamination Occurrence at the Hanford Reservation, Richland, Washington on November 14, 1973*, Atlantic Richfield Hanford Company, Richland, Washington.
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- WHC-SD-WM-SARR-016, 1996, *Tank Waste Compositions and Atmospheric Dispersion Coefficients for Use in Accelerated Safety Analysis Consequence Assessments*, Rev. 2, Westinghouse Hanford Company, Richland, Washington.
- WHC-SD-WM-SARR-037, 1996, *Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Figure 2-1. Graph of Resuspension Fraction Vs. Time

AERODYNAMIC ENTRAINMENT OF URANIUM DIOXIDE POWDER FROM SMOOTH, SANDY SOIL AT AN AIR VELOCITY OF 2.5 MPH ±

From Figure 14 of BNWL-1732

Figure 2-2. Geometrical Parameters for MICROSKYSHINE Calculations

Table 2-1 Bounding Activity Concentrations, by Waste Type*

Isotope	Concentration (Bq/L)					
	SST Liquids	SST Solids	DST Liquids	DST Solids	Aging Waste Liquids	Aging Waste Solids
⁶⁰ Co	9.53E+06	4.18E+08	6.97E+06	1.45E+07	7.71E+05	4.85E+08
⁹⁰ Sr	1.05E+10	1.63E+12	4.59E+08	5.16E+10	5.60E+09	2.88E+12
⁹⁰ Y	1.05E+10	1.63E+12	4.59E+08	5.16E+10	5.60E+09	2.88E+12
¹³⁷ Cs	2.21E+10	1.01E+11	5.86E+10	5.86E+10	8.84E+10	9.80E+10
¹⁵⁴ Eu	2.35E+09	5.75E+09	4.18E+07	3.00E+08	0.00	1.11E+10
²³⁷ Np	0.00	0.00	2.30E+05	8.11E+05	9.20E+04	9.92E+08
²³⁸ Pu	9.21E+04	1.87E+08	1.78E+06	7.15E+07	2.75E+03	6.74E+07
²³⁹ Pu	3.62E+07	4.40E+08	7.65E+06	1.57E+09	1.20E+06	4.40E+08
²⁴¹ Pu	2.57E+08	3.22E+09	1.84E+07	3.81E+09	3.39E+05	1.65E+09
²⁴¹ Am	4.23E+07	2.29E+08	3.40E+07	2.71E+09	1.10E+06	1.10E+10
²⁴⁴ Cm	4.23E+05	2.29E+06	1.22E+05	1.64E+07	1.10E+04	6.08E+07

*From WHC-SD-WM-SARR-037 (1996)

Table 2-2. Unit Liter Doses for Inhalation and Ingestion.

Composite	Inhalation ULD (Sv/L)	Ingestion ULD (Sv-m ³ /s-L)
Single-shell tank liquids	1.1 E+04	0.052
Single-shell tank solids	2.2 E+05	4.1
Double-shell tank liquids	6.1 E+03	0.068
Double-shell tank solids	5.3 E+05	0.48
Aging waste facility liquids	1.4 E+03	0.092
Aging waste facility solids	1.7 E+06	8.1

NOTE: The information in this table is from WHC-SD-WM-SARR-037, 1996, Development of Radiological Concentrations and Unit Liter Doses for THRS FSAR Radiological Consequence Calculations, Westinghouse Hanford Company, Richland, Washington.

ULD = unit liter dose.

Table 2-3. Centerline Atmospheric Dispersion Coefficients for 200-Area Tank Farm Acute, Ground Level Release

Maximum individual	Bounding integrated χ/Q' (s/m^3)	Bounding integrated χ/Q' (s/m^3) with plume meander	Maximum puff χ/Q ($1/m^3$)
Onsite sector and distance	3.41 E-02 E 100 m	1.13 E-02 ESE 100 m	9.85 E-03 E 100 m
Offsite sector and distance	2.83 E-5 N 8,760 m	2.12 E-05 N 8,760 m	1.14 E-7 NNW 8,690 m

NOTE: The information in this table is from WHC-SD-WM-SARR-016, 1996, Tank Waste Compositions and Atmospheric Dispersion Coefficients for Use in Accelerated Safety Analysis Consequence Assessments, Westinghouse Hanford Company, Richland, Washington.

E = east
ESE = east, southeast.
N = north
NNW = north north west

Table 2-4. Photon Production Rates Entered in the MICROSHIELD and MICROSKYSHINE Codes, Unmitigated Accident Analysis

Group Midpoint Energy (MeV)	Photon Production Rate for 1 Ci Sr-90 in Concrete (photons/s)	Photon Production Rate Entered into Code for 2.1E7 Ci of Sr-90 (photons/s)
0.015	1.24E+09	2.6E+16
0.025	6.26E+08	1.3E+16
0.035	3.99E+08	8.4E+15
0.045	2.83E+08	5.9E+15
0.055	2.14E+08	4.5E+15
0.065	1.69E+08	3.5E+15
0.075	1.37E+08	2.9E+15
0.085	1.14E+08	2.4E+15
0.095	9.61E+07	2.0E+15
0.150	5.03E+08	1.1E+16
0.250	1.95E+08	4.1E+15
0.350	9.98E+07	2.1E+15
0.475	7.84E+07	1.6E+15
0.650	4.89E+07	1.0E+15
0.825	1.82E+07	3.8E+14
1.000	1.28E+07	2.7E+14
1.225	6.95E+06	1.5E+14
1.475	2.46E+06	5.2E+13
1.700	6.12E+05	1.3E+13
1.900	1.51E+05	3.2E+12
2.1	1.59E+04	3.3E+11
2.3	8.51E+01	1.8E+09

Table 2-5. Summary of Unmitigated Dose Estimates, by Pathway

Pathway	Onsite Receptor	Offsite Receptor
Inhalation	2300 mSv (230 rem)	355 mSv (35.5 rem)
Ingestion	NA	5.2 mSv (0.52 rem)
Shine, gamma	74 mSv (7.4 rem)	negligible, in comparison to inhalation dose
Shine, bremsstrahlung	10 mSv (1 rem)	negligible, in comparison to inhalation dose
Skyshine, gamma	740 mSv (74 rem)	negligible, in comparison to inhalation dose
Skyshine, bremsstrahlung	170 mSv (17 rem)	negligible, in comparison to inhalation dose
Total Dose	3300 mSv (330 rem)	360 mSv (36 rem)

Table 2-6. Sum-of-Fraction of Risk Guidelines for a Unit Release of Chemicals and Gases.

*The sum of fractions are multiplied by the release rate for continuous release and release amount for a puff releases. Release rates for continuous releases are in units of liters per second for liquids and solids, and m^3/s for gases. Puff release quantities are in units of liters for solids and liquids and m^3 for gases.

