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7. Abstract

This document provides the basis for interim stabilization of tank 241-C-103. The document covers the removal of the organic liquid layer and the aqueous supernatant from tank 241-C-103. Hazards are identified, consequences are calculated and controls to mitigate or prevent potential accidents are developed.

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SAFETY EVALUATION FOR THE INTERIM STABILIZATION OF TANK 241-C-103

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SAFETY EVALUATION FOR THE INTERIM STABILIZATION OF TANK 241-C-103

G. R. Geschke
N. J. Milliken

ABSTRACT

This document provides the basis for interim stabilization of tank 241-C-103. The document addresses the removal of both the organic liquid layer and the aqueous supernatant from tank 241-C-103. Hazards are identified and evaluated, consequences are calculated and controls to mitigate or prevent potential accidents are developed.

EXECUTIVE SUMMARY

This safety evaluation addresses the hazards associated with the activities involving interim stabilization of tank 241-C-103. WHC-SD-WM-SARR-001 (Postma et al. 1994) and its supplement (Postma and Grigsby 1995) evaluate the hazards associated with tank 241-C-103 in both the pre- and post-interim stabilized conditions.

Tank 241-C-103 contains a bottom layer of sludge, a middle layer of aqueous supernatant, and a top layer of organic liquid. Interim stabilization will involve the removal of both the aqueous supernatant and the organic liquid layers.

Interim stabilization of tank 241-C-103 was reviewed to determine whether the release of radioactive materials could occur during operation. It was concluded that there are four potentially credible scenarios: a transfer line leak/break, a spray release from a transfer line, and a pool fire in the double-contained receiver tank or the receiving double-shell tank. The probabilities of the transfer line leak/break and the spray release were determined to fall within the range of Anticipated events, as established by WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual. The probability of both the double-contained receiver tank and double-shell tank pool fires were determined to be Extremely Unlikely; therefore, all four accident scenarios were analyzed to calculate the dose consequences. The transfer line leak/break is determined to be the bounding accident. The bounding onsite and

offsite dose consequences are calculated to be 2.2 x 10^{-2} Sv (2.2 rem) and 1.0 x 10^{-5} Sv (1.0 x 10^{-3} rem). Both the onsite and offsite consequences are acceptable for the range of anticapted events, as established in WHC-CM-4-46.

Compliance with the controls presented in Section 8.0 will ensure that interim stabilization of tank 241-C-103 remains within the envelope of this safety analysis and can be considered a safe activity.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TERMS

ARR	airborne rate release
DCRT	double-contained receiver tank
DST	double-shell tank
FIC	Food Instrument Corporation
HLW	High-level Waste
LFL	lower flammability limit
MBD	material balance discrepancy
NPH	normal paraffin hydrocarbon
OSD	operating safety document
SST	single-shell tanks
TBP	Tributyl Phosphate (low-level non-Tru liquid waste)
TOC	total organic carbon
TRU	Transuranic (waste)
USQ	unreviewed safety question
WHC	Westinghouse Hanford Company

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1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

During the last 40 years, the management and handling of liquid radioactive waste has focused on reducing the volume of liquid in underground storage tanks. Part of this liquid waste reduction strategy is based on pumping as much liquid as possible from the single-shell tanks (SSTs) to minimize the volume of liquid available to leak into the ground. This process of removing supernatant and interstitial liquids from the SSTs is known as interim stabilization. Interim stabilization of tank 241-C-103 requires additional consideration due to the presence of an organic liquid layer. Throughout this document, interim stabilization will refer to the removal of the organic liquid, in addition to the aqueous supernatant; however, this document does not restrict transferring the organic and aqueous separately, if possible, during batch transferring. This safety analysis will demonstrate that interim stabilization of tank 241-C-103, using the equipment described herein, can be considered a safe activity provided the associated controls, as established in Section 8, are complied with.

1.2 SCOPE

The intent of this safety analysis process is to permit interim stabilization of tank 241-C-103. The analysis will address the safety criteria and hazards associated with the transfer of the liquid contents from tank 241-C-103 to a receiving double-shell tank (DST). To avoid unnecessary restrictions on Tank Farms Operations, the receiving DST and transfer route will not be specified.

The transfer process is broken down into two segments. The first segment will consider transfer from tank 241-C-103 to the double-contained receiver tank (DCRT). The second segment will consider transfer from the DCRT to the DST. This analysis will address the safety of the two segments, as well as the overall transfer process.

1.3 BACKGROUND

1.3.1 Overview of Tank 241-C-103

Tank 241-C-103 is one of 16 SSTs located in the C Tank Farm within the 200 East Area of the Hanford Site. The tank is nominally 23 m (75 ft) in diameter and has a rated storage capacity of 2.0×10^6 L (530,000 gal).

The organic liquid layer in tank 241-C-103 resulted from the transfer of Plutonium Uranium Extraction (Facility) (PUREX) organic wash waste containing elevated levels of solvent to tank 241-C-102, and the subsequent transfer of all free liquid from tank 241-C-102 to tank 241-C-103 in November of 1975. In 1969, tank 241-C-102 was observed to contain a 25- to 33-cm (10- to 13-in.) layer of organic material, or a volume of $\approx 1.0 \times 10^5$ to 1.4×10^5 L (27,500 to 35,750 gal) (Anderson 1990). Estimates of the total volume of organics transferred to tank 241-C-103 range up to 2.8 x 10^5 L (75,000 gal) (Welty 1988). Currently, the organic layer is believed to be about 3.8-to 5-cm (1.5- to 2-in.) thick (Huckaby 1994a), corresponding to a volume of ≈1.5 x 10^4 to 2.1 x 10^4 L (4,100 to 5,500 gal). The liquid organic is floating on an aqueous supernatant liquor ≈1.2-m (4-ft) thick, or 5.0 x 10^5 L (133,000 gal). The supernatant liquid, in turn, tops a 2.3 x 10^5 L (62,000 gal) sludge layer, for a total waste content of ≈7.4 x 10^5 L (195,000 gal) and a total waste depth of 2 m (6 ft 8 in.) (Hanlon 1994).

Based on recent sample results, the organic phase contains ≈ 1.31 wt% water and 25 wt% unidentified material including inorganic salts, primarily silicates, and phosphates. The PUREX process used an organic liquid, composed of 30% tributyl phosphate (TBP) and 70% normal paraffin hydrocarbon (NPH) on a volumetric basis as an extractant. Partial evaporation of the organic liquid during periods of forced ventilation of tank 241-C-103 between 1975 and 1992 has reduced the volume of the liquid and depleted the more volatile hydrocarbons that were initially present in the NPH. The organic liquid has a density of 0.876 g/mL (0.032 lb/in^3) and a viscosity of 0.04 Pa·s (4 cP) at 25 °C (77 °F).

1.3.2 Determination of Unreviewed Safety Question

During 1992, the safety of continued storage of the floating organic liquid in tank 241-C-103 was reviewed by Westinghouse Hanford Company (WHC). As a result of the review, the storage of the potentially flammable liquid in tank 241-C-103 was determined to be a Unreviewed Safety Question (USQ) (Grantham 1992). Several actions were triggered by the USQ determination.

- Operations at the facility are restricted to those deemed to be necessary for safe operation.

- A justification for continued operations was prepared to identify allowable operations and the basis for why the allowed operations do not pose an unacceptable hazard in light of the USQ designation (Carothers 1993).

- A safety review of the facility/operation is to be prepared to determine what hazards exist and their potential consequences. Based on the findings of the safety review, a judgment will be made that the hazards fall within currently defined safety envelopes, that larger safety envelopes apply and are acceptable, or a mitigation effort is required to reduce the potential risk.

During May of 1994, the USQ concerning tank 241-C-103 was closed (Sheridan 1994); however, closure of the USQ does not resolve the organic safety issue. Therefore, utilizing the safety review process described above, this safety analysis will demonstrate that interim stabilization of tank 241-C-103 will assist the resolution of the remaining safety issue.

2.0 DESCRIPTION OF ACTIVITY

Tank 241-C-103 interim stabilization requires that many decisions must be made. This section will address the alternatives associated with the stabilization activity.

2.1 CHOICE OF PUMP

Two basic types of pumps, a saltwell jet pump and a submersible pump, are currently used in tank waste transfers. It is not the intent of this safety analysis to specify the pump to be used in this operation. All analyses conducted in this report will address the pump representing a worst-case condition or potential accident. The following subsections provide a description of the two pumps.

2.1.1 Saltwell Jet Pumping System

A typical jet pumping system is illustrated in Figure 2-1. The jet pumping assembly consists of two main components: the centrifugal pump and the jet assembly. The centrifugal pump circulates liquid through the jet continuously. The jet action draws liquid in from the well through a check valve, see Figure 2-2. The check valve restricts liquid from flowing out of the system back into the well during priming. The pump will hold prime for ≈20 min when shut off unless the check valve becomes fouled. The jet nozzle and the jet tube are inside the jet body. After flowing through the jet, the liquid travels through a pipe leading to the suction of the centrifugal pump. From the pump, the liquid flows to a tee where it is either bled off through the diaphragm-operated valve to the DCRT or is recycled to the jet.

A centrifugal pump, rated at ≈114 L/min (30 gal/min) at 2.07×10^5 Pa gauge (30 psig), is located in the pump pit at the top of the tank. The pump circulates liquid through a submerged jet within a recirculation loop at ≈38 L/min (10 gal/min) at 5.5×10^5 Pa gauge (80 psig). Approximately 0.19 to 11.4 L/min (0.05 to 3.0 gal/min) at 4.14×10^5 Pa gauge (60 psig) is bled off the loop through a diaphragm-operated value and is routed to a DCRT. Raw water is used to fill the loop and prime the pump for initial operations, or whenever the pump prime is lost.

The combination of the pump and the jet is needed to overcome suction lifts greater than 10.4 m (34 ft). A weight factor-specific gravity dip tube assembly is installed inside the saltwell. Liquid level within the saltwell is maintained relatively constant within a predefined range by the DOV in the bleed-off line loop. At low pumping rates (0.19 to 11.4 L/min [0.05 to 3.0 gal/min]), the formation of solids in the interstitial liquid, which is saturated, is a potential problem. The circulation of liquid within the recirculation loop alleviates the problem as the energy to operate the pump heats up the recirculated liquid to ≈16.7 °C (30 °F) above the tank ambient temperature, thus increasing the solubility of the salts.

The saltwell system is a 25.4 cm (10-in.) diameter saltwell casing consisting of a stainless steel saltwell screen welded to a schedule 40 carbon steel pipe. The casing and screen are to be inserted into the 30-cm (12-in.) tank riser located in the pump pit. The stainless steel portion of the system will extend through the tank waste to near the bottom of the tank. The saltwell screen portion of the casing is an ≈3 m (10 ft) length of 300-series, 25.4-cm (10-in.) diameter, stainless steel pipe with screen openings (slots) of 0.13 cm (0.050 in.) (400 mesh). Because the waste level is less than 2.0 m (6 ft 8 in.), the saltwell screen will extend above the tank waste. The purpose of the saltwell screen is to minimize the size and amounts of pumped solids.

A schematic flow diagram of a typical jet pumping system is shown in Figure 2-3. A three-way valve is installed in the pump pit piping, which permits backflushing of the piping and the jet pump. When the valve is set at the run position, the liquid is channeled back down to the jet and recirculated. Two other settings are possible on the three-way valve. In position AB, the liquid from the nozzle flows straight through the three-way valve and out the flush drain leg back into the saltwell. This setting is used to backflush the upper piping and relieve pressure in the flush line before startup. Position AC directs liquid coming up from the jet (opposite to normal flow) out through the flush drain leg. This setting is used to backflush the pump and jet assembly. The pump is backflushed whenever an extended downtime is expected to avoid blockage problems in the piping. Positions AB and AC are also used during pump priming.

2.1.2 Submersible Pump

There are two types of submersible pumps available onsite that are designed for this type of work. One is made by Flygt, the other is a Floway*. Due to a 1.3 cm (0.5 in.) tube inside the saltwell screen installed in tank 241-C-103, only the Floway will fit. The equipment required for submersible pumping an SST includes the following:

- A pump pit
- A saltwell screen
- submersible pump assembly
- Flushing assembly
- Flex-hose jumpers
- Associated controls.

The dome of the SST is built with several risers of different diameters, one of which protrudes into the pump pit. A pump pit is a concrete structure located above the tank dome near the center of the tank. The pumping system is housed within the pump pit with portions of the system extending into the riser.

The submersible pump will be mounted to a 5.1 cm (2 in.) transfer pipe extending up through the tank and the adapter flange to the pump pit. From the adapter flange, the waste is routed through a horizontal discharge flange.

*Floway is a registered trademark of Peabody Company.

From the discharge flange, the transfer pipe will then be connected to a flushing tee. The flushing tee is to be connected by flex hose to the connector head attached to the wall nozzle and to the permanent waste transfer line (SN-250).

The submersible pump assembly is needed to raise the liquid from the saltwell screen into the pump pit, nominally a 10.7-m (35-ft) elevation rise. A typical submersible pump has a 3,700 W (5 hp) motor, driven by 480 volt, three phase power. The motor itself is below the pump intake and is submersed in the liquid being pumped. The pump is rated at 150 L/min (40 gal/min) at 3.9×10^5 Pa (130 ft total dynamic head), for liquid with a specific gravity of 1.7. The pump motor is cooled by the liquid being pumped, and the minimum specified velocity past the motor is 0.08 m/s (0.25 ft/s). To aid in the flow past the motor, the pump has a flow director (shroud) installed. Important instrument and control systems include leak detection and submersible pump controls, including safety interlocks.

Leak detection is provided in the 241-C valve pit. The leak detectors are interlocked to shut down the pump in case there is a leak in the transfer piping. A flashing light at the valve pit and an audible alarm alert tank farm operators to the shutdown condition.

The Floway pump is current overload protected but not thermally protected. Addition of thermal overload protection to the Floway pump, if chosen, will be required before pumping operations begin. This interlock is designed to shut off the pump in the event the pump motor temperature increases due to abnormal pumping conditions. The hazards associated with failure of a submersible pump are evaluated in Section 4.3.1.