Tank waste type (Units of sum of fractions follow tank waste type)	Maximum individu al	Accident frequency, 1/yr		
		1 - 10 ⁻²	10 ⁻² - 10 ⁻⁴	10 ⁻⁴ - 10 ⁻⁶
DST or SST solid or liquid continuous release				
Single-shell liquids(s/L)	Onsite	9.6 E+03	7.5 E+02	2.0 E+02
Single-shell liquids(s/L)	Offsite	8.0 E+00	8.0 E+00	6.2 E-01
Single-shell solids(s/L)	Onsite	4.0 E+04	2.1 E+04	1.0 E+03
Single-shell solids(s/L)	Offsite	9.4 E+01	3.3 E+01	1.7 E+01
Double-shell liquids(s/L)	Onsite	1.0 E+04	7.5 E+02	2.1 E+02
Double-shell liquids(s/L)	Offsite	8.4 E+00	8.4 E+00	6.2 E-01
Double-shell solids (s/L)	Onsite	1.8 E+04	3.3 E+03	6.3 E+02
Double-shell solids(s/L)	Offsite	1.9 E+02	1.5 E+01	2.8 E+00
DST or SST liquid or solid puff release				
Single-shell liquids (L ⁻¹)	Onsite	2.8 E+03	2.2 E+02	5.7 E+01
Single-shell liquids (L ⁻¹)	Offsite	3.2 E-02	3.2 E-02	2.5 E-03
Single-shell solids (L ⁻¹)	Onsite	1.2 E+04	6.0 E+03	2.9 E+02
Single-shell solids (L ⁻¹)	Offsite	3.8 E-01	1.3 E-01	6.9 E-02
Double-shell liquids (L ⁻¹)	Onsite	2.9 E+03	2.2 E+02	6.0 E+01

Table 2-6. Sum-of-Fraction of Risk Guidelines for a Unit Release of Chemicals and Gases.

*The sum of fractions are multiplied by the release rate for continuous release and release amount for a puff releases. Release rates for continuous releases are in units of liters per second for liquids and solids, and m³/s for gases. Puff release quantities are in units of liters for solids and liquids and m³ for gases.

Tank waste type (Units of sum of fractions follow tank waste type)	Maximum individu al	Accident frequency, 1/yr		
		1 - 10 ⁻²	10 ⁻² - 10 ⁻⁴	10 ⁻⁴ - 10 ⁻⁶
Double-shell liquids (L ⁻¹)	Offsite	3.4 E-02	3.4 E-02	2.5 E-03
Double-shell solids (L ⁻¹)	Onsite	5.2 E+03	9.7 E+02	1.8 E+02
Double-shell solids (L ⁻¹)	Onsite	7.7 E-01	5.9 E-02	1.1 E-02

**Table 4-1. Consequences of Surface Leak Resulting in Pool,
Compared to Evaluation Guidelines**

Receptor/Hazard	Calculated Dose/Exposure		Evaluation guideline		
	Unmitigated	Mitigated	Anticipated	Unlikely	Extremely Unlikely
Offsite/radiological	360 mSv	4.4E-03 mSv	1 mSv	5 mSv	40 mSv
Onsite/radiological	3300 mSv	2.3 mSv	5 mSv	50 mSv	100 mSv
Offsite/toxicological sum-of-fractions	0.32	6.1E-06	1	1	1
Onsite/toxicological sum-of-fractions	5.0	1.2E-03	1	1	1

APPENDICES

APPENDIX A

**Historical Tank Farm Leaks Surface Leaks and Leaks
Inside Transfer Structures**

Historical Tank Farm Surface Leaks and Leaks
Inside Transfer Enclosures

Occurrence Number	Date	Leak Type	Description
73-78	11/14/73	surface pool leak	During transfer from Tank 107-S to 102-S the transfer line plugged and waste backed up and flowed out the tank riser onto the ground. Cause: transfer line apparently plugged due to crystallization of the waste. The resulting surface pool contained an estimated 8600 gal of waste covering a surface area of 3000 yd ² .
ROR-75-2-7	2/13/75	Leak to surface from OGT line	Spill of contamination to ground during overground transfer from Tank BY-105. Plastic wrapped joints on overground line did not hold the leak. The contamination covered about 30 sq. ft at levels to 5 rads/h at 6 inches.
75-78	7/16/75	Leak Inside Diversion Box	Jumper connector failure during waste transfer from Tank TX-107 to U-103 cause leak. Jumper located in 153-TXR Diversion Box. Cause for leak: threads were stripped on flex jumper.
75-110	10/02/75	leak inside pit	Radiation alarm in 101-AY "B" leak detection pit after transfer from 152-AX diverter catch tank. Unknown cause. Transfer pipeline may have leaked.

75-111	10/03/75	Misroute through open jumper	2200 gal waste transfer through open jumper nozzle flowed via pump pit drain into incorrect target tank. Cause: human error, jumper not installed for transfer, route not checked.
75-115	10/11/75	Above grade leak from overground transfer line	Small, slow leak occurred in overground transfer line between Tanks 108-C and 103-C. Cause: leak at connector head to transfer pump.
75-134	11/21/75	Misroute into pit	Misrouted waste transfer from 104-SX to 101-SX pit. Cause: operator error. Operator changed valve settings while walking through a procedure.
76-61	4/25/76	Leak from overground transfer line	Spilled 500 gal of water when overground line from 104-TX to 108-TX pump pit connection failed.
76-131	9/27/76	Leak in pit	Radioactive waste spill during jumper disconnection in 105-U pump pit. Cause: waste transfer ongoing in adjacent tank pressurized jumper due to partial failure of a closed valve.
77-64	4/30/77	Misroute into pit	Misrouted waste transfer into 103-SY leak detection pit (and tanks 101-SY and 103-SY) during transfer from 111-U to 102-SY. Cause: human error.
77-189	10/19/77	Misroute into tank annulus	Failure of blank between pump pit and leak detection pit results in contamination spread to 102-SY annulus.

77-205	12/06/77	Leak inside pit	Spray leak from 111-X pump pit during leak check of salt well pump and jumpers. The leak check was not done with cover blocks installed. Cause: failed gasket at pump inlet flange.
80-26	2/21/80	leak to encasement pipe	Line leak in slurry line SL 126 between 241-SD valve pit and Tank 107-S cross site pump pit. Leak assumed to be caused by corrosion.
80-81	8/26/80	Leak inside pit	Spray leak in 241-AW-05A central pump pit during slurry transfer to Tank 105-AW. Cause: worker unable to tighten connection between jumper and distributor sufficiently.
80-90	11/11/80	Leak to encasement pipe	Slurry line SL-176 leaked during transfer from 242-S evaporator to tank 103-SY. Cause assumed to be corrosion of carbon steel transfer line.
82-02	1/05/82	Leak to concrete encasement	Failure of process line V-402 during TX-farm salt well pumping. Cause: mechanical failure. Line failure confirmed by pressure test.
82-21	5/15/82	Leak to concrete encasement	Failure of process line (V-398) between 241-TX-155 and 241-U-151.
84-71	11/19/84	Leak to encasement	Transfer line between B-Plant and 244-A lift station (Line SN-233) leaked to encasement.
85-34	4/12/85	Leak to encasement pipe	Unneutralized Tank F-18 (PUREX) transfer resulted in pipe damage in line between 241-AW-A valve pit and 241-101-AW distributor. Cause: human error--failure to neutralize batch prior to transfer.