2.2 TRANSFER ROUTE

This description will only address the specifics about the transfer route from tank 241-C-103 up to diversion box 241-ER-153. The route beyond the diversion box is subject to the choice of the receiving DST, a choice that will not be made in this safety analysis (see Section 2.2.3). A schematic of the transfer route from tank 241-C-103 to the DCRT is provided in Figure 2-4. The liquid waste will be directed from tank 241-C-103 through the 241-C valve pit, the 244-CR-003 DCRT, the 241-ER-153 diversion box, and then on to the designated receiving DST. The following subsections describe each component along the specified transfer route.

2.2.1 Transfer Line SN-250

Transfer line SN-250 connects tank 241-C-103 to the 241-C valve pit. SN-250 is a 5.1 cm (2 in.) diameter, single-encased pipeline, ≈16.7 m (53 ft) long. For the purposes of the pipe failure rate analysis (see Section 4.2.2), the length of this pipeline has been conservatively estimated at 18.3 m (60 ft).

2.2.2 241-C Valve Pit

In the 241-C valve pit, the transfer line from tank 241-C-103 is manifolded to the receiving tank (244-CR-003) line by using a series of valves and jumper connections. Two- and three-way valves are built into each jumper to divert the flow where needed. The 241-C valve pit is a steel caisson with a hinged steel cover. The 241-C valve pit is equipped with leak detection that is interlocked to the pump and has a drain line connected to a flush pit.

Diverting liquid flow from one tank to another using valve pits usually does not require major jumper changes. Although multi-valve, multi-connector jumpers reduce radiation exposure and field time (less frequent jumper changes), valving mistakes that misroute process solution are more frequent with these types of jumpers.

Valve pit jumpers can connect to several wall nozzles, each leading to a different outlet with two- and three-way valves built in to divert the flow where needed. The valve handles extend through penetrations in the cover blocks to reach the valve stems inside the valve pits. The cover blocks and valve handles have a flow diagram painted on them to assist the operator in valving the correct tank.

2.2.3 Transfer Line SN-275

Transfer line SN-275 connects the 241-C valve pit with the tank 244-CR-003 DCRT. SN-275 is a 7.6 cm (3 in.) diameter, single-encased pipeline, ≈115 m (378 ft) long. For the purposes of the pipe failure rate analysis (see Section 4.2.2), the length of this pipeline has been conservatively estimated at 122 m (400 ft).

2.2.4 244-CR-003 DCRT

The 244-CR vault is located in the 200 East Area south of the 241-C Tank Farm and north of 7th Street. The 244-CR-003 tank in the 244-CR vault will be used as a DCRT for the interim storage of saltwell waste from the 241-C Tank Farm.

The 244-CR vault is a two-level, multi-cell structure constructed below grade. The lower cell contains the process tanks and the upper cells contain piping and equipment. Only the structures and support systems for tank 244-CR-003 will be discussed. It is the only tank that will be used as a DCRT for the removal of the organic liquid from tank 241-C-103.

2.2.4.1 Structure. The vault structure is covered by 0.61-m- (2-ft-) thick concrete cover blocks that, when removed, permit access to the piping and equipment cells. The reinforced-concrete vault that contains tank CR-003 is 4.88 m x 6.10 m x 5.79 m high (16 ft x 20 ft x 19 ft).

All of the side walls and slab floors of the vault are 0.61-m- (2-ft-) thick concrete. Each tank vault is equipped with a sump, 0.61 m x 0.91 m x 0.30 m deep (2 ft x 3 ft x 1 ft).

If the sump pit probe detects a leak, a signal is sent to a transmitter. Pumping operations protected by that section of the master shutdown circuitry are shut down immediately.

Tank 244-CR-003 is constructed of type 347 stainless steel, 9.5-mm- (3/8-in.-) thick and has a capacity of 56,781 L (15,000 gal) with an operating level of no greater than 51,103 L (13,500 gal). OSD-T-151-00011.2.B.1 (Schofield 1994) gives the maximum specification limit for liquid level in 244-CR-003 as 4.3 m (168 in.). This corresponds to a volume of 45,400 L (12,000 gal).

2.2.4.2 Pumps. There is one waste transfer pump, P-CR-003, that is located inside tank 244-CR-003. The waste transfer pump is rated at 189 L/min (50 gal/min) at 49 m (160 ft) pressure head. A sump pump has been fabricated but not installed. It is available for use if required.

2.2.4.3 Ventilation System. The tank 244-CR-003 ventilation system consists of a gravity or ambient inlet air supply with air directed and controlled through the vault by operation of the 291-CR ventilation, air filtration, and exhaust system. Tank farm operating procedure TO-060-205, *Perform Ventilation Control and Surveillance at 244-CR Vault* (Houdasheldt 1994), contains detailed instructions for the ventilation system covering CR-003.

2.2.5 Transfer Line SN-244

Transfer line SN-244 connects the 244-CR-003 DCRT to the 241-ER-153 diversion box. SN-244 is a 7.6 cm (3 in.) diameter, schedule 40, stainless steel, single-encased pipeline, ≈237 m (779 ft) long. For the purposes of the pipe failure rate analysis (Section 4.2.2), the length of this pipeline has been conservatively estimated at 244 m (800 ft).

2.2.6 241-ER-153 Diversion Box

The 241-ER-153 diversion box is located north of the 244-A lift station. The diversion box connects the SST 241-C Tank Farm to all of the 200 West Area DSTs and supports diversion box 241-ER-151 for potential 200 West Area to 200 East Area transfers.

The diversion box is a reinforced-concrete structure with approximate overall dimensions of 4.6 m long x 4.6 m wide x 3.7 m deep (15 ft x 15 ft x 12 ft) with a cover block thickness of 0.5 m (1 ft 8 in.). The walls and floor are 30.5 cm (12 in.) thick. The entire floor and 0.6 m (2 ft) up the inner walls are lined with 0.3 cm (1/8-in.) ASTM A-240 type 304L stainless steel.

In addition to the 7.6 cm (3 in.) nozzle connection from the 244-CR Vault, penetrating lines include a 7.6 cm (3 in.) drain line (V228) to the 241-ER-151 diversion box. The 7.6 cm (3 in.) floor drain empties liquid from the sump to the 244-A lift station. Three process lines (SN-232, SN-233, and SN-234) connect the 241-ER-153 diversion box to the 244-A lift station. Line SN-233 failed and is out of service. A 10.2 cm (4 in.) lift station overflow nozzle also exists. The box drains to 244-A and is equipped with a leak detector that alarms at 242-A. Waste transferred out of the 244-A lift station can be routed to any of the 200 East Area DSTs.

2.2.7 Transfer to Receiving Double-Shell Tank

The transfer route to a receiving DST is dependent on choice of the DST. The transfer route to the receiving DST will likely utilize double-encased piping. The analysis performed for piping failure (Section 5.1) encompasses accidents involving both single- and double-encased piping, and conservatively estimates the pipeline length using a 3.7 km (2.3 mi) cross-site transfer line (Leach and Stahl 1993).

2.3 CHOICE OF DOUBLE-SHELL TANK

It is not the intent of this safety analysis to determine the appropriate receiving DST; however, the receiving DST must meet the safety criteria discussed in Section 3.0, as well as the controls established in Section 8.0.

2.4 POSTPUMPING CONDITIONS

2.4.1 Conditions in Tank 241-C-103 After Transfer

The interim stabilization of tank 241-C-103 is expected to remove a majority of the liquid contents; however, it is not possible to remove all of the liquid. The majority of the remaining supernatant liquid in tank 241-C-103 will likely be organic, because the organic is the top layer and pumping occurs from the bottom of the tank. The safety of tank 241-C-103 in the post-interim stabilized condition is addressed in a companion document, SARR-001 Supplement (Grigsby and Postma 1995).

2.4.2 Conditions in 244-CR-003 DCRT After Transfer

There is a high probability that the DCRT will contain trace amounts of organic liquid after the transfer process is complete, much like tank 241-C-103. The hazards associated with remaining organic in the transfer system are evaluated in Section 4.4.2.

2.4.3 Conditions in Receiving DST After Transfer

The DST will also likely contain traces of organic liquid following completion of the transfer. The hazards associated with remaining organic in the transfer system are evaluated in Section 4.4.2.

Figure 2-1. Typical Saltwell Jet Pump System.

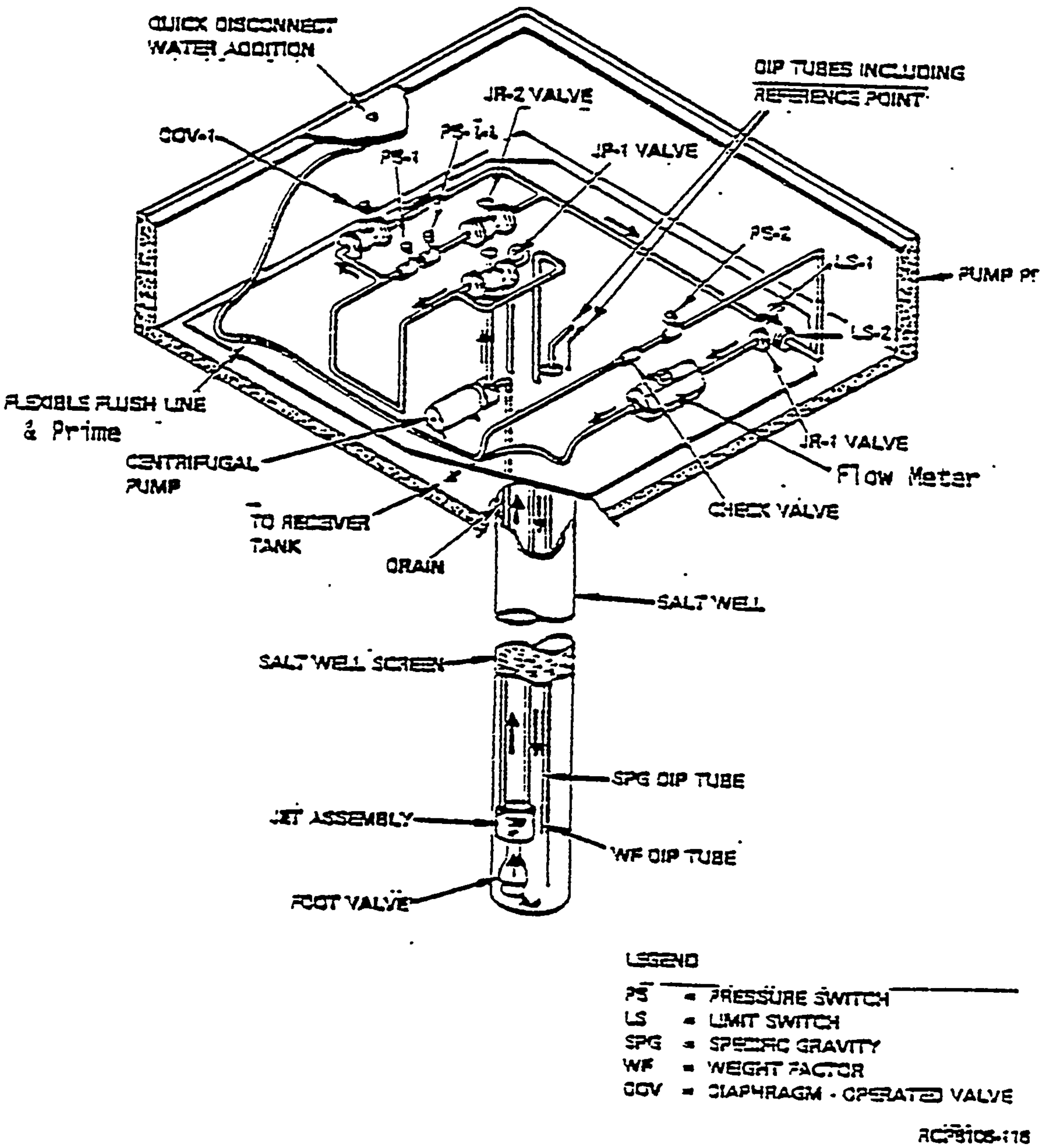


Figure 2-2. Cutaway View of Jet Assembly.

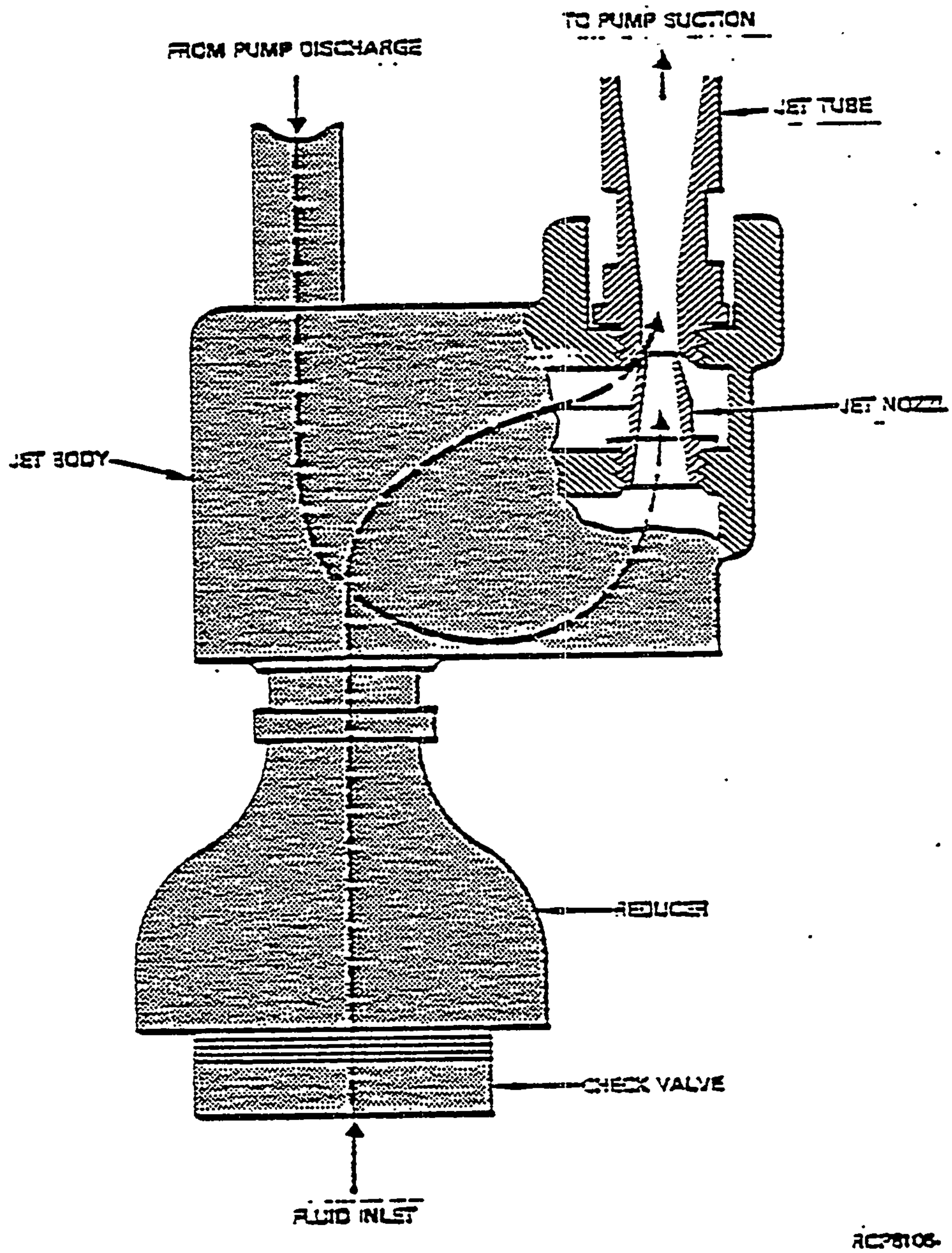
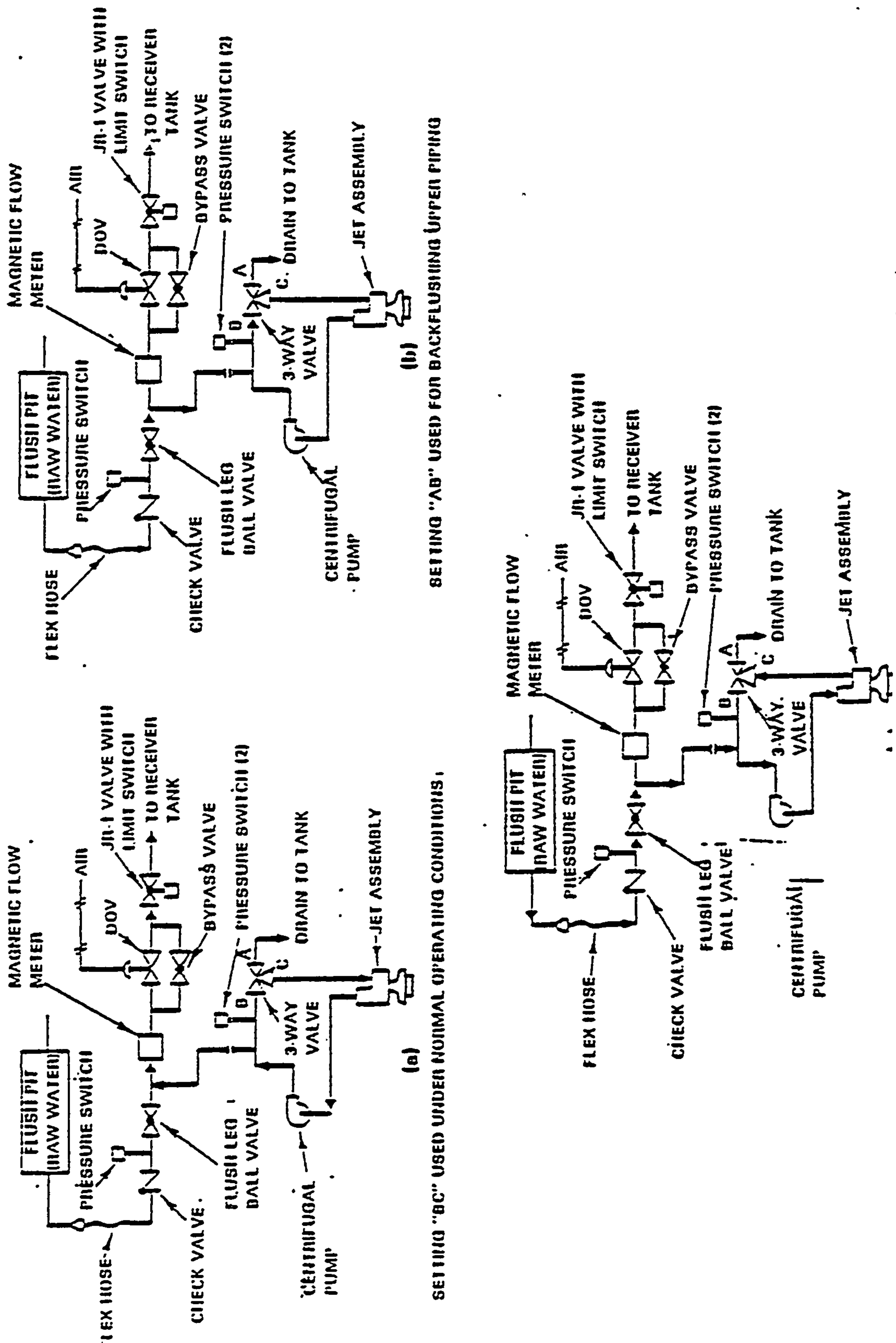


Figure 2-3. Jet Pump System Schematic-241-S.



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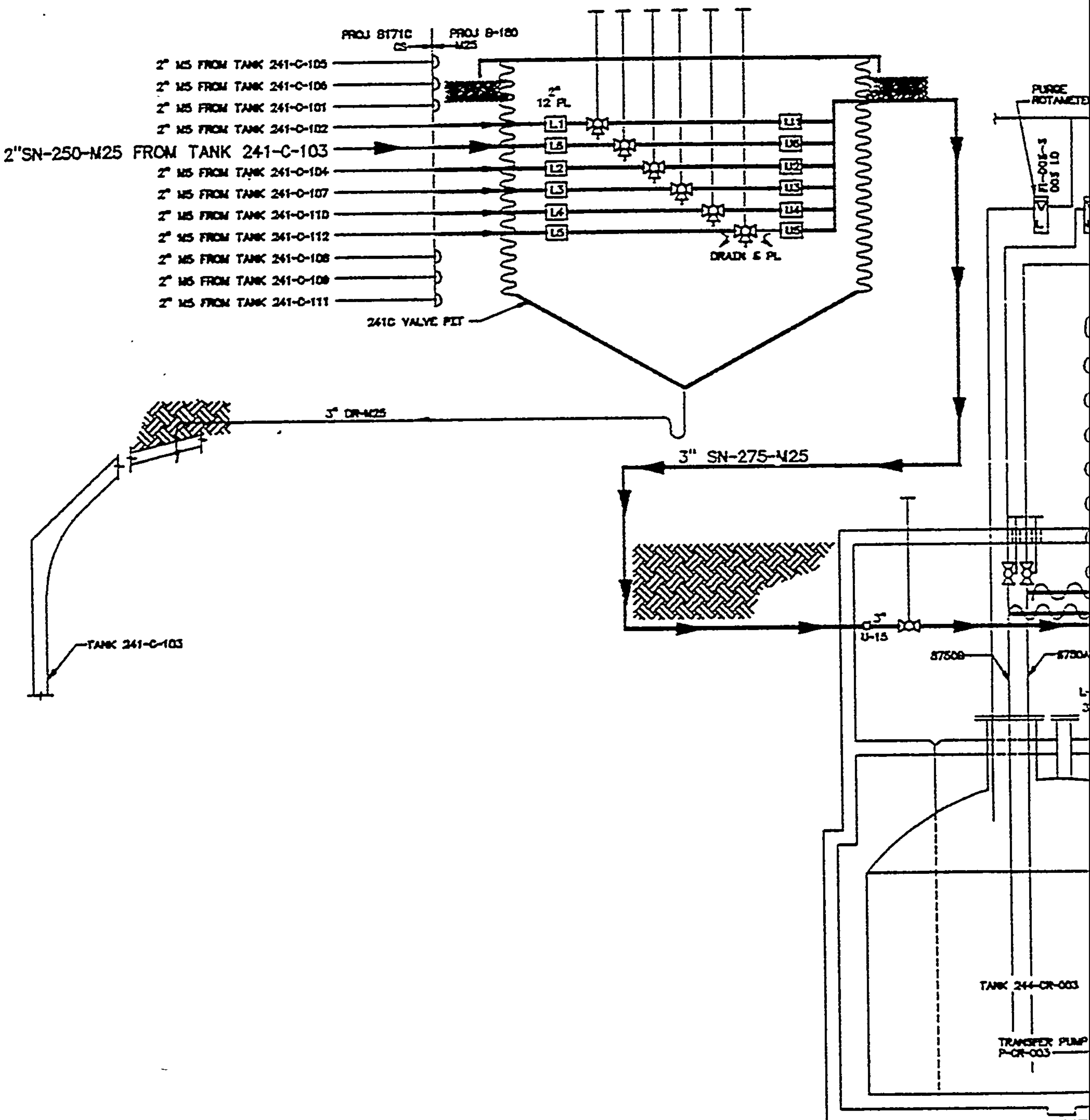
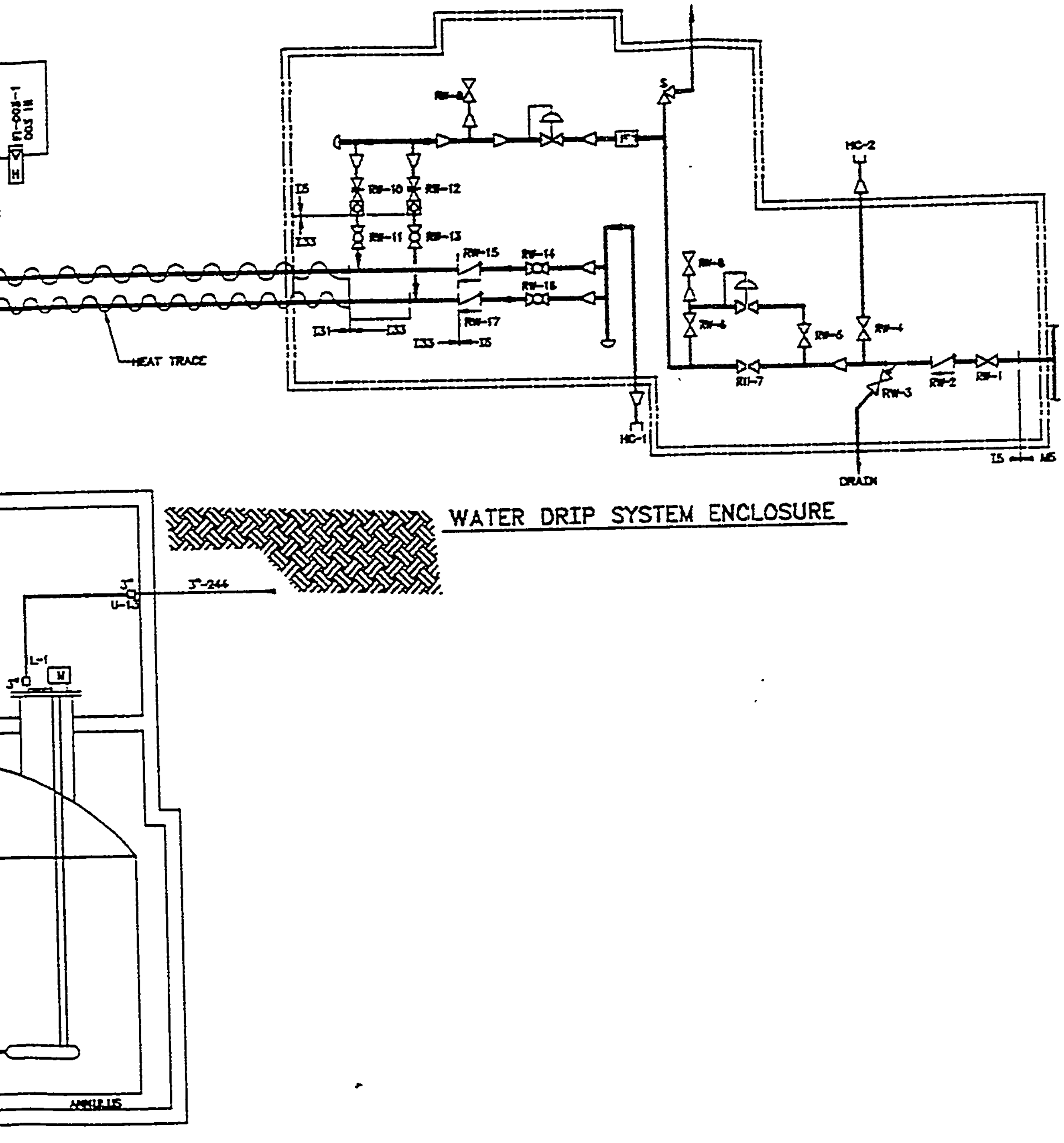


TANK 244-CR-00
FLOW

Figure 2-4. Tank 244-CR-003
Receiver Vault Flow Diagram.



RECEIVER VAULT
AGRAM

244CR-01

3.0 SAFETY CRITERIA

The following sections describe the safety criteria associated with interim stabilization of tank 241-C-103. Table 3-1 summarizes these criteria.

3.1 GENERAL PROCESS CRITERIA

3.1.1 Criticality

In accordance with WHC-SD-WM-DQO-001.6.1.1, the criticality limits for transferring to and storage in DSTs depend on several factors including total plutonium concentration. In all cases, the pH of the transferred waste must be greater than 8. For DSTs containing less than 10 kg (22 lbm) of plutonium after completion of a transfer, transfer may be made without consideration of the solids content if the plutonium concentration in the transferred waste is less than 0.013 g/L (1.08×10^{-4} lbm/gal).