HC-TANKFARM-1992-09	5/05/92	Misroute to pit and subsurface leak	While conducting a hydrostatic pressure test of underground waste transfer lines in the 241-S Tank Farm, water was heard draining into a 241-S valve pit. SL-119 leaked to ground forming a small pool of water at the surface. Berm eroded away.
WHC-TANKFARM-1992-46	6/12/93	Leak to encasement	Attempted to hydro test transfer line SN-215, line did not hold pressure for 30 seconds. Assumed line failed.
WHC-TANKFARM-1993-08	1/15/93	Leak to pit	Transfer from 204-AR to 101-AY failed due to frozen jumpers in path.
WHC-TANKFARM-1994-59	10/26/94	Leak to encasement	Transfer line SL-503 failed during transfer from 204-AR to Tank 102-AY. Tripped leak detector in sluice pit on Tank 102-AY.
WHC-TANKFARM-1994-62	11/2/94	Leak inside pit	During saltwell pumping of 109-BY a high radiation dose was measured over the pump pit. The saltwell pump discharge developed a leak.
WHC-TANKFARM-1995-23	3/7/95	Leak inside pit	Transfer from 204-AR to 102-AY leaked into 241-A-A valve pit through nozzle. Leak drained into catch tank A-350.
WHC-TANKFARM-1995-41	4/13/95	Leak inside pit	Leak found by 244-A camera crew during B Plant transfer.
WHC-TANKFARM-1995-81	10/4/95	Leak inside pit	Transfer line SN-274 leaked during transfer between AX-B valve pit and 101-AN. Leak at flexible jumper connection.

WHC- TANKFARM- 1995-109	11/21/94	Leak into encasement	Pressure test of supernate transfer line SN-246 failed, indicating loss of integrity. Line is encasement for part of its length.
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APPENDIX B

Information Validation Form: Maximum Transfer Pump Flowrate

Information Validation Form

Tracking # IVF-Chapter 3-H4

Name of Originator Brett Hall	Organization or Team Consequence Analysis	Date 8/13/96
<p>Statement of Problem: need to define the maximum pump flowrate to assume in the "surface leak resulting in pool" accident analysis. The representative accident to be analyzed is a misroute into a pit through an open nozzle, or a catastrophic leak inside a pit due to a jumper falling off during a transfer. Misroutes into pits through open jumpers have occurred in tankfarms. The maximum flowrate is needed to estimate the time period required to overflow the pit and to estimate the size of the surface pool formed.</p> <p>Several pump performance curves for DST, DCRT, and AWF transfer pumps are attached. A maximum flowrate of 50 gpm appears to be appropriate for SST transfers, based on the pump curve for the submersible pump used in the recent BX-106 transfer (calculation also attached). Please specify the maximum flowrate that should be assumed in the analysis for AWF transfers, DST transfers, DCRT transfers, and SST transfers. All four values are needed to define the worst case scenario for analysis and to ensure proper controls are selected for pool leaks throughout the tankfarms.</p>		
Alternatives		Consequences to Alternatives
Decision Reached		Basis for Decision
Date Requested 8/13/96	Sent To Lankford Ruffin, Jeff Andrews	Date Requested By 8/16/96
<p>Response #1 Based upon engineering's calculations the bounding flowrate should be 350 gpm for DST, AWF, and DCRT transfers. For SST transfers use 50 gpm as the bounding case.</p>		
<p>Response #2</p>		

Attachments (List)	References (List)	
Responder #1 Name and Signature JE Andrews <i>L.H. for JE. Andrews</i> 5/15/16	Responder #2 Name and Signature	
POC:	Filed:	Routed:
Further Action Required (i.e., RML, Senior Management Attention, etc.)		

ROCKWELL INTERNATIONAL CORP
TAG: 6411-2225-79P-TX4 THRU
6411-2225-83P-TX-4EA
10-20 HR. PROCESS PUMPS (1F-2)
TEST NO. PC-B781 6 JOL-005

Peabody Floway

DWG. NO. 80-2277-
Form FPI-214

Comp. in 102-11

... GALLONS PER MINUTE

WHC-30-W-1-C-1

BEST AVAILABLE COPY

B.H.P.

EFFICIENCY

ATLANTIC BROOMFIELD HANFORD CO.
P.O. BOX 1441-4251
NON-CORROSIVE SERVICE PUMP
PUMP DESIGNATION C-17-101
PUMP TEST HPC-2120

TYPE 6 JOL
NO. OF STAGES 2
R.P.M. 3505
PUMP SERIAL NO. 76-8200-1

DWN. BY DAM DATE 12-28-64

Performance shown is the result of a test conducted in accordance with latest Hydraulic Institute Standards. Other standards applicable when mutually agreed upon.

FLOWAY PUMPS, INC., FRESNO, CALIF.

ATTY BROTHERS, INC.
BOX 2367-105 S. THIRD AVE.
FHA, WASHINGTON 98901

76-8200-1

59 29 55

DATE 4-8-74

REV. DATE

GOULDS PUMPS, INC.
 SENECA FALLS, NEW YORK 14850

CENTRIFUGAL PUMP CHARACTERISTICS

 CERTIFIED PERFORMANCE DATA
 GOULDS PUMPS, INC.
 SENECA FALLS, N.Y.

Van A. Johnson
BEST AVAILABLE COPY
 RPM 3550 CDS 2298
 MODEL 3796 8 1/2"
 SIZE 2 x 2-10
 IMP. DWG. 76797 B10000
 PATTERN 56229 5181
 EYE AREA 4.9 SQ. IN.

 GOULDS SER. NO. 706650-1-2
 CUSTOMER ROCKWELL INT'L. CORP.
 P.O. NO. WOH-XBB-212132
 ITEM NO. 11 EQUIP # 207AR-BB3-71420
 SERVICE

WTC-SDWM-CN-049 Rev. 0

DISCOUNT FACTOR MAY INCLUDE

WESTINGHOUSE HANFORD OPERATION
 RICHLAND WASHINGTON
 25HP CLOSE COUPLED PUMP
 ITEM NO. 834-TX1
 PUMP TEST: PC# 17469

EFFICIENCY
 70%
 60%
 50%
 40%
 B.H.P.
 25.0
 15.0
 5.0

PUMP EFF.

BOWL HEAD IN FEET

450
 400
 350
 300
 250
 200
 150

U.S. GALLONS PER MINUTE

0 48 80 120 160 200

PICATTI BROS. INC.
 185 S. THIRD AVE.
 YAKIMA WA. 98909

TYPE 6JOLL
 NO. OF STAGES 7
 R.P.M. 3575
 PUMP SERIAL NO. 91-02163

DWN. BY E.K. DATE 31-Mar-92

DWG. NO. 91-02163-T1

BEST AVAILABLE COPY

WH-SD-WM-CN-04 Rev. 0

104 cm

1. *Chrysomelids* (Coleoptera: Chrysomelidae)

PICATTI BROTHERS
P.O. BOX 9576
YAKIMA, WASH. 98901

Peabody Floway

TYPE 6. JOL
NO. OF STAGES 27
R.P.M. _____
PUMP SERIAL NO 80-2277

DWG. NO. 80-2277-
Form FPI-214

BEST AVAILABLE COPY

OWN. BY D.T. _____ DATE 9-25-80

WFC-SD-WM-CN-CHM, Rev 0

102 SY SPARE

Performance shown is the result of a test conducted in accordance with latest Hydraulic Institute Standards. Other Standards applicable when mutually agreed upon.