If the receiving DST contains greater than 10 kg (22 lbm) of plutonium, the solids/plutonium mass ratio for waste already in the DST must exceed 1,000 or the solids/plutonium mass ratio of incoming waste must be at least 1,000 with a plutonium concentration less than or equal to 0.033 g/L (2.75×10^{-4} lbm/gal). If the measured density of solids is not available, assumption of a solids density of 1,200 g/L (10 lbm/gal) is acceptable. Hazards associated with criticality are evaluated in Section 4.2.1.

3.1.2 Vapor Concentration

In accordance with OSD-T-151-00030.2.C.1, the vapor concentrations of flammable gases must be less than 25% of the lower flammability limit (LFL) before work can be started in the primary ventilation space or in any associated exhaust ventilation system. Therefore, a control has been established to ensure that the concentrations of flammable gas are <25% of the LFL prior to any tank intrusive activities. See Section 4.1.3 for additional discussion.

3.2 SOURCE WASTE CRITERIA (TANK 241-C-103)

3.2.1 Flammable Gas Accumulation

In accordance with WHC-SD-WM-DQO-001.6.1.2, the specific gravity of the source waste shall be less than 1.3 or the specific gravity of the weighted mean of the co-mingled waste shall be less than or equal to 1.41. The density of the aqueous supernate in tank 241-C-103 is

- 1.078 g/mL (9 lbm/gal) (Pool and Bean 1994)
- 1.06 g/mL (8.8 lbm/gal) (Edrington 1991)
- 1.08 g/mL (9 lbm/gal) (Weiss 1989).

The density of the organic supernate in tank 241-C-103 is 0.876 g/mL (7.3 lbm/gal) (Pool and Bean 1994).

These densities are well below the limit of 1.3 and the transfer is allowed.

3.2.2 Energetics

In accordance with WHC-SD-WM-DQO-001.6.1.3, the source waste should have no separable organic and the source and receiving wastes (individually) should have an absolute value of the exotherm/endotherm ratio < 1.0; otherwise, a detailed technical evaluation shall be performed of the reactivity of the waste to determine the conditions needed for safely receiving and storing the waste. The source waste does have a separable organic phase; this hazard is evaluated in Section 4.2.3. See Section 3.4.3 for additional criteria for separable organics.

3.3 TRANSFER CRITERIA

3.3.1 Transfer of Waste

In accordance with OSD-T-151-00030.2.C.3, transfer of waste into any watch list tank requires written approval by the U.S. Secretary of Energy. Flush water will drain back from the 241-C valve pit to tank 241-C-103. Flushing is not considered transfer of waste, and is therefore allowed.

3.3.2 TRU Segregation

In accordance with WHC-SD-WM-DQO-001.6.2.1, if the source waste (TRU) ≥ 3,700 Bq/g (100 nCi/g), the waste shall be transferred to a TRU storage tank. If the source waste (TRU) < 3,700 Bq/g (100 nCi/g), the waste shall be transferred to a non-TRU tank unless a technical evaluation is performed demonstrating that TRU segregation will not be jeopardized.

Based on the concentration data presented in Section 4.2.1 for the criticality discussion, the aqueous and organic supernates are not TRU — they have concentrations of ≈1,630 Bq/g (44 nCi/g) and 20 Ba/g (0.55 nCi/g) total alpha. However, any significant carryover of tank 241-C-103 solids, which have $^{239/240}$Pu concentrations > 4.4 x 10^5 Bq/g (12,000 nCi/g), would result in a TRU waste stream. Based on these considerations, the supernate from tank 241-C-103 should be transferred to a TRU storage tank, if significant solids carryover is not prevented.

3.3.3 Line Blockage

In accordance with WHC-SD-WM-DQO-001.6.2.4, the Reynold's number should be greater than or equal to 20,000 and the vol% solids should be less than 30 at the conditions of transfer. Otherwise, a technical evaluation shall be performed to justify transfer without plugging. Line blockage is evaluated in Section 4.3.5.

3.3.4 Corrosivity

In accordance with WHC-SD-WM-DQO-001.6.1.4, for receiving tanks with operating temperatures < 75 °C (167 °F), the following tank compositions shall be maintained:

- $[NO_3^-] \leq 1.0M$
- $0.01M \leq [OH^-] \leq 8.0M$
- $0.011M \leq [NO_2^-] \leq 5.5M$.

The concentrations of the aqueous supernate from tank 241-C-103 are:

- NO_3^- = 2,400 µg/g = 0.04M
- OH^- = 3.2×10^{-5}M (based on pH of 9.5)
- NO_2^- = 23,000 µg/g = 0.54M.

Therefore the tank 241-C-103 aqueous supernate is out of specification for OH^- concentration and must be adjusted to 0.01M or greater. This OH^- concentration adjustment can either be done by addition of sodium hydroxide in the 244-CR-003 DCRT or by mixing the waste with existing DST tank contents, which have excess OH^-. A particular concern with OH^- concentration adjustment is the potential for a saponification* reaction of sodium hydroxide with TBP which would result in the formation of an aqueous-soluble sodium salt of sodium dibutyl phosphate (NaDBP) and butanol. Flammable gas generation in the headspace of the receiving tanks (DCRT and DST) is evaluated in Sections 4.4.1 and 4.5.2.

3.4 RECEIVING TANK CRITERIA (BOTH INTERMEDIARY AND DST)

3.4.1 Liquid Level

In accordance with OSD-T-151-00007, the receiver tank liquid level shall not exceed its maximum specification limit. The DCRT has a maximum operating level of 4.5×10^4 L (12,000 gal) (Schofield 1994). To accommodate the level

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*The chemical reaction in which an ester is heated with aqueous alkali such as sodium hydroxide, to form an alcohol (usually glycerol), and the sodium salt of the acide corresponding to the ester (Hawley 1977).

requirements of the DCRT the transfer will have to be performed in a number of segments or batches. DSTs must not exceed their maximum operating limits. A control has been established which specifies the amount of space required in the receiving tanks.

3.4.2 Heat Generation Rate

In accordance with OSD-T-151-00007.7.2.8, the maximum heat generation rates for the 241-AN, -AP, and -AW tank farms is 20,515 W (70,000 Btu/hr), 14,650 W (50,000 Btu/hr) for the 241-SY tank farm, and 1.2 x 10^6 W (4.0 x 10^6 Btu/hr) for the 241-AY and -AZ tank farms. It shall be verified that the heat generation limit in the receiving tank will not be exceeded prior to transferring additional waste into a tank. The heat generation associated with the addition of the liquid contents of tank 241-C-103 to a DST is evaluated in Section 4.5.1.

3.4.3 Energetics (Separable Organic)

In accordance with OSD-T-151-00007.7.2.1.D, the characterized PUREX waste that may contain TBP and/or NPH in a separable organic phase are allowed in the DSTs as long as the tank and waste temperatures are maintained below 74 °C (165 °F). Other separable organic waste streams shall require complete characterization prior to incorporation into the specification. A control has been established to ensure that the separable organics is transferred to a DST with temperatures less than 74 °C (165 °F) (which may exclude the aging waste tanks [241-AY and -AZ farms]).

3.4.4 Total Organic Carbon Concentration

In accordance with WHC-SD-WM-DQO-001.6.2.3, if the mean TOC is > 10 g/L (0.083 lbm/gal) at double-shell slurry feed (DSSF) composition, then the waste shall be transferred to a complexant waste receiver tank. In this case, TOC concentration is being used as an indicator of complexant concentration. A control in accordance with the waste compatibility program for TOC concentration is established in Section 8.0.

3.4.5 Flammable Gas Generation in the Double-Shell Tank

The conclusions for the generation of flammable gases within the DST shall not be affected by the addition of the organic layer to the DST. This hazard has been evaluated in Section 4.5.3.

Table 3-1. Safety Criteria. (2 sheets)

	Concern	Criteria	Condition	Impacts
General Process Criteria	Criticality	Aqueous: 0.013 g/L (8.12 x 10^{-4} lbm/ft^3) If <10 kg (22 lbm) of Pu in tank no further evaluation for criticality required	From Section 4.2.1 Aqueous: 5.4 x 10^{-4} g/L (3.4 x 10^{-5} lbm/ft^3) Organic: Pu concentration 100 times less than aqueous (therefore considered insignificant)	Criticality evaluated in Section 4.2.1.
	Vapor Concentration	Concentration shall be maintained <25% of the LFL for any intrusive activities.	From Section 4.1.3 Tank vapor samples indicate that concentrations are <7% of the LFL.	Control established to ensure that the concentrations of flammable gas are <25% of the LFL prior to any tank intrusive activities.
Source (tank 241-C-103) Tank Criteria	Flammable Gas Accumulation	Liquid SpG less than 1.3	Aqueous SpG = 1.08 Organic SpG = 0.876	Criteria is met.
	Energetics	No separable phase	Separable phase	Separable organic phase evaluated in Section 4.2.2.
Transfer Criteria	Transfer of Waste	No waste transfer to a Watch List Tank	Tank 241-C-103 is an Organic Watch List Tank	Transfer to a Watch List DST is not allowed.
	TRU Segregation	[TRU] >100 nCi/g to TRU segregation tank [TRU] <100 nCi/g to non-TRU tank unless technical evaluation is completed	Aqueous [TRU] = 44 nCi/g Organic [TRU] = 0.55 nCi/g Solids [TRU] ≥ 12,000 nCi/g	Control has been established for transfer to TRU receiving tank, if significant solids carryover is not prevented.

Table 3-1. Safety Criteria. (2 sheets)

	Concern	Criteria	Condition	Impacts
Transfer Criteria	Line Blockage	Reynold's number >20,000 and <30 vol% solids required	Pumping should not remove any significant quantities of solids	Hazard evaluated in Section 4.3.5.
	Corrosivity	$[NO_3^-] \leq 1.0M$ $0.01M \leq [OH^-] \leq 8.0M$ $0.011M \leq [NO_2^-] \leq 5.5M$	$[NO_3^-] = 0.04M$ $[OH^-] = 0.000032M$ $[NO_2^-] = 0.54M$	Aqueous supernate will require adjustment of OH^- concentration. Hazard associated with pH adjustment evaluated in Sections 4.4.1 and 4.5.2.
Receiving Tank Criteria	Liquid Level	DST or DSTs having appropriate capacity	4.9×10^5 L (130,000 gal) Aqueous 2.3×10^4 L (6,000 gal) Organic	Control established to ensure any receiving tank does not exceed its maximum liquid level specification.
	Heat Generation Rate	Maximum heat generation rate in receiver tank not to be exceeded	From Section 4.5.1: Aqueous concentrations: 53.7 µCi/g ^{137}Cs 65.5 µCi/g ^{90}Sr	Hazard evaluated in Section 4.5.1.
	Separable Organic	A separable organic waste stream must be characterized and placed in a DST with temperatures <74 °C (165 °F)	Separable organic present	Control established that specifies temperature of receiving DST <74 °C (165 °F).
	TOC Concentration	Transfer to complexant waste tank if TOC > 10 g/L	TOC concentration not verified. Receiving DST not selected.	Control established to ensure compatible waste transfer.
	Flammable gas generation	Not in increase the tank to generation rates above the LFL	See discussion in Section 4.X.	Hazard evaluated in Section 4.X.

4.0 IDENTIFICATION AND EVALUATION OF HAZARDS

The following sections evaluate those hazards identified in Section 3.0, as well as additional concerns associated with the interim stabilization of tank 241-C-103. These hazards are summarized in Table 4-1.

4.1 HAZARDS ASSOCIATED WITH EQUIPMENT INSTALLATION

The following hazards associated with the installation of equipment into a waste tank have been analyzed in several previously reviewed safety analysis documents:

- Loss of containment due to riser damage
- Penetration of the tank bottom liner from dropped objects
- Accidental combustion of vapor space gases
- Toxic vapor exposure
- Water addition.

Hazards associated with equipment removal, such as the withdrawal of radiation sources, are not included in this safety analysis. It is not the intention to remove equipment at this time. However, work plans can be prepared as a contingency in the event equipment fails and requires removal and replacement. The safety of the removal will be evaluated when the procedures are better defined.

4.1.1 Riser Damage

Damage to the riser could occur if equipment drops and strikes the riser with sufficient force. This is extremely unlikely, because all lifts of greater than 1.1 kN (250 lb) will be performed as critical lifts, see Section 4.1.2; however, if any equipment drops and the riser is damaged, gas and vapor confinement can still be maintained by using a thick torus type gasket or a glove bag.

4.1.2 Tank Liner Penetration

The possibility exists for unintentional equipment drop from ground level, while the equipment is being lowered into the tank. Tank bottom liner penetration is a potential hazard. It would take a relatively sharp object (e.g., a thermocouple tree) weighing several hundred pounds and dropped several feet to penetrate the 0.6 cm (0.25 in.) steel bottom liner (Farley 1992).

To prevent this extremely unlikely but potential accident, all lifts of greater than 1.1 kN (250 lb) shall be treated as critical lifts, requiring additional operator training and rigging inspections. It is judged that additional training and inspections will reduce the likelihood of a crane drop accident from extremely unlikely to incredible ($<10^{-6}$). Therefore, these lifts are to be treated as critical lifts as defined by the *Hanford Site Hoisting and Rigging Manual* (RL 1993).

4.1.3 Electrostatic or Electrical Sparks

A reading for level of flammable gas concentration shall be taken before any tank intrusive activities. The potential for episodic gas releases or steady-state hydrogen concentrations greater than the LFL of 4% by volume is not expected and will be confirmed by the initial testing with a grounded combustible-gas meter. A combustible gas meter calibrated with pentane, before and after use, yielded readings of 4% to 7% of the LFL when an inlet tube drew air from the upper part of the tank headspace (Huckaby 1994a). A major part of this reading may be attributed to hydrogen. Based on a hydrogen concentration of 2% of the LFL (Postma et al. 1994) and a meter response factor of 2 for hydrogen (response factors provided by the manufacturer of the combustible gas meter), a combustible gas meter reading of 4% LFL is attributable to hydrogen. The additional 3% LFL may be attributed to the other combustible gases present in sampled air.

If the concentration is ≥25% of the LFL, a sample shall be taken in accordance with the *Tank Farm Health and Safety Plan* (Hewitt 1994). A combustible gas meter may not detect NPH effectively; however, the meter is not expected to be off by more than a factor of 2 (Estey 1992). Also, NPH vapor presents virtually no flammability hazard at ordinary temperatures such as those either outside the tank, inside the tank head space, or in the tank breather filter system (Richardson 1992).

4.1.4 Toxic Gas Exposure

During the opening of the riser there is a possibility of a release of toxic gases (i.e., ammonia, organic vapors, and nitrous oxide) and combustible gas (i.e., hydrogen). A technician from the Industrial Hygiene, Safety, and Fire Protection Organization shall be present whenever a riser is open to enforce supplied fresh air requirements, provide guidance, and monitor for toxic gases in accordance with the requirements of the *Tank Farm Health and Safety Plan*, WHC-SD-WM-HSP-002 (Hewitt 1994). Refer to Postma et al. (1994) for discussions on the specific toxic and combustible gases that may be present in the headspace of tank 241-C-103.

4.1.5 Changes in the Waste Due to Water Addition

Water addition may be necessary to facilitate saltwell screen flushing and system decontamination, though it is not expected. The safety of water addition to ferrocyanide tanks is considered in *Safety Assessment for Thermocouple Tree Installation and Operation in Nonleaking Ferrocyanide Tanks*, WHC-SD-WM-SAD-014 (Farley 1992). The document looks at increased radiolysis of the water, reduced pH values of the waste, and released toxic or combustible gases. Based on the conclusions of that safety analysis, water addition will not result in an increased potential for the release of radioactive or hazardous materials.

All SSTs are now inactive, meaning they can no longer receive wastes. Water addition for operational purposes, in this instance, is not receipt of waste. Because stabilization is a required operation and the addition of water has been analyzed for impact, water addition is considered acceptable; however, the amount of water added is to be minimized.

4.2 HAZARDS ASSOCIATED WITH TANK 241-C-103

4.2.1 Criticality

This section investigates the possibility of a criticality. The aqueous and organic phases are investigated individually.

4.2.1.1 Aqueous Phase. The criticality specifications will not impact transferring the liquid contents of tank 241-C-103. Plutonium concentrations are well below limits, regardless of plutonium concentration in the receiving tank, and the pH is greater than 8.

The following plutonium concentrations have been reported for the aqueous supernate in tank 241-C-103:

- 8.9×10^{5} Bq/L (9.1×10^{-5} Ci/gal) $^{239/240}Pu$ (Edrington 1991)
- 1.2×10^{6} Bq/L (1.2×10^{-4} Ci/gal) $^{239/240}Pu$ (Weiss 1989
- 1.5×10^{3} Bq/g (1.8×10^{-5} Ci/lbm) total alpha ($\approx 1.6 \times 10^{6}$ Bq/L [1.6×10^{-4} Ci/gal]) (Pool and Bean 1994).

Discussions with tank farms nuclear safety personnel indicate that using the highest measured plutonium concentration would provide the best indication of plutonium concentration. Based on this, the plutonium concentration in tank 241-C-103, assuming a specific activity of 2.3×10^{9} Bq/g (28.2 Ci/lbm), is 5.4×10^{-4} g/L (4.5×10^{-6} lbm/gal). This is significantly less than the limit of 0.013 g/L (1.08×10^{-4} lbm/gal) and the transfer criteria is met.

If the receiving tank has a plutonium mass of less than 10 kg (22 lbm) (e.g., 241-AY-101 or much of the AN tank farm), the transfer can occur without further evaluation for criticality. If the receiving tank has a plutonium mass of greater than 10 kg (22 lbm), additional criteria, as identified above, must be met.

An assessment of the total ^{239}Pu mass and solids/plutonium mass ratio in the receiving tank is not possible because the tank has not been selected. However, an evaluation of the solids/plutonium mass ratio of the incoming waste can be performed. Assuming 1,200 g/L (10 lbm/gal) solids density with a plutonium concentration of 5.4×10^{-4} g/L (4.5×10^{-6} lbm/gal), the solids/plutonium ratio is 2.2×10^{6}. This ratio is several orders of magnitude greater than the lower acceptable limit of 1,000. As a result, the choice of receiving tank does not depend on ensuring that less than 10 kg (22 lbm) total ^{239}Pu is present.

4.2.1.2 Organic Phase. The following plutonium concentration has been reported for the organic supernate in tank 241-C-103:

- 7.2 Bq/g (8.8×10^{-8} Ci/lbm) $^{239/240}$Pu ($\approx 6.3 \times 10^{3}$ Bq/L [6.4×10^{-7} Ci/gal]) (Pool and Bean 1994)

This concentration is more than 100 times less than the aqueous concentration and is considered insignificant for evaluation. As pH increases, the plutonium concentration will likely further decrease. Even if all of this plutonium were to migrate to the aqueous phase, the total contribution would be less than 0.6 g (1.3×10^{-3} lbm).

4.2.2 Exothermic Reactions in Tank 241-C-103

Exothermic reactions inside of any tank are possible only if the contents can sustain a reaction. Because organic liquid has been transferred into Tank 241-C-103 from tanks 241-C-102 and 241-C-104, the potential of an exothermic reaction in this tank has been a concern (Hopkins 1992).

WHC-SD-WM-SARR-001 (Postma et al. 1994) evaluated the exothermic reaction hazards associated with the organic liquid layer in tank 241-C-103. The following potential hazards of uncontrolled exothermic chemical reactions during interim storage of the organic liquid in tank 241-C-103 were identified.

- Deflagration in tank headspace air
- Pool fire at the air/organic liquid interface
- Organic-nitrate/nitrite reactions in liquid and solid wastes.

These three hazards were evaluated to identify conditions under which significant reaction could occur.

This study found that uncontrolled exothermic reactions can be prevented by imposing minimal controls and monitoring requirements. The occurrence of a pool fire can be precluded by preventing the introduction of energetic ignition sources. A deflagration in headspace air can be prevented by maintaining the concentration of combustible species below the LFL. The hazard associated with a pool fire has been reevaluated in SARR-001, Supplement (Grigsby and Postma 1995). Organic-nitrate/nitrite reactions do not pose a significant hazard because reactant concentrations are too low to yield significant energy.

4.2.3 Energetics

WHC-SD-WM-DQO-001.6.1.3 specifies that the source waste shall have no separable organic and the source and receiving wastes should have an absolute value of the exotherm/endotherm ratio < 1.0 otherwise a detailed technical evaluation shall be performed.

Based on data presented in WHC-SD-WM-SARR-001, Rev. 0 (Postma et al. 1994), organic carbon levels in the aqueous phase are not adequate to evaporate water present in the event of an organic-nitrate/nitrite reaction. In the event of a transfer of the waste to a DST, another reaction must be considered. A saponification reaction of NaOH with TBP will produce NaDBP and butanol, both of which are highly soluble. The result of this reaction would be an increase in the organic carbon concentration sufficient enough to alter the conclusions made in WHC-SD-WM-SARR-001. It is assumed that all of the TBP in the organic phase was reacted with NaOH and further that all of the resulting material (NaDBP and BuOH) dissolved in the aqueous phase. The result was a tripling of the aqueous organic carbon concentration. However, the exothermic energy (from an organic-nitrate/nitrite reaction) released is less than 1/4 that required to evaporate the water present. Therefore, following the logic of SARR-001, "one can conclude that organic-nitrate/ nitrite reactions pose no threat in the aqueous supernatant liquid."

Based on an adiabatic calorimetry study of the tank 241-C-103 organic liquid (Postma et al. 1994), it was concluded that the organic

> ...possesses a faintly perceptible self-heating tendency above 230 °C (446 °F) when maintained as a liquid by high pressure. Subsequent general boiling completely tempers and absorbs this tendency. The final stages of unboiled residue decomposition yield only a small and short-lived self-heating event.

This indicates that the absolute value of the exotherm/endotherm ratio for the separable organic layer is less than 1.0.

Therefore, the source waste meets the criteria for the exotherm/endotherm ratio. Controls have been established to ensure that the receiving waste also meets the exotherm/endotherm ratio criteria, and the separable organic is transferred to an appropriate tank.

4.3 HAZARDS ASSOCIATED WITH THE TRANSFER PROCESS

4.3.1 Pump Failure

Two types of pumps are considered for this transfer operation: a saltwell jet pump and a submersible pump. Either pump will fail in a fail-safe mode, removing the motive force of any potential or additional releases. Jet pumps are installed in the pump pit above the tank. Therefore, failure cannot result in heat up of the tank waste or ignition of any potential flammable vapors in the dome space of a tank.

Analyses of submersible pump failures have previously been performed in Milliken (1992) and are discussed here. A failure study, including a fault-tree analysis, for a transfer from tank T-101 to tank SY-102 using a submersible pump was performed. Due to a concern for pump failures resulting in impacts to the tank waste, bounding heat transfer calculations were performed for the failure of the submersible pump. Failure is considered the loss of flow past the pump, which would result in loss of cooling for the running pump leading to a possible pump burnup. The calculations conservatively modeled heat transfer only in the radial direction and neglected significant transport pathways upward and downward, particularly the heat loss expected to occur as the air in the salt well is heated and rises to mix with the vapor space gases. The minimum time required to reach 200 °C (390 °F) in the sludge under these conditions was estimated to be 1.5 days (Milliken 1992). However, the conclusion of the failure study was that the probability of occurrence of this event was incredible. Additionally, failure of the submersible pump from overheating will not cause the liquid temperature to rise above 200 °C (390 °F), which is well below its ignition temperature. Unless already present before pumping operations begin, the addition of thermal overload protection to the submersible pump is required. Also, the current drawn by the pump motor is monitored for a drop of more than 50%, which would indicate a loss of pump suction. This is used as an additional criteria for pump shut down by the operator.

Also analyzed was the ability of the submersible pump to ignite flammable gases that might be present in the dome space. Based on the pump specific-ations, the pump has undergone a megger insulation test. Furthermore, based on the required minimum resistance for the megger test and assuming the wiring connections are performed to the specifications, it is assumed that no sparks are possible from the pump. This conclusion further supplemented by the fact that the motor and pump are submersed in the tank liquids, which would conduct any power leakage to the grounded saltwell. For these reasons that a spark will not occur that could possibly ignite any flammable gases present in the dome space of the tank.

It is therefore concluded that the failure of either a saltwell jet pump or a submersible pump does not contribute to the consequences of failure of the transfer system and additional controls to prevent or mitigate a pump failure are not necessary.

4.3.2 Piping Failure

Waste transfer line leaks/breaks are considered one of the most likely accidents to occur in the tank farms because waste transfers occur regularly and often involve the use of piping and equipment beyond their intended design life. Radioactive dose consequences could result if these wastes reach the soil surface and are aerosolized for possible human inhalation. Doses could also result from direct radiation exposure from these wastes. Accidents were considered where waste transfer lines could be potentially breached due to corrosion or accident and waste liquids being transferred could be leaked to the surrounding soil.

4.3.2.1 Transfer From Tank 241-C-103 TO 244-CR DCRT. Waste transfer from tank 241-C-103 to the 244-CR DCRT will use existing single-encased pipelines. This single-encased piping is often referred to as direct buried and has either been buried in trenches or laid at ground level and shielded.

4.3.2.2 Accident Scenario. Analysis efforts focused on the use of the single-encased pipelines expected to be used for the transfer from tank 241-C-103 to the DCRT. Only one containment barrier separates the high-level waste (HLW) from the soil. Additionally, the majority of the single-encased piping planned for use are beyond intended design life.

An accident scenario is postulated that a waste transfer line would develop a break during a transfer from tank 241-C-103 along the route to the 244-CR-003 DCRT. The break of the piping is speculated to develop as a result of corrosion and aging.

It is assumed that the pump involved in the transfer operation is pumping at a maximum flowrate and continued to do so for the duration of the accident. Dose consequences assumed that an onsite individual is subjected to a maximum of 8-hours exposure (one shift). Offsite individuals could be subjected to a maximum of 24 hours of exposure until the spill is effectively contained.

The accident scenario assumed that bermed piping is involved in the piping failure. This piping was laid at ground level and shielded with a layer of ground cover. No credit for soil cover is assumed for accident mitigative purposes. It is assumed that all of the waste liquid from a breached pipeline will reach the soil surface.

The accident scenario also assumes that waste leak volumes are limited by regular MBD surveillances. These surveillances are conducted to confirm that volumes of waste pumped are equivalent to volumes of waste received at the designated station.

4.3.2.3 Accident Frequency. Frequencies of leaks were estimated and postulated leak volumes were determined. The frequency of pipeline leaks within the SST waste transfer system is predicted by first determining the waste transfer route for use in the organic removal process and determining if the route involve use of single-encased bermed piping. The length of the piping in this route is then determined, as well as the expected duration of use. Experience data is then applied to predict the frequency of pipeline failures based on the length and hours of use per year.

The data used to predict the frequency of pipeline failures was developed by Idaho National Engineering Laboratory (Eide et al. 1990), because no Site-specific data was available. The comprehensive generic component failure data base is noted as applicable for light water and sodium liquid reactor probabilistic risk assessments and by engineering judgment deemed to be acceptable for this application. The failure rate for 2.5- to 7.6-cm (1- to 3-in.) pipe leakage is recommended at 3.3×10^{-8}/hour-m (1.0×10^{-8}/hour-ft), with an error factor of 30. Because the piping to be used is beyond its design life and several documented Hanford Site occurrence reports note pipeline failures during pretransfer pressure tests, the worst-case piping failure data was applied. This can be expressed as

$$3.3 \times 10^{-8}/hour\text{-}m\ (leakage) \times 30$$
$$= 9.9 \times 10^{-7}/hour\text{-}m\ (3.0 \times 10^{-7}/hour\text{-}ft).$$

The potential leak volume and frequency of leaks is discussed in this subsection.