WESTINGHOUSE - HANFORD FACILITY
25HP CLOSE COUPLE AMP
DASH # 615Y1
PUMP TEST # 14269

57 of 94

CERTIFIED CORRECT FOR
OUR ORDER NO. 29049
CUST. ORDER NO. 29049
DATE 12-17-81
BY 132 FIELD HP @ 1,488 Sp. gr.

PICATTI BROS INC
YAKIMA, WASH 98908

BEST AVAILABLE COPY WTC-SD-WM-CN-049 Rev. D
There's a difference...

TYPE 87044
NO. OF STAGES 8
R.P.M. 1725
PUMP SERIAL NO. 87-01556

1721-2000-00118-0000

58 to 85

TOTAL HEAD IN FEET

PICATTI BROS., INC.
P.O. BOX 9576
YAKIMA, WASHINGTON 98901

QWC NO.

80-2268-9

U.S. GALLONS PER MINUTE

3.0 HP @ 17.5 GPM

B. H. P.

EFFICIENCY

ROCKWELL INTERNATIONAL CORP.
TAG: P-102 (51-02A-1 THRU-3)
102 54
3-20 HP CROSS COUNTRY TRANSFER PUMPS

Peabody Floway

TYPE 6.001
NO. OF STAGES 22
R.P.M. 1760
PUMP SERIAL NO. 80-2289-2291

1200 AVAILABLE BEST

OWN BY L.S.H. DATE 4-16-80

WHC-5D-WM-C2-27, 580

JOHNSTON PUMP COMPANY
BROOKSHIRE, TEXAS

CUSTOMER: WESTINGHOUSE HANFORD
JOB #: TC-6702 S/N: TC-6702 POF#: 66190 TC #: 06558

PURCHASE ORDER # WAP-XVV-20972

ITEM # 1

3565 RPM

BEST AVAILABLE COPY

WAP-20-2011-01-01, 2000

TOTAL HEAD IN FEET

59 of 94

2012

244A
spare

244-TX

WHC-SD-WM-CN-049, Rev C

BEST AVAILABLE COPY

PUMP RUN-IN DATA SHEET

PAGE 9 OF 9

WORK ORDER NO. E-04865 TEST RUN-IN # 3 DATE 1-7-88
 PUMP IDENTIFICATION # 2225-243P-TX-1 TEST SPECIFICATION # FS-F-10
 SHAFT ROTATION CCW PUMP LENGTH 18' 4 1/2" DISCHARGE PIPE SIZE 2"

PERFORMANCE DATA

	WIDE	3/4	RATED FLOW	1/4	SHUT
	OPEN	FLOW	FROM CRITERIA	FLOW	OFF
	FLOW				HEAD
1 GPM	186	143	100	50	0
2 DISCHARGE PRESSURE, PSIG.	9.2	88.5	152.7	199+1	199+
3 DISCHARGE PRESSURE, FEET (PSIG X 2.31)	21.3	204.4	352.7	461.8+	461.8+
4 GAGE CORRECTION (CENTER LINE OF GAGE TO WATER LEVEL IN FT)	7	7	7	7	7
5 VELOCITY HEAD DISCH PIPE	5	3	1.4	.4	—
6 PIPE DISCHARGE CORRECTION (ELBOW COUPLINGS)	26	19	14.3	10.4	9
7 TOTAL DISCHARGE HEAD FT. (ADD LINES 3+4+5+6)	59.3	233.4	375.4	479.6+	477.8+
8 NHPS	25.22	25.50	23.94	18.95	12.77
9 VIBRATION (MILS)	.3mils	.3mils	.3mils	.3mils	.3mils

RUN-IN-DATA

TIME	DISCHARGE PRESSURE PSIG	FLOW RATE GPM	AMPS	MOTOR BEARING TEMP. (150 DEGREES MAX.)	PUMP BRNG. TEMP.	VIBRATION (MILS)	COMMENTS
8:35	154.4	100	23.94	142°	86°	.3 mils	
9:15	158.7	100	24.22	146°	95°	.3 mils	
10:15	164.1	100	24.17	145°	100°	.3 mils	
11:15	165.6	100	24.14	140°	101°	.3 mils	
12:15	165.0	100	24.05	137°	103°	.3 mils	
1:15	165.2	100	24.05	141°	102°	.3 mils	
2:15	165.3	100	24.04	141°	103°	.3 mils	
3:15	165.4	100	24.00	140°	102°	.3 mils	
CC BY							
DATE							
1-8-88							
STAMP							
QCRN							

60 of 94

1-7-88

BEST AVAILABLE COPY

PUMP RUN-IN DATA SHEET

ORDER NO. E04885 TEST RUN-IN # 1 ONE DATE 12/21/87
 IDENTIFICATION # 2225-213P-TX-1 TEST SPECIFICATION # FS-F-10
 RELATION CCW PUMP LENGTH 18'4 3/4" DISCHARGE PIPE SIZE 2"

PERFORMANCE DATA

	WIDE OPEN FLOW	3/4" RATED FLOW	1/4" SHUT OFF HEAD
GPM	180	140	100
DISCHARGE PRESSURE, PSIG	9.2	86	148.4
DISCHARGE PRESSURE, FEET (PSIG X 2.31)	21.3	198.7	342.8
GAGE CORRECTION (CENTER LINE OF GAGE TO WATER LEVEL IN FT)	7	7	7
VELOCITY HEAD DISCH PIPE	4.6	2.8	1.4
PIPE DISCHARGE CORRECTION (ELEV. COUPLINGS)	25.3	19	14.3
TOTAL DISCHARGE HEAD FT. (ADD LINES 3+4+5+6)	58.2	227.5	365.5
AMPS	16.200	16.17	16.12
VIBRATION (MILS)	.3	.3	.3

RUN-IN DATA

TIME	DISCHARGE PRESSURE PSIG	FLOW RATE GPM	AMPS	MOTOR BEARING TEMP. (150 DEGREES MAX.)	PUMP BRNG. TEMP.	VIBRATION (MILS)	COMMENTS
8:30	149.4	100	15.87	129°	92°	.2	
9:30	154	100	15.90	137°	112°	.3	
10:30	158.8	100	15.85	133°	129°	.3	
11:30	158.3	100	15.90	134°	126°	.3	
12:30	157.6	100	15.96	132°	125°	.3	
1:30	158.5	100	15.93	117°	123°	.3	
2:30	156.8	100	15.30	155°	131°	.3	
3:30	157.8	100	15.42	149°	139°	.3	

OC REP.

DATE

STAMP

GCRN

SEE PAGE 9

 61 of 94
 OC INSPECTION RECORD 34828

BEST AVAILABLE COPY

EFFICIENCY

B. H. P.

TYPE 6 TOL

FILE NO.	NO. OF STAGES	27
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
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92	92	92
93	93	93
94	94	94
95	95	95
96	96	96
97	97	97
98	98	98
99	99	99
100	100	100

R.P.M.

R.P.M. _____
SERIAL NO 80-2277

OWN. BY D.T. DATE 9-25-80

PROCKWELL INTERNATIONAL CORP.
TAG: 6411-2225-79P-TX4 THRU
6411-2225-38P-TX-4EA
10-20 HP. PROCESS PUMPS (HF-2)
TEST NO. PC-8781 6 JOL-005

Performance shown is the result of a test conducted in accordance with latest Hydraulic Institute Standards. Other standards applicable when mutually agreed upon.

... GALLONS PER MINUTE

Peabody Floway

PICATTI BROTHERS
P.O. BOX 9576
YAKIMA, WASH. 98201

Pump # 87P-TX4/9PTX6
oil lube
204P

102-AY

Pit 02D

OWA: NO. 80-2277-

Form FPI-214

· 62 of 94

Performance shown is the result of a test conducted in accordance with latest Hydraulic Institute Standards. Other standards applicable when mutually agreed upon.

ATLANTIC REGIONAL HEADQUARTERS
P.O. BOX 44-4251
NEW ORLEANS, LOUISIANA 70117
PUMP DISTRIBUTION (P-10)
PUMP TEST 800-5120

TOTAL HEAD IN FEET

B. H. P.

EFFICIENCY

U. S. GALLONS PER MINUTE

ST. BROTHERS, INC.
BOX 2367-105 S. CHURCH AVE.
MAY, WASHINGTON 98901

FLOWAY PUMPS, INC., FRESNO, CALIF.

TYPE	6 JOL
NO. OF STAGES	3
R.P.M.	3503
PUMP SERIAL NO.	76-8200-2

76-8200-1
101-HY
Pump # 122P-10
7.5HP
BEST AVAILABLE COPY
OWN BY DAM DATE 12-28-76

WTC-SD-WM-CN-049, Rev 0

BEST AVAILABLE COPY

SST Submersible Pump Flow
calculation

Westinghouse
Hanford Company
Calculations

Page 1

Engineering

Subject: BX-106 FLYGT B-2600 PUMP RUN-IN PERFORMANCE AGAINST DERIVED
OGT SYSTEM CURVE OF THE CONCEPTUAL CONFIGURATION

- References:
1. QC INSPECTION RECORD OF WORK ORDER NUMBER 2H9500114F, p. 29 AND ATTACHED CALCULATIONS
 2. SCHEMATIC OF BX-106 PUMP PIT PIPING CONFIGURATION FOR OGT SALTWELL PUMPING (H-2-821842 SH 1)
 3. FLEXONICS INC., FLEXIBLE METAL HOSE AND FITTINGS, p. 14
 4. CAMERON HYDRAULIC DATA, p. 3-8, 3-112, 3-113, 3-118
 5. TANK FARM SURVEILLANCE AND WASTE STATUS SUMMARY REPORT FOR SEPTEMBER 1992, p. C-11
 6. H-2-41348 and H-2-37852
 7. WHC-SD-WM-SAR-034, Rev. 0-A

Objective of Analysis: To show that the pump performance-system configuration operating points for BX-106 OGT saltwell pumping fall within the bounds of WHC-SD-WM-SAR-034, REV 0-A, SECTION 9.0 (ACCIDENT SAFETY ANALYSIS)

Design Input and their Sources: All of the above references

Results of Literature Review: N.A.

Calculations: (Description of calculations to be performed, models and methods used.)

BX-106 SYSTEM CURVE

The model being developed is the system curve (see attached) for the proposed BX-106 pumping configuration. A submersible pump will be lowered into the tank and then pump waste solution out of the top of the heel pit and transfer the waste to 244-BX. The model developed is for the flow that would result if a catastrophic failure occurred at the location where the piping leaves the heel pit. This is the worst case scenario for the accident analysis described in Section 9.2.1.1 of WHC-SD-WM-SAR-034, Rev 0-A.

The derived system curve will be comprised of the lift from the top of the waste to the top of the heel pit, along with all the resistances along the flow path to the top of the heel pit. Shown are the following calculations for the derived system curve:

Prepared by:
Date:

Perry J. Bowman
4/29/95

Checked by:
Date:

A. [Signature]
09/29/95

Hanford Operations and Engineering Contractor for the US Department of Energy

Westinghouse Hanford Company Calculations

BEST AVAILABLE COPY

Engineering

Total static head (referenced from beginning waste level in BX-106)

Tank bottom elevation = 614 ft. (ref. H-2-37852)

Waste level from tank bottom = 1.4 ft. (ref. #5)

Top elevation of BX-106 heel pit = 654.83 ft. (ref. H-2-41348)

Total static head = 654.83 - (614 + 1.4) = 39.43 ft

Friction Intake Side

0

Friction Discharge Side

2 inch pipe:

55 ft standard pipe, C=130 (ref. H-2-68521, 2 and ref. #4 p. 3-8)

one elbow, 5.17 ft standard pipe (ref #4 p. 3-120)

1 inch pipe:

6.8 ft standard pipe, C=130 (ref. #2 and ref. #4 p. 3-8)

4 ft flexible metal hose, at 3 times loss at C=130 (ref. #3 and ref. #4 p.3-8)

Valve, K=0.69 (ref. #4 p. 3-112)

Two long radius elbows, r/d=4, K=0.32 (ref. #4 p. 3-113)

One standard elbow, K=0.69

two reducers, 2 in. to 1 in., 45 deg angle, K=0.23 (ref. #4 p. 3-118)

exit loss, K=1.0 (ref. #4 p. 3-116)

Friction loss in terms of pipe length, ft. = $1044 * (\text{flow, gpm})^{1.85} * \text{Equivalent length, ft.} / 100 / (C=130, \text{friction factor for new steel pipe})^{1.85} / (d=1.05 \text{ for 1 inch Sch 40 pipe, or } d=2.07 \text{ for 2 inch Sch 40 pipe})^{4.8655}$ (ref. #4 p.3-7) Note: This loss calculation method is conservative for the desired analysis. The above formula is for water at 60 degrees with new pipe. The BX-106 waste solution is a more viscous than water and would result in more friction loss per unit flow and when combined with the diminished pump performance due to viscosity the resulting flow at the catastrophic break location decreases.

Friction loss in terms of velocity head, ft. = $K * (\text{velocity, ft/sec})^2 / 2 / (g = \text{gravity constant} = 32.2)$, where velocity, ft/sec = $0.408 * (\text{flow, gpm}) / (d, \text{inside diameter, in.})^2$.

Total system head required of the pump to produce flow at the top of the heel pit during a catastrophic primary line failure = Total static head + friction losses = 39.43 ft. + 1 inch line losses + 2 inch line losses = 39.43 ft + [(6.8 + 4*3), straight 1" pipe + (K=.69+2*.32+.69+2*.23+1), velocity head] + [(35+5.17), straight 2 in pipe]

The above equation reduces to the following:

Total system head = $39.43 + 0.0190 * Q^{1.85} + 0.0074 * Q^2 + 0.00149 * Q^{1.85}$ where Q, gpm

Prepared by:
Date:

Derry J. Bowman
04/29/95

Checked by:
Date:

[Signature]
[Signature]

Hanford Operations and Engineering Contractor for the US Department of Energy

Westinghouse
Hanford Company
Calculations

Engineering

Page 3

From the total system head equation will be developed a system curve to compare against the run-in tests. Q is varied from 0 to 60 gpm by increments of 10 gpm.