4.3.2.4 Using Submersible Pump. Tank 241-C-103 has ≈5.3 x 10^5 Ln (140,000 gal) of organic and supernatant liquid. Because submersible pumps are capable of pumping up to 380 L/min (100 gal/min), the 5.3 x 10^5 L (140,000 gal) could be removed as quickly as 1,400 min (≈1 day). However, nominal pumping rates using submersible pumps are more like 38 L/min (10 gal/min). Using this nominal pumping rate, pipeline use could be as long as 14,000 min (≈10 days). These estimated durations assume that the transfer is not broken into segments (batches) to or from the DCRT; however, once a leak has developed it is postulated that the pump flow could increase to 380 L/min (100 gal/min) with no back pressure. Therefore, the nominal pumping rate (38 L/min [10 gal/min]) is used to determine a conservative frequency of a piping failure because the frequency is heavily dependent on the pumping duration. And then the 380 L/min (100 gal/min) maximum pumping rate will be used to determine the amount of liquid released during a piping failure. Although, this maximum pumping rate is conservative because a control has been established to shut down the pumping operation when a current drop of more than 50% is reached, indicating pump overspeed.

The overall length of the pipe, including all of the single-encased piping known to be utilized in a transfer from tank 241-C-103 (SN-250 and -275), is conservatively estimated at 140 m (460 ft).

$$\text{Conservative } Pipe\ Length = 140\ m\ (460\ m)$$
$$(Tank\ 241\text{-}C\text{-}103\ to\ 244\text{-}CR\text{-}003\ DCRT).$$

The maximum transfer volume is based on the amount of liquid to be transferred from tank 241-C-103. This is conservatively assumed to be 5.7 x 10^5 L (150,000 gal).

$$\text{Maximum } Transfer\ Volume = 150{,}000\ gal$$

$$\text{Failure } Frequency\ Rate = 9.9 \times 10^{-7}/hrsm \times 140\ m \times 250\ hours$$
$$(pumping\ duration\ at\ nominal\ 38\ L/\text{min})$$
$$= 3.5 \times 10^{-2}/event.$$

4.3.2.5 Using Saltwell Jet Pump. The use of a saltwell jet pump will result in a much longer pumping duration. Saltwell jet pumps are capable of pumping up to 19 L/min (5 gal/min), but typically run at 11 L/min (3 gal/min). For this failure rate analysis, the typical rate of 11 L/min (3 gal/min) is used to determine the pumping duration. The pipeline length and the maximum transfer volume remain the same as described above.

$$\text{Maximum } Transfer\ Volume = 150{,}000\ gal$$

$$\text{Failure } Frequency\ Rate = 9.9 \times 10^{-7}/hrsm \times 140\ m \times 833\ hours$$
$$(pumping\ duration\ at\ nominal\ 11\ L/\text{min})$$
$$= 1.1 \times 10^{-1}/event.$$

Pipeline failures using either pump are in the anticipated frequency range (between 1.0 and 1.0 x 10^{-2} events/year) using the guidelines of WHC-CM-4-46 included in Section 6.0. The consequences associated with a bounding pipeline failure scenario are analyzed in Section 5.1.

4.3.2.6 Transfer From 244-CR DCRT to Receiving DST. An accident analysis was conducted to evaluate the risk from leaks/breaks of DST/AWF waste transfer process piping during waste transfer operations. The analysis included the single-encased piping used from the 244-CR-003 DCRT to the tank 241-ER-153 diversion box (SN-244). The DST/AWF transfer line facilities use double-contained process piping. The secondary containment includes leak-detection devices and drainback routes in case of primary piping failure. These design features serve to contain primary pipeline leaks and notify operations personnel should they occur.

This analysis considered an excavation accident to be bounding for DST/AWF cross-country transfer facilities pipeline leaks/breaks, because failure of the primary piping from corrosion is expected to be detected and mitigated by existing design features. An excavation accident could result in a direct release of HLW to the soil surface should a transfer be in process when the accident occurred.

4.3.2.7 Accident Scenarios. The postulated accident scenario involves either a single-encased pipeline break, as a result of corrosion and aging, or a double-encased pipeline break due to a planned ground excavation using power equipment. The sequence of events in this ground excavation accident scenario includes the following:

- An excavation is planned in the tank farm facilities in proximity of a waste transfer route.
- An administrative error results in the work order identifying the wrong location for the excavation, or an operator error results in the work crew reporting to the wrong location for excavation.

- A waste transfer is in process at the location that the work crew commences excavation.
- The power digging equipment causes a breach of the waste transfer piping.
- The excavation crew observes the pipeline break and evacuates the area. They immediately take action to notify waste transfer operations personnel of the pipeline breach.
- Waste transfer operations personnel, on notification, immediately take action to shut down waste transfer operations in the affected areas.

4.3.2.8 Accident Frequencies. The overall failure frequency of this accident will be determined by summing the frequency of the single-encased pipeline (SN-244) failure and the frequency of the double-encased pipeline break due to excavation.

The failure of the single-encased piping is a function of the length of the pipeline as well as the pumping duration. In this case, the pump in the DCRT is rated at 190 L/min (50 gal/min); however, the nominal pumping rate for a submersible pump is used (38 L/min [10 gal/min]). Therefore, the pumping duration is calculated as 125 hours, based on a limiting volume of 64.35 kL (150,000 gal). The length of line SN-244 is conservatively estimated at 244 m (800 ft). The failure frequency of single-encased piping remains the same as described above.

$$\text{Failure } Frequency\ Rate = 9.9 \times 125^{-7}/hrs\ m \times 244\ m \times 250\ hours$$
$$(pumping\ duration\ at\ 10\ gal/\text{min})$$
$$= 6.0 \times 10^{-2}/event.$$

4.3.2.9 Double-Encased Piping Failure Frequency. Pipeline breaks caused by onsite excavation activities during waste transfers are considered to be in the unlikely frequency range (1×10^{-2} to 1×10^{-4} events/yr), per WHC-CM-4-46, using qualitative judgement. This judgement is based on the fact that excavation permits are required prior to conduct of excavation activities (WHC-CM-8-7). Prior evaluation of potential transfer routes potentially impacted by excavation is required prior to permit issue. Operations personnel including WHC organizations, contractors, or subcontractors within the facilities, plants, and areas managed by WHC are not permitted to conduct excavation activities in areas of active waste transfers.

4.3.2.10 Overall Failure Frequency. The failure frequency of the single-encased piping (SN-244) is calculated as 6.0×10^{-2}/event. The frequency of a double-encased pipeline break is qualitatively determined to be Unlikely. It is assumed that the qualitative unlikely frequency can be quantified as 1×10^{-2}/event — the high end of the range. Therefore, this results in an overall failure frequency of 7.0 x 10^{-2}/event — which is within the anticipated range. To verify pipeline integrity prior to transferring any waste, a pressure test of the direct buried transfer route is required. The consequences associated with a bounding pipeline failure scenario are analyzed in Section 5.1.

4.3.2.11 Spray Release in Pit. Spray releases are of particular concern because the resulting aerosol could readily be inhaled by a human receptor. Spray releases could result from small holes developing in the transfer system, improperly installed transfer jumpers, defective or degraded seals or gaskets, and small cracks in transfer piping. Spray releases within pits are considered bounding because valves, jumpers, and connectors in the pits result in locations where a spray leak may occur due to the localized pressure buildup corresponding to flow restrictions and redirection.

Analyses were performed to consider the effects of a liquid spray release from a potential breach of waste confinement piping or equipment in a SST pump pit, DCRT pump pit, or a valve pit.

4.3.2.12 Accident Scenarios. It was postulated that an accident causes a breach of waste transfer piping or equipment inside of a pump pit, DCRT pump pit, or a valve pit, which results in a liquid spray. The liquid spray is constant but insufficient quantity, or the orientation of the spray, prevents the leak detection devices from initiating an alarm. Drains in the pump pits or valve pits remove accumulated liquid before it reaches the leak detection alarm level. Therefore, it should be noted there is no credit given to leak detection capabilities, though a control has been established to ensure all leak detectors along the transfer route are operational prior to transferring waste. See Section 4.3.3 on limits of leak detection during organic waste transfers.

Existing requirements mandate that cover blocks be installed during waste transfers for their defined scope of applicability. The requirements specify verification that the covers are installed and secured in accordance with operating procedures. Surveillance is mandated once within 72 hours prior to transfer and once every 24 hours after transfer begins for permanent covers, or once every 12 hours for temporary covers. This control is established in Section 8.0. During a design basis earthquake (DBE), credit for cover blocks cannot be taken. This accident is analyzed in Appendix C.

The accident scenario assumes that pumping flow rates range from 190 L/min to 380 L/min (50 gpm to 100 gpm) and the maximum pressure in the transfer system is 1.43 x 10^6 Pa (207 psi). These assumptions are considered bounding because the transfer rate and maximum pressure encompass all transfers within the SSTs and transfer to or from the DCRTs.

Engineering judgement assumes that the leak is not discovered for 24 hours. Onsite individuals are assumed to be exposed to aerosol spray resulting from a spray leak for a maximum of 8 hours (one shift). Offsite individuals are assumed to be exposed to resulting aerosol spray for a maximum of 24 hours. The following assumptions are utilized in this analysis.

- The cover blocks are in place.
- A leak develops at each end of a jumper. The optimum hole size is calculated to be 0.16 cm (0.063 in.).
- The pressure at the release point is 1.43×10^6 Pa (207 psi).
- Leak detection in the pit area is not effective and does not cause the condition alarm. Each jumper pit (pump or valve pit) is provided with leak detection that, if activated, will stop the transfer pump. However, it is possible that the orientation of the leaks could be such that, without the cover blocks in place, the liquid is sprayed out of the pit and escapes to the atmosphere without activating the detectors. In this case, the leak would continue until it was observed by visual inspection that the cover blocks are not in place.
- The spray leak continues until operators visually observe that the cover block was left off or that a spray leak has developed. This time was determined to be a maximum of 24 hours.

4.3.2.13 Accident Frequencies. The expected frequencies of spray releases in pump pits, valve pits, and DCRT pump pits have been calculated in Stahl and Coles (1992), Attachment A, "Accident Sequence Analysis for Safety Assessment of Interim Stabilization of Nonwatchlist Tanks." A breach of a connection, pipe, or valve body in a pit area, using the enveloping parameters, was predicted to occur as follows:

- Connecting piping in a pit

$$9.9\ 10^{-7}/hour\text{-}m\ 6.1\ m \times 8{,}760\ (h/yr)$$
$$= 5.3\ x10^{2}/yr.$$

- Gaskets

$$5.0 \times 10^{-8}/hours\ gaskets \times 2\ gaskets \times$$
$$8{,}760\ (h/yr) = 8.8 \times 10^{-4}/yr.$$

- Valve packing

$$3.5 \times 10^{-6}/hours\ valve \times 2\ valves \times$$
$$8{,}760\ (h/yr) = 6.1 \times 10^{-2}/yr.$$

- Total = 1.15×10^{-1}/yr.

NOTE: Gasket and valve packing failure rates were taken from Dexter (1982) and piping failure rates were taken from Eide et al. (1992).

These predicted component failure rates do not include the frequency of faulty jumper connections that may be caused by maintenance errors. The contribution from faulty maintenance would not be expected to significantly add to the overall predicted failure frequency.

The annual frequency of experiencing a spray leak in one of the transfer line pits of the tank farm at the same time as one of its covers is off was reviewed and recalculated (SAIC 1994) using refined techniques in human reliability analysis and a detailed specific modeling of the surveillance program. With credit given for recovery actions under the rules of HRA and taking the allowed credit for risk improvement afforded by the tank farm surveillance program establishes a high confidence that the frequency for the postulated accident of a spray leak with pit cover removed is below the 1×10^{-6} credibility cut-off limit is established (SAIC 1994). This conclusion is based on assumptions that applicable controls and surveillances are implemented as described Section 8.0.

The consequences of a spray release in a pit are evaluated in Section 5.2.

4.3.3 Loss of Leak Detection

The transfer piping (SN-250, SN-275, SN-244) from tank 241-C-103 to the 241-ER-153 diversion box consists of single-encased (direct-buried) piping. Leak detection along single-encased piping is not available, but leak detection is available at the 241-C valve pit, the 244-CR-003 DCRT, and the 241-ER-153 diversion box. However, credit cannot be given for the leak detectors while transferring organic liquid. The leak detectors use conductivity probes which are incapable of detecting the presence of the organic liquid. Therefore, throughout the piping failure and spray release analysis (Sections 5.1 and 5.2), no credit is being taken for automatic shutdown of the transfer process due to leak detection. However, leak detection will be available during the majority of the transfer process, as ≈95% of the liquid volume to be transferred is aqueous supernate.

The piping from the 241-ER-153 diversion box to the receiving DST may be double-encased with leak detection. Currently, two types of double-encased designs are used: pipe-in-pipe and concrete-encased pipe. Double-encased piping has leak detection capability due to the annulus space between the primary pipe and the encasement.

Leak detection in pipe-in-pipe systems consists of 3.8 cm (1.5 in.) diameter pipe risers that provide access to the annular space for installation of permanent, dedicated, alarm-connected conductivity probes that detect the presence of liquid in the space between the pipes. Leak detection test risers are located at the low ends of each inter-tank farm and generator-import transfer line.

The leak detection used in the concrete encasement mainly depends on test risers. A test riser is a 2.5 cm (1 in.) pipe that provides access to the inside of the encasement to check for liquids or high radiation levels. Test risers also are called "swab risers" because a swab can be used to check for leaks in the encasement. Conductivity detectors on the floor of the diversion boxes and other pits also provide leak detection capability.

Outer pipes also have drain lines at diversion boxes that allow leaks from primary pipes to drain into boxes via nozzles directly below the primary nozzles. Conductivity leak detectors on the floor of diversion boxes register alarms when leaks drain into the diversion boxes. As stated above, the conductivity leak detectors are not capable of detecting organic liquid, and thus credit for leak detection during waste transfer accidents is not being taken.

4.3.4 Loss of Level Detection

Level detection during the waste transfer process is conducted periodically by MBDs. MBDs are performed by operators, therefore loss of level detection would be a procedural noncompliance, as compared to erroneous readings from faulty equipment. The operators are required to perform MBDs hourly, however, the consequence analysis in Section 5.1 considers that the operator may not detect a leak on the first hour and on the second MBD (second hour) the operator will shut down the pumping operation.