GPM	Total system head, ft.
0	39.43
10	41.6
20	47.6
30	57.2
40	70.1
50	86.4
60	106.0

These results are plotted and compared against the pump run-in curve of 4/10/95 (see attached). The run-in test developed the performance curve of the pump, i.e., total head against flow. The intersection of both curves is the operating point of the pump at the specified parameters, i.e., catastrophic break at top of heel pit.

Note: Both the run-in test and the system curve derivation are for water. The waste solution in the tank has a greater viscosity than water. The resulting intersection of the true field curves would result in less flow and less head than the water-based analysis.

Assumptions:

Drawing H-2-41348 has the most accurate and up to date elevation data. This elevation was surveyed for the drawing and went through QA.

Summary of Results and Conclusions:

The discharge flow rate at the worst case scenario of a pipe break point right outside the pump pit will amount to less than 50 gpm. The pressure head (as water) of the pumping system deadhead is 35 psig. The pump-system configuration of BX-106 is within the bounds of WHC-SD-WM-SAR-034, REV. 0-A, SECTION 9.0 (ACCIDENT SAFETY ANALYSIS), where maximum pressure is 60 psig and maximum flow is 60 gpm.

Reviews and Approvals:

Prepared by:
Date:

Rory J. Bowron
4/28/95

Checked by:
Date:

[Signature]
4/28/95

Hanford Operations and Engineering Contractor for the US Department of Energy

BX-1.06 SYSTEM CURVE

catastrophic failure at exit of heel pit

FLYGT B-2060 RUN-IN

BX-106 SETUP (4-10-95)

APPENDIX C

Holding Capacities of 200 East Area Valve Pits and Pump Pits

Table C-1. Summary of Ancillary Containment System Dimensions, East Area

Unit	Inside Pit Dimensions			Volume, ft ³ (gal)
	Length (ft)	Width (ft)	Depth (ft)	
241-AN Farm				
241-AN-01A thru -07A central pump pits	14	8	6	672 (5030)
241-AN-A and -B valve pits	12	12	6.67	960 (7180)
241-AP Tank Farm				
241-AP-01A thru -08A central pump pits	16	10	7.83	1250 (9370)
241-AP-102D pump pit	6	11	10.83	715 (5350)
241-AP valve pit	59	14	8	6610 (49,400)
241-AW Tank Farm				
241-AW-01A thru -06A central pump pits	14	8	6	672 (5030)
241-AW-02E feed pump pit	7	7	9.92	486 (3640)
241-AW-A and -B valve pits	12	10	6.58	790 (5910)
241-AY/AZ Tank Farms				
241-AY-01A, AY-02A, AZ-01A and AZ-02A pump pits	12	8	7.5	720 (5390)
241-AX-A and 241-AX- B valve pits	12	10	4.75	570 (4260)
241-A-A and A-B valve pits	12	10	4.75	570 (4260)

From DOE/RL-90-39, Rev. 0

APPENDIX D

Calculation of Maximum Pit Drain Rate

Calculation of Maximum Pit Drain Rate

Wanted: Determine the maximum drain rate for the A-A valve pit, based on pit being full of waste pit.

Data: Pit drain diameter, D: 3 in

Maximum liquid height in pit before overflow: 4'9" + 1'8" = 6.4 ft (pit depth up to bottom of cover block from Table Appendix C + 1'8" cover block thickness, assuming cover block off)

Assumptions: Height difference from bottom of drain to top of drain 2'.

References: Ref 1. Bober and Kenyon, 1980, Fluid Mechanics, John Wiley and Sons, Inc., New York.

Solution: From Bernoulli's Eqn.

$$h_1 + V_1^2/2g + z_1 = h_2 + V_2^2/2g + z_2 + h_{ent} + h_{exit} \text{ Eqn. 1)}$$

where:

$h_1 = h_2$ = atmospheric pressure head above pit and in tank, these terms cancel

V_1 = velocity of surface of liquid in pit, ft/s

V_2 = velocity of liquid exiting pit drain into storage tank, ft/s

z_1 = height of liquid in pit and drain = 6.4 ft + 2 ft = 8.4 ft

z_2 = height of bottom of drain = 0 (set as basis)

h_{ent} = head loss of contraction entering drain, ft

h_{exit} = head loss of expansion in exiting drain into tank, ft

g = gravitational constant = 32.2 ft/s²

[frictional losses in the drain line are neglected]

$h_{ent} = CV_2^2/2g$, where $C = 1.0$ (Ref. 1)

$h_{exit} = CV_1^2/2g$, where $C = 1.0$ (Ref. 1)

$V_1 \ll V_2$

Canceling V_1 , h_1 , h_2 , and z_2 and substituting in for h_{ent} and h_{exit} gives:

$$\begin{aligned} V_2 &= \text{SQRT}(2gz_1/3) \\ &= \text{SQRT}[(2)(32.2 \text{ ft/s}^2)(8.4 \text{ ft})/3] = 13.4 \text{ ft/s} \end{aligned}$$

from the continuity eqn,

$$Q = AV_2$$

where:

$$Q = \text{flowrate out drainpipe into pit, ft}^3/\text{s}$$

$$A = \text{cross-sectional area of drain pipe, ft}^2$$

$$A = (\pi)(D/2)^2 = (3.14)(1.5 \text{ in})^2(1 \text{ ft}^2/144 \text{ in}) = 4.9\text{E-}2 \text{ ft}^2$$

Therefore,

$$Q = (4.9\text{E-}2 \text{ ft}^2)(13.4 \text{ ft/s}) = 0.657 \text{ ft}^3/\text{s}$$

Converting to gpm gives,

$$Q = (0.657 \text{ ft}^3/\text{s})(7.48 \text{ gal/ft}^3)(60 \text{ s/min}) = 295 \text{ gal/min}$$

APPENDIX E

MICROSHIELD Output Files

CASE 1. MICROSIELD Input and Output for Direct Shine Due to
Gamma Emitters, Unmitigated Accident Scenario

MicroShield 4.00 - Serial #4.00-00128

Westinghouse Hanford Company

Page : 1

DOS File: UPOOLG.MS4

Run Date: September 10, 1996

Run Time: 4:08 p.m. Tuesday

Duration: 0:00:29

File Ref: _____

Date: ____/____/____

By: _____

Checked: _____

Case Title: Unmitigated Surface Leak, dose from gamma emitters

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	and inches
Dose point coordinate X:	18600.0	610.0	2.8
Dose point coordinate Y:	153.5	5.0	.4
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	3.5	0.0	1.4
Cylinder radius:	8600.0	282.0	1.8
Side Clad:	10000.0	328.0	1.0

Source Volume: 8.13233e+8 cm³ 28719. cu ft. 4.96265e+7 cu in.