The Food Instrument Corporation gauges (FICs) currently in most tanks cannot accurately detect organic layers. Tank Farms is currently replacing the FIC gauges with nonconductivity level measurement series 854 ATG level gauges. These new gauges are able to detect organic layers. An nonconductivity level measurement gauge installed in tank 241-C-103 since August of 1994 has consistently read (3.8 cm [1.5 in.]) higher than the previous FIC readings. This corresponds well to the predicted (3.8 cm [1.5 in.]) separable organic inside this tank.

Few tanks have installed nonconductivity level measurement level gauges. Tank 244-CR-003 does not contain an nonconductivity level measurement gauge. Installation of an nonconductivity level measurement gauge is required in 244-CR-003 and the receiving DST to better determine organic levels and as an indicator of leaks. This safety analysis assumes that detection of the liquid level is capable only through performance of MBDs, which will utilize these installed nonconductivity level measurement gauges or other nonconductivity level measurement.

4.3.5 Line Blockage

Based on the proposed pumping schemes for transfer of the tank 241-C-103 supernate, the vol% solids will be much less than 30%. The Reynold's number during transfer will depend on the pumping rate and diameter of the underground transfer piping. Based on a 7.6 cm (3 in.) diameter transfer line, the minimum flow rate required to meet the Reynold's number criteria is 167 L/min (44 gal/min) or greater.

If a skimmer pump (not available at this time) or saltwell screen is used, as is likely, the solids concentration will be minimized and the flow rate can be significantly lower. This is one reason why saltwell pumping with a low-flow jet pump is acceptable. A control has been established to ensure that the transfer is routed through the saltwell screen.

4.3.6 Transfer of Aqueous Solution

It is the intent of this safety analysis to cover the transfer of all the liquid contents from tank 241-C-103. Approximately 4.9 x 10^5 L (133,000 gal) of aqueous supernate will be transferred with the ≈2.3 x 10^4 L (6,000 gal) of organic liquid. The aqueous supernate poses no additional safety concerns during the transfer; however, the large volume of supernate to be transferred is the driving force behind the pool size realized by a piping failure and the resulting dose consequences, as analyzed in Section 5.1.

4.4 HAZARDS ASSOCIATED WITH THE INTERVAL BETWEEN SEGMENTS OR AFTER TRANSFER

4.4.1 Flammable Gas Generation in the Headspace of Tank 244-CR-003

The generation of flammable gases in the headspace of the CR-003 DCRT was analyzed by the Enserch Environmental Corporation (Bartley 1995). As discussed in Section 3.3.4, the required adjustment of the pH in the DCRT may result in the generation of flammable gases. Two potentially flammable gases are expected to be generated by the addition of NaOH: butanol and ammonia.

4.4.1.1 Butanol Generation. Enserch determined that if tank 244-CR-003 is closed, without ventilation, it will take hours for the concentration of butanol in the headspace of the tank to reach 10% of the lower explosive limit (LEL). If tank 244-CR-003 is ventilated, the concentration of butanol in the headspace will remain below 10% of the LEL (See Table 4-3.1).

Table 4-3.1. Butanol Concentration in Headspace With Active Ventilation.

Ventilation Rate m^3/min (CFM)	%LEL in Headspace
0.14 (5)	0.06%
2.8 (100)	0.00%
8.5 (300)	0.00%
14.2 (500)	0.00%

The following assumptions were made to derive the results above.

- Tank 244-CR-003 has a capacity of 5.7×10^4 L (15,000 gal).
- The operating capacity of the tank is 80% of the full capacity, or 4.5×10^4 L (12,000 gal).
- 1.5×10^4 L (4,000 gal) of organic could potentially be placed in the tank.
- pH adjustment would be accomplished using 1 M NaOH.
- The temperature of the tank is 70 °C (158 °F).
- The pressure inside the tank is 760 mmHg (1 atm).
- The reaction rate at the temperature and pressure above would be 2.3×10^{-3} g TBP/L (1.9×10^{-5} lbm TBP/gal) of aqueous phase per hour.
- The reaction only takes place in the aqueous phase.
- All behavior is ideal.
- All butanol formed instantaneously volatilizes.

The conclusions are considered to be conservative due to the following.

- The reaction takes place only in the aqueous phase, requiring any butanol formed to dissolve into the organic phase from the aqueous phase, diffuse through the organic layer to the organic/air interface, and evaporate into the air.
- Butanol is partially soluble in both the aqueous phase and the organic phase, resulting in less butanol in the vapor phase than the total amount of butanol formed.
- The temperature of the tank is assumed to be 70 °C (158 °F). The temperature of the waste in tank 241-C-103 is currently 48 °C (119 °F).

4.4.1.2 Ammonia Generation. If tank 244-CR-003 is closed, without ventilation, it will take 156 days at a liquid pH of 12 and 153 days at a liquid pH of 14 for the concentration of ammonia in the headspace of the tank to reach 10% of the LEL. If the tank is ventilated at 0.14 m^3/min (5 ft^3/min) or more, the concentration of ammonia in the headspace will remain below 0.0% of the LEL at a pH of either 12 or 14.

The following assumptions were made to derive the results.

- Tank 244-CR-003 has a capacity of 5.7×10^4 L (15,000 gal).
- The operating capacity of the tank is 80% of the full capacity, or 4.5×10^4 L (12,000 gal).

- pH adjustment would be accomplished using 1 M NaOH.
- The temperature of the tank is 70 °C (158 °F).
- The pressure inside the tank is 760 mmHg.
- The reaction rate at the temperature and pressure above is 1.4×10^{-11} m^3 NH_3/L (1.89×10^{-9} ft^3 NH_3/gal) of aqueous phase per minute at pH 10. From the equilibrium constant, the reaction rate is assumed to be 18% higher at pH 12 (1.65×10^{-11} [2.23×10^{-9}]) and 20% higher at pH 14 (1.68×10^{-11} [2.27×10^{-9}]).
- All behavior is ideal.
- All ammonia formed instantaneously volatilizes.

If the pH adjustment is performed in the DCRT, a control has been established ensuring 0.14 m^3/min (5 cfm) flow through the DCRT to prevent the potential accumulation of flammable gases.

4.4.2 Remaining Organic in Transfer System Following Transfer

There are two hazards associated with the remaining organic in the 244-CR-003 DCRT or the DST: corrosion and pool fire. Currently, the corrosivity of the supernatant liquid is out of specification for a receiving tank (see Section 3.3.4). However, adjustment of the pH can bring the supernatant to within specifications and flushing of the DCRT may alleviate the majority of the remaining organic.

The hazards associated with a pool fire in the DCRT and the DST are evaluated in Sections 4.4.3 and 4.5.3.

4.4.3 Pool Fire in 244-CR-003 DCRT

The hazard of concern is a pool fire in the 244-CR-003 DCRT following the receipt of supernatant liquids from tank 241-C-103. The organic liquid from tank 241-C-103 has a flash point greater than 200 °F (93.3 °C) and is therefore ranked in the lowest class of flammable liquids (Class III B) in NFPA-30 (NFPA 1990).

High flashpoint liquids can be ignited only by means of high energy ignition sources. A safety analysis of solvent fires in tank 241-C-103 concluded that lightning strikes and gasoline spills were the only identified initiators that could deliver the large energy bursts required to ignite a pool fire (SARR-001, Supplement [Grigsby and Postma 1995]). Therefore, the ignition of a pool fire in a waste tank is a low-probability event.

In order to assess the risk posed by solvent fires in the DCRT, consequences of fires were evaluated under the assumption that a pool fire was ignited by an unspecified means. The technical approach is described in detail in SARR-001, Supplement (Grigsby and Postma 1995). Solvent fire risks in a DCRT and a DST were evaluated using the following steps:

- Postulate the ignition of a pool fire
- Compute temperature and pressure transients for a range of possible fire parameters
- Compare predicted peak pressures with tank structural limits to evaluate the possibility of failure due to overpressure
- Evaluate radiological and toxicological consequences on the basis of pollutants carried in the smoke plume generated by the postulated fire.

The radiological consequences of a pool fire in a DCRT are analyzed in Section 5.3. The toxicological consequences are included in Appendix B.

4.5 HAZARDS ASSOCIATED WITH DST RECEIVING WASTE

4.5.1 Heat Generation Rate

Per OSD-T-151-00007.7.2.8 (Schofield 1994), the maximum heat generation rate is 20,515 W (70,000 Btu/hr) for the 241-AN, -AP, and -AW Tank Farms and 14,650 W (50,000 Btu/hr) for the 241-SY Tank Farm. The heat generation rate in the tanks is limited to prevent localized boiling from occurring. The ventilation systems for AN, AP, AW, and SY Tank Farms were not designed for boiling and internal boiling could cause a release of contamination. The heat content limit for the 241-SY Tank Farm is based on its design criteria, which is more restrictive than the point where internal boiling occurs.

Bartley (1995) performed calculations to determine the heat generation rate in the aqueous phase of tank 241-C-103. It was concluded that the heat generation rates of ^{137}Cs and ^{90}Sr are

- 14 W (47.5 Btu/hr) for ^{137}Cs
- 24 W (82.0 Btu/hr) for ^{90}sr

These numbers were determined by:

$$\text{Concentration} \times Volume\ C1 \times C2 \times C3$$

where

Concentration = radionuclide concentration from Pool and Bean (1994):

- 1.98×10^6 Bq/g 53.7 μCi/g for ^{137}Cs
- 2.42×10^6 Bq/g 65.5 μCi/g for gross Beta (assume to be all ^{90}Sr).

Volume = aqueous supernate volume (5.0×10^5 L [133,000 gal])

C1 = radionuclide activity to heat generation conversion:

- 1.3×10^{-13} W/Ba (1.64×10^{-2} Btu/L) for ^{137}Cs
- 1.8 x 10-13 W/Ba (2.32 x 10-2 Btu/L) for ^{90}Sr

C2 = curies to micro curies conversion (Ci/1.0×10^6 μCi)

C3 = specific gravity of aqueous (1.08 g/mL).

Therefore, it can be concluded that the heat generation rate in the aqueous phase of tank 241-C-103 is negligible to the heat generation of the receiving tank. In addition, the supernate temperatures in tank 241-C-103 have not exceeded 54 °C (130 °F) in the past three years. According to Kummerer (1994), the DST with the highest temperature (excluding aging waste tanks) is tank AN-104 at 50 °C (122 °F). Therefore, the receiving DST will also not exceed its operating temperature limits.

4.5.2 Adequacy of Existing Ventilation System

All of the DSTs are actively ventilated. The applicable operating specifications documents specify that in the event that active ventilation in the tank farm cannot be maintained, operations in the affected tank farm shall be curtailed.

The ventilation system in the receiving DST is important due to the adjustment of the pH. Potentially, flammable gases can be generated due to this pH adjustment. Verification that the existing ventilation system in the receiving DST is operable will ensure no generation of flammable concentrations in the tanks head space due to pH adjustment.

4.5.3 Double-Shell Tank Flammable Gas Generation

Waste in DSTs generate flammable gases through the general mechanisms. One of which is dissociation or decomposition of organic compounds in the waste by heat, pressure, and radiation. Therefore it can be surmised that the addition of the organic layer from tank 241-C-103 to the DST will increase the generate rate of flammable gases from the tank.

In the analysis performed for the tank farm accelerated safety analysis program as documented in WHC-SD-WM-SAR-065, a hypothetical set of operational parameters was chosen that could provide a bounding case for analysis. The parameters were selected to encompass the most conservative observed parameters found in the DSTs excluding aging waste tanks) for generation. This amounted to maximizing the potential for hydrogen generation and minimizing the head space volume. Even through the organic layer increases the overall TOC content, the overall results and conclusions were unchanged for the hypothetical tank, the addition of the organic layer does not perceptively change the time to reaching the concentration of concern.

4.5.4 Pool Fire in Double-Shell Tank

The hazard of a pool fire in a DST is similar to a pool fire in a DCRT, as described above. The radiological consequences of a pool fire in a DST are analyzed in Section 5.4. The toxicological consequences are included in Appendix B.

Table 4-1. Summary of Safety Concerns. (4 sheets)

Hazard Evaluated	Potential Accidents	Safety Controls and Conclusions
Riser Damage	Loss of gas and vapor confinement, resulting in release of hazardous materials	Riser damage is expected to be extremely unlikely; however, if any equipment was dropped and the riser was damaged, gas and vapor confinement could still be maintained by using a thick torus type gasket or glove bag.
Tank Liner Penetration	Tank liner penetration, resulting in the release of hazardous materials	To prevent liner penetration, all lifts of over 113 kg (250 lb) will be treated as critical lifts.
Electrostatic or Electrical Sparks	Waste surface reaction initiated by sparking flammable gases within the tank	A reading for level of flammable gas concentration shall be taken before any tank intrusive activities. If the concentration is ≤25% of the LFL, operations may proceed; but if the concentration exceeds 25% of the LFL, a sample shall be taken.
Toxic Gas Exposure	Release of toxic and/or flammable gases	A technician from the Industrial Hygiene, Safety, and Fire Protection Organization shall be present whenever a riser is open to enforce supplied fresh air requirements, provide guidance, and monitor for toxic gases in accordance with the requirements of the *Tank Farm Health and Safety Plan*, WHC-SD-WM-HSP-002 (Hewitt 1994).
Changes in Waste Due to Water Addition	Change in waste composition, increased potential of release of materials	Water addition to tank 241-C-103 will not alter the status of the tank. Water addition to tank 241-C-103 is to be minimized.
Criticality	Criticality resulting in release of hazardous materials	Plutonium concentrations are well below limits, regardless of plutonium concentration in the receiving tank. The pH of the liquid is greater than 8.