MATERIAL DENSITIES (g/cm³)

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 Transition

INTEGRATION PARAMETERS

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

SOURCE NUCLIDES

Nuclide	curies	$\mu\text{Ci/cm}^3$	Nuclide	curies	$\mu\text{Ci/cm}^3$
Ba-137m	1.8919e+006	2.3264e+003	Co-60	3.5135e+003	4.3204e+000
Cs-137	2.0000e+006	2.4593e+003	Eu-154	7.9459e+004	9.7708e+001

Page : 2

DOS File: UPOOLG.MS4

Run Date: September 10, 1996

Run Time: 4:08 p.m. Tuesday

Title : Unmitigated Surface Leak, dose from gamma emitters

===== RESULTS =====					
Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate		Exposure Rate In Air	
		(MeV/sq No Buildup	cm/sec) With Buildup	(mR/hr) No Buildup	With Buildup
0.1	1.190e+015	2.262e+001	7.982e+002	3.461e-002	1.221e+000
0.2	2.008e+014	1.547e+001	2.858e+002	2.730e-002	5.045e-001
0.4	2.098e+013	6.742e+000	5.946e+001	1.314e-002	1.159e-001
0.5	6.366e+012	3.246e+000	2.312e+001	6.371e-003	4.539e-002
0.6	6.322e+016	4.698e+004	2.837e+005	9.170e+001	5.538e+002
0.8	1.146e+015	1.543e+003	7.343e+003	2.935e+000	1.397e+001
1.0	1.034e+015	2.203e+003	8.883e+003	4.060e+000	1.637e+001
1.5	1.277e+015	6.217e+003	1.930e+004	1.046e+001	3.248e+001
TOTAL:	6.810e+016	5.699e+004	3.204e+005	1.092e+002	6.185e+002

CASE 2. MICROSHIELD Input and Output for Direct Shine Due to
Bremsstrahlung Radiation, Unmitigated Accident Scenario

MicroShield 4.00 - Serial #4.00-00128

Westinghouse Hanford Company

Page : 1

DOS File: UP00LB.MS4

Run Date: September 10, 1996

Run Time: 4:16 p.m. Tuesday

Duration: 0:01:14

File Ref: _____

Date: ____/____/____

By: _____

Checked: _____

Case Title: Unmitigated Surface Leak, dose from bremsstrahlung rad

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	and inches
Dose point coordinate X:	18600.0	610.0	2.8
Dose point coordinate Y:	153.5	5.0	.4
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	3.5	0.0	1.4
Cylinder radius:	8600.0	282.0	1.8
Side Clad:	10000.0	328.0	1.0

Source Volume: 8.13233e+8 cm³ 28719. cu ft. 4.96265e+7 cu in.MATERIAL DENSITIES (g/cm³)

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 Transition

INTEGRATION PARAMETERS

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

SOURCE WAS ENTERED AS ENERGIES ONLY

Page : 2

DOS File: UPOOLB.MS4

Run Date: September 10, 1996

Run Time: 4:16 p.m. Tuesday

Title : Unmitigated Surface Leak, dose from bremmstrahlung rad

===== RESULTS =====					
Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate		Exposure Rate In Air	
		(MeV/sq	cm/sec)	(mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.015	2.600e+016	5.360e-010	9.403e-010	4.598e-011	8.065e-011
0.025	1.300e+016	1.408e-001	5.952e-001	2.429e-003	1.027e-002
0.035	8.400e+015	4.565e+000	4.524e+001	2.892e-002	2.866e-001
0.045	5.900e+015	1.319e+001	2.505e+002	4.386e-002	8.331e-001
0.055	4.500e+015	2.071e+001	5.841e+002	4.662e-002	1.315e+000
0.065	3.500e+015	2.560e+001	8.803e+002	4.648e-002	1.598e+000
0.075	2.900e+015	2.986e+001	1.108e+003	4.867e-002	1.806e+000
0.085	2.400e+015	3.253e+001	1.215e+003	5.053e-002	1.888e+000
0.095	2.000e+015	3.422e+001	1.238e+003	5.238e-002	1.894e+000
0.15	1.100e+016	4.745e+002	1.193e+004	7.813e-001	1.964e+001
0.25	4.100e+015	4.985e+002	7.211e+003	9.197e-001	1.330e+001
0.35	2.100e+015	5.118e+002	5.168e+003	9.873e-001	9.970e+000
0.475	1.600e+015	7.338e+002	5.484e+003	1.440e+000	1.076e+001
0.65	1.000e+015	8.768e+002	4.941e+003	1.702e+000	9.593e+000
0.825	3.800e+014	5.449e+002	2.532e+003	1.033e+000	4.798e+000
1.0	2.700e+014	5.749e+002	2.319e+003	1.060e+000	4.274e+000
1.225	1.500e+014	4.840e+002	1.701e+003	8.566e-001	3.010e+000
1.475	5.200e+013	2.447e+002	7.671e+002	4.135e-001	1.296e+000
1.7	1.300e+013	8.138e+001	2.358e+002	1.322e-001	3.830e-001
1.9	3.200e+012	2.500e+001	6.841e+001	3.928e-002	1.075e-001
2.1	3.300e+011	3.142e+000	8.185e+000	4.785e-003	1.246e-002
2.3	1.800e+009	2.049e-002	5.111e-002	3.030e-005	7.558e-005
TOTAL:	8.927e+016	5.214e+003	4.769e+004	9.689e+000	8.678e+001

APPENDIX F
BREMCALC Data

Photon Production Rates for Sr-90/Y-90 in Mixtures using
BREM CALC (photons per second from 1 curie of each isotope)

Midpoint Energy	Water Z = 6.60	Paper Z = 6.35	Air Z = 7.36	Concrete Z = 10.99	AlZr Z = 33.38
0.015	7.83E+08	7.59E+08	8.56E+08	1.24E+09	3.72E+09
0.025	3.99E+08	3.87E+08	4.35E+08	6.26E+08	1.88E+09
0.035	2.56E+08	2.48E+08	2.79E+08	3.99E+08	1.19E+09
0.045	1.82E+08	1.77E+08	1.98E+08	2.83E+08	8.42E+08
0.055	1.38E+08	1.34E+08	1.50E+08	2.14E+08	6.34E+08
0.065	1.09E+08	1.06E+08	1.19E+08	1.69E+08	4.98E+08
0.075	8.91E+07	8.66E+07	9.67E+07	1.37E+08	4.03E+08
0.085	7.42E+07	7.21E+07	8.05E+07	1.14E+08	3.34E+08
0.095	6.29E+07	6.11E+07	6.82E+07	9.61E+07	2.81E+08
0.15	3.33E+08	3.24E+08	3.60E+08	5.03E+08	1.45E+09
0.25	1.32E+08	1.29E+08	1.42E+08	1.95E+08	5.50E+08
0.35	6.88E+07	6.71E+07	7.37E+07	9.98E+07	2.74E+08
0.475	5.50E+07	5.38E+07	5.87E+07	7.84E+07	2.10E+08
0.65	3.53E+07	3.46E+07	3.75E+07	4.89E+07	1.26E+08
0.825	1.36E+07	1.33E+07	1.43E+07	1.82E+07	4.49E+07
1	9.82E+06	9.66E+06	1.03E+07	1.28E+07	3.02E+07
1.225	5.54E+06	5.46E+06	5.75E+06	6.95E+06	1.53E+07
1.475	2.06E+06	2.03E+06	2.12E+06	2.46E+06	4.94E+06
1.7	5.34E+05	5.29E+05	5.45E+05	6.12E+05	1.11E+06
1.9	1.36E+05	1.35E+05	1.38E+05	1.51E+05	2.46E+05
2.1	1.49E+04	1.48E+04	1.50E+04	1.59E+04	2.31E+04
2.3	8.25E+01	8.23E+01	8.28E+01	8.51E+01	1.05E+02

APPENDIX G

MICROSKYSHINE Output Files

CASE 1. MICROSKEYSHINE Output for Unmitigated Accident,
Dose due to Gamma Emitters

MicroSkyshine

=====

(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1

File Ref: _____

File: UPOOLG.SKY

Date: ____/____/____

Run: 4:13 p.m.

By: _____

: September 9, 1996

Checked: _____

CASE: Unmitigated Surface Pool, dose from gamma emitters

GEOMETRY: Vertical cylinder area source behind a wall

DIMENSIONS (meters):

Distance between wall and detector.....	X	✓ 99.
Depth of source behind wall.....	Y	✓ 0.956
Offset of detector.....	Z	✓ 0.
Depth of dose point.....	H	✓ -0.544
Distance between center of source and wall...	R1	87.
Thickness of cover slab.....	T1	0.
Thickness of second shield.....	T2	0.
Radius of source.....	W	✓ 86.
Height of source.....	L	✓ 0.035

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			1.4
Concrete			
Iron			
Lead			
Zirconium			
Urania			

Buildup factor based on: AIR.

CASE: Unmitigated Surface Pool, dose from gamma emitters

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	1.8919e+06 ✓	Co-60	3.5135e+03 ✓
Cs-137	2.0000e+06 ✓	Eu-154	7.9459e+04 ✓

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.30	1.307e+15	2.362e-20	1.273e+02
2	1.03	9.800e+14	2.359e-20	9.531e+01
3	.84	5.398e+14	2.246e-20	4.999e+01
4	.66	6.385e+16	2.209e-20	5.816e+03
5	.48	2.870e+13	2.142e-20	2.535e+00
6	.40	6.157e+12	2.034e-20	5.164e-01
7	.24	1.941e+14	1.686e-20	1.350e+01
8	.20	6.679e+12	1.526e-20	4.204e-01
9	.12	1.190e+15	1.194e-20	5.855e+01
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		6.810e+16		6.164e+03

CASE 2. MICROSKEYSHINE Output for Unmitigated Accident,
Dose Due to Bremsstrahlung Radiation

MicroSkyshine

=====

(Nuclear & Radiological Safety Analysis - 1.16-007)

Page: 1

File Ref: _____

File: UPOOLB.SKY

Date: ____/____/____

Run: 1:27 p.m.

By: _____

: September 7, 1996

Checked: _____

CASE: Unmitigated Surface Pool, dose from beta emitters

GEOMETRY: Vertical cylinder area source behind a wall

DIMENSIONS (meters):

Distance between wall and detector.....	X	99.
Depth of source behind wall.....	Y	0.956
Offset of detector.....	Z	0.
Depth of dose point.....	H	-0.544
Distance between center of source and wall...	R1	87.
Thickness of cover slab.....	T1	0.
Thickness of second shield.....	T2	0.
Radius of source.....	W	86.
Height of source.....	L	0.035

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			1.4
Concrete			
Iron			
Lead			
Zirconium			
Uranium			

Buildup factor based on: AIR.

CASE: Unmitigated Surface Pool, dose from beta emitters

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	1.8919e+06	Co-60	3.5135e+03
Cs-137	2.0000e+06		

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.90	3.200e+12	2.362e-20	3.117e-01
2	1.70	1.300e+13	2.321e-20	1.244e+00
3	1.48	5.200e+13	2.257e-20	4.839e+00
4	1.23	1.500e+14	2.383e-20	1.474e+01
5	1.00	2.700e+14	2.346e-20	2.612e+01
6	.82	3.800e+14	2.231e-20	3.495e+01
7	.65	1.000e+15	2.212e-20	9.120e+01
8	.47	1.600e+15	2.136e-20	1.409e+02
9	.35	2.100e+15	1.954e-20	1.692e+02
10	.25	4.100e+15	1.710e-20	2.891e+02
11	.15	1.100e+16	1.354e-20	6.142e+02
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		2.067e+16		1.387e+03

APPENDIX H

Peer Review Checklist

PEER REVIEW CHECKLIST *BT*

Document Reviewed: Calculation Notes for ²Subsurface Leak
Resulting in Pool, TWRS FSAR Accident Analysis

Scope of Review: Entire Document

Yes	No	NA	
☐	☐	☒	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☒	☐	☐	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☐	☐	☒	Software input correct and consistent with document reviewed.
☐	☐	☒	Software output consistent with input and with results reported in document reviewed.
☒	☐	☐	Limits/criteria/guidelines applied to analysis results are appropriate and referenced.
☐	☐	☒	Limits/criteria/guidelines checked against references.
☐	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☐	☐	☒	Format consistent with appropriate NRC Regulatory Guide or other standards
☐	☐	☒	Review calculations, comments, and/or notes are attached.
☒	☐	☐	Document approved. <i>Did not review App D as results do not affect dose. Did not verify App C.</i>

Reviewer (Printed Name and Signature)

Date

Did not review Sky share or Direct share
RM Manush 9/11/96

65 of 99-814

92 of 94

PEER REVIEW CHECKLIST

Document Reviewed: WHC-SD-WM-CN-049
 Author: B. Hall
 Date: September 1996
 Scope of Review: Direct shine and skyshine dose calculations, (Section 2.4.3, 2.4.4, and Appendices E, F, and G)

Yes No NA

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

J. C. Van Keuren *J. C. Van Keuren*
 Reviewer (Printed Name and Signature)

9/11/96
 Date

CHECKLIST FOR PEER REVIEW

Document Reviewed: Calculation Notes for Surface Leak Resulting in Pool,
TWRS FSAR Accident Analysis, WHC-SD-WM-CN-049

Scope of Review: *Calculational Notes*

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

Harvey Goldberg
Reviewer (Printed Name and Signature)

19/9/96
Date

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

DISTRIBUTION SHEET

To Distribution	From B. W. Hall	Page 1 of 1
Project Title/Work Order Calculation Notes For Surface Leak Resulting in Pool, TWRS FSAR Accident Analysis, WHC-SD-WM-CN-049		Date 9/20/96
		EDT No. 619400
		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
C. Carro	A2-34	X			
E. R. Bruschi	A2-34	X			
B. W. Hall <i>(2)</i>	A3-34	X			
D. S. Leach	A3-34	X			
R. M. Marusich	A3-34	X			
J. C. Van Keuren	A3-34	X			
W. J. Powell	S2-48	X			
TWRS S & L Project Files <i>(1)</i>	A2-26	X			
Central Files (original + 2)	A3-88	X			

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** BW Hall A3-34 (1)*
** TWRS Proj. File A2-26 (1)*