Table 4-1. Summary of Safety Concerns. (4 sheets)

Hazard Evaluated	Potential Accidents	Safety Controls and Conclusions
Exothermic Reactions in tank 241-C-103	Exothermic reaction leading to tank deflagration	Exothermic reactions in tank 241-C-103 have been previously evaluated in Postma et al. (1994). Exothermic reactions can be prevented by the controls and monitoring requirements, as established in Section 8.
Pool Fire in tank 241-C-103	Fire resulting in dome pressurization, release of hazardous materials, and possible tank dome collapse	Hazard evaluated in SARR-001, Supplement (Grigsby and Postma 1995).
Pump Failure	Pump burnup leading to ignition of organic liquid and/or flammable gases	Probability of occurrence of this event is based on potential human error failure during the material balance calculations and the failure of a thermal overload switch to activate, preventing the pump from shutting down. The probability of this event is determined to be incredible.
Piping Failure - Transfer line leak/break	Loss of containment during transfer, resulting in release of hazardous materials	Piping failure is a credible accident and is evaluated in Section 5.1.
Piping Failure - Spray Release	Loss of containment during transfer, resulting in release of hazardous materials	A spray release is a credible accident and is evaluated in Section 5.2.
Loss of Leak Detection	Increased volume of waste released to the environment	Credit for leak detection is not being taken in the pipe failure analysis. The consequences associated with piping failure as analyzed are bounding.
Loss of Level Detection	Increased volume of waste released to the environment	Level detection (MBD) is performed by operators. Piping failure accident scenario considers failure of detection by first MBD (first hour) and shutdown of transfer on the second MBD (second hour).

Table 4-1. Summary of Safety Concerns. (4 sheets)

Hazard Evaluated	Potential Accidents	Safety Controls and Conclusions
Line Blockage	Increased potential for pipe failure due to increased pressure in transfer lines	Pipe failure due to line blockage is bound by previous piping failure consequences. A control has been established to ensure a saltwell screen is in place to minimize the amount of solids transferred.
Transfer of Aqueous Solution	Increased volume of released waste	The large volume of aqueous supernate is included in the piping failure analysis. The aqueous solution does not pose any additional safety concerns.
Flammable Gas Generation in 244-CR-003	Concentration of flammable gas in headspace leading to possible deflagration	Requirement of 0.14 m^3/min (5 cfm) flow through 244-CR-003 will ensure that the flammable gas concentration will remain below 0.06% of the LFL.
Remaining Organic in Transfer System after Transfer	Traces of organic causing potential flammable environment	Hazards evaluated in SARR-001, Supplement (Grigsby and Postma 1995), and Sections 5.3 and 5.4 of this analysis.
Pool Fire in DCRT	Fire resulting in dome pressurization, release of hazardous materials, and possible tank dome collapse	A pool fire in the DCRT is analyzed in Section 5.3.
Heat Generation Rate	Exceeding DST heat generation limits, localized boiling of liquid waste, release of hazardous materials	Heat generation rate in the aqueous phase of tank 241-C-103 is 38 W (129.5 Btu/hr) for ^{137}Cs and ^{90}Sr. This heat generation rate is negligible to the heat generation of a receiving DST.

Table 4-1. Summary of Safety Concerns. (4 sheets)

Hazard Evaluated	Potential Accidents	Safety Controls and Conclusions
Adequacy of Existing Ventilation System in DST	Loss of ventilation, flammable gas accumulation	All DSTs are actively ventilated. A control has been established to verify operability of receiving DST ventilation prior to transfer.
Pool Fire in DST	Fire resulting in dome pressurization, release of hazardous materials, and possible tank dome collapse	A pool fire in the receiving DST is analyzed in Section 5.4.
Flammable gas generation in a DST	Increased flammable gas generation in DST due to TOC increase due to transfer	Addition or organic layer does not affect the conclusions for worst case flammable gas generator DST

DCRT = double-contained receiver tank
DST = double-shell tank
LFL = lowere flammability limit
MBD = material balance discrepancy.

5.0 ANALYSIS RESULTS

5.1 RADIOLOGICAL CONSEQUENCE ANALYSIS

The analysis in this section contains the radiological consequences from evaluated accidents. The toxicological consequences are included in Appendix B.

5.2 PIPING FAILURE - TRANSFER LINE LEAK/BREAK

Waste transfer line leaks/breaks will result in the release of HLW liquid to the soil column and possibly to the soil surface. Humans could receive dose consequences from inhalation of airborne particles re-suspended from a surface pool, soil contamination and migration of leaked waste to ingestion sources, or direct radiation if they are in close proximity to the surface pool. The key assumptions for this piping failure analysis are summarized in Table 5-1.3.

5.2.1 Source Term

The source term activity concentrations for the following calculations utilized a maximum sample activity composite for SST liquids and solids. It was assumed that a maximum of one-third solids carryover could occur. The composite was created using the maximum activity concentrations for all of the nuclides found in the sample data for SST liquids (excluding 6 non-interim stabilized tanks [C-106, C-107, T-104, U-105, U-107, and U-109] and 1 interim stabilized tank [AX-102]), and SST solids (Savino 1994). The isotopes and quantities of the source term are summarized in Appendix D.

Waste transfer line leaks were determined to be anticipated, and potentially significant volumes of released waste were considered likely to reach the soil surface. A calculation was performed to conservatively determine the maximum volume of waste that could reach the soil surface if a transfer line failed.

5.2.1.1 Maximum Release Volume Due to Piping Failure. A control has been established that requires MBDs to be performed every hour. If a pipe ruptures directly after performance of a MBD, a leak could continue undetected for ≈1 hour. It is assumed, for the purpose of this analysis, that on the performance of the next MBD a leak is suspected, but no action (pumping stopped) is taken until performance of the following MBD (≈2 hours later). This limits the amount of waste leaked to two hours of continuous pumping at 378.5 L/min (100 gal/min).

$$378.5\ L/\text{min}\ (100\ gal/\text{min})\ x\ 120\ \text{min} = 45{,}424\ L\ (12{,}000\ gal)$$

The potential amount of waste in the transfer lines due to line holdup following the last transfer. Two scenarios provide different release volumes. The first scenario, a leak in the single-encased pipeline from tank 241-C-103 to the 244-CR DCRT contributes a volume corresponding to 140 m (460 ft). The second scenario, a pipeline leak/break between the 244-CR DCRT and the receiving DST could potentially provide a volume corresponding to ≈5,200 (1,585 m) of pipe. The source term remains the same for both scenarios, therefore only the bounding scenario needs to be evaluated. Obviously, the second scenario will result in the bounding release volume, as calculated below:

Release Volume:

$$5{,}280\ ft\ x \left[\pi\frac{(3.068\ in.)^2}{4}\right] x \left[1\ \frac{ft^2}{144}\ in^2\right] x \left(\frac{1\ L}{3.5315\ x\ 10^{-2}\ ft^3}\right)$$

This results in a total release volume of 53,100 L (14,028 gal).

5.2.1.2 Airborne Radiological Dose Consequences. The airborne (only) dose consequences for a waste transfer line leak that results in a waste surface pool of 53,100 L (14,028 gal) waste was calculated, for both an onsite (at 100 m [328 ft]) and an offsite receptor.

5.2.1.3 Composite Unit Liter Dose. A composite (2/3 liquids, 1/3 solids) concentration is calculated to account for carryover of solids. The liquids source term was taken to be the SST liquids (excluding 6 non-interim stabilized tanks and 1 interim stabilized tank) and SST solids (see Appendix D).

$$\text{Composite } ULD = [(2/3)\ x\ 1.1\ x\ 10^3\ Sv/L]$$

$$+ [(1/3)\ x\ 2.4\ x\ 10^5\ Sv/L]$$

$$\text{Composite ULD} = 8.1 \times 10^4 \text{ Sv/L}$$

5.2.1.4 Onsite Dose. For the onsite receptor, inhalation over a period of 8 hours (one shift) was considered. The Mishima (1993) ARRs of 4.0×10^{-6}/hour for the first hour and ARR of 3.6×10^{-7} for remainder of event duration will be used. The first hour assumes that the pool is entirely on the surface, with a 48 km/hr (30 mph) wind blowing across the top. The remaining time period assumes that the pool begins to soak into the soil, and the wind is blowing at 8 km/hr (5 mph). The assumption used to calculate the release rate (8-48 kph [5-30 mph]) is not consistent with the atmospheric dispersion coefficients (≈3.2 kph [2 mph]). This is conservative because the assumption of higher windspeeds results in higher release rates, while the lower wind speed used for dispersal results in greater downwind concentrations (i.e., less dispersion). The liters of respirable HLW released from a surface pool of 53,100 L (14,028 gal) are calculated as

Overall Airborne Release Rate

$$(4.0 \times 10^{-6}/hour \times 1\ hour) + (3.6 \times 10^{-7}/hour \times 7\ hours) = 6.52 \times 10^{-6}$$

5.2.1.5 Amount Respirable.

$$Q(L) = 53{,}100\ L \times 6.52 \times 10^{-6} = 0.35\ L\ respirable\ HLW$$

using

$$D(Sv) = Q(L) \times \chi/Q\ ft\ (s/m^3) \times R(m^3/s \times C\ (Sv/L)$$

where

D = Inhalation Dose (Sv)
Q = Amount Respirable (L)
χ/Q' = Atmospheric Dispersion Coeff. (onsite 8-hr release duration) ($6.51 \times 10^{-3}\ s/m^3$)
R = Breathing Rate (light activity) ($3.3 \times 10^{-4}\ m^3/s$)
C = Unit Liter Dose Concentration (8.1×10^4 Sv/L)

gives

$$D(Sv) = 0.35\ L \times 6.51 \times 10^{-3} \times 3.3 \times 10^{-4} \times 8.1 \times 10^{4}$$

or

$$D(Sv) = 6.1 \times 10^{-2}\ Sv = 6.1\ rem$$

5.2.1.6 Offsite Dose. For the offsite receptor, inhalation over a period of 24 hours was considered. The Mishima ARRs of 4.0×10^{-6}/hour for the first hour and ARR of 3.6×10^{-7}/hour for remainder of event duration will be used to calculate the liters or respirable HLW released from a surface pool of 53,100 L (14,028 gal).

5.2.1.7 Overall Airborne Release Rate.

$$(4.0 \times 10^{-6}/hour \times 1\ hour + (3.6 \times 10^{-7}/hour \times 23\ hours) = 1.228 \times 10^{-5}$$

Amount Respirable

$$Q(L) = 53{,}100\ L \times 1.228 \times 10^{-5} = 0.65\ L\ respirable\ HLW$$

using

$$D(Sv) = Q(L) \times \chi/Q'\ (s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

χ/Q' = Atmospheric Dispersion Coeff. (offsite 24-hr release duration) (3.29×10^{-6} s/m^3)
R = Breathing Rate (24-hr average) (2.7×10^{-4} m^3/s)

gives

$$D(Sv) = 0.65\ L \times 3.29 \times 10^{-6} \times 2.7 \times 10^{-4} \times 8.1 \times 10^{4}$$

or

$$D(Sv) = 4.7 \times 10^{-5}\ Sv = 4.7 \times 10^{-3}\ rem$$

5.2.1.8 Results. These results, considering airborne radiation dose consequences only, are summarized in the following table.

Table 5-1.1. Dose Consequences Due to Inhalation of Airborne Respirable Radionuclide Particles Resulting from Piping Break.

Onsite rem (EDE)	Offsite rem (EDE)
6.1 (6.1×10^{-2} Sv)	4.7×10^{-3} (4.7×10^{-5} Sv)

5.2.1.9 Direct Radiation (Gamma) Dose Consequences. Direct radiation dose consequences for a 53,100 L (14,028 gal) waste surface pool were calculated. Line-of-sight and sky-shine contributions were calculated using the MICROSHIELD and MICRSKYSHINE computer codes (Savino 1995, included as Appendix A).

The direct radiation dose rate from a 53,100 L (14,028 gal) pool size are calculated to be 4.6 x 10^{-3} Sv/hr (460 mR/hr). This value was obtained by ratioing the dose rate for a 64,352 L (17,000 gal) spill (5.603 x 10^{-3} 50 Sv/hr [560.3 mem/hr]) to 53,100 L (14,028 gal). This is valid because the dose rate is proportional to the spin volume when the source team activity concetrations are the same. At an 8-hour exposure duration, this equates to a direct radiation dose of. The inhalation consequences are calculated as follows:

Combining the airborne radiological dose consequences and the direct radiation doses will give the accident scenario combined dose consequences provided in the following table.

Table 5-1.2. Unmitigated Combined Dose Consequences Resulting from Transfer Line Leaks/Breaks; Using EDE Unit Doses.

Onsite dose rem (EDE)	Offsite dose rem (EDE)
6.1 (6.1 x 10^{-2} Sv) (Airborne)	4.7 x 10^{-3} (4.7 x 10^{-5} Sv) (Airborne)
3.7 (3.7 x 10^{-2} Sv) (Direct)	Insignificant (Direct)
9.8 (0.098 Sv) (Combined)	4.7 x 10^{-3} (4.7 x 10^{-5} Sv) (Combined)

5.2.1.10 Mitigated Dose Consequences. The results for an onsite receptor do not meet risk acceptance guidelines for Anticipated events. However, these results are conservative in that they assume the onsite receptor is exposed to the release for 8 hours. The accident scenario assumes that the release is discovered after 2 hours. Therefore, it is likely that the onsite receptor will evacuate and will not be exposed for the full 8 hours. As these results do not meet risk acceptance guidelines, mitigation of this event is required. Mitigation will be performed by limiting the flow rate through the pump to 38 L/min (10 gpm). This flow will be verified by use of a flow meter. A control has been established in Section 8 to represent this mitigation. In order to operate at flow rates higher than 38 L/min (10 gpm), means to minimize the amount of solids carryover will have to be analyzed. A 38 L/min (10 gpm) flowrate for 2 hours will yield a pool size of 12,220 L (3,228 gal) (including 9,464 L [2,500 gal] line holdup).

The direct radiation dose rate from a 12,220 L (3,228 gal) pool size are calculated to be 1.06 x 10^{-3} Sv/hr (106 mR/hr). This value was obtained by ratioing the dose rate for a 64,352 L (17,000 gal) spill (5.603 x 10^{-3} 50 Sv/hr [560.3 mem/hr]) to 12,220 L (3,228 gal). This is valid because the dose rate is proportional to the spin volume when the source team activity concetrations are the same. At an 8-hour exposure duration, this equates to a direct radiation dose of 0.8 x 10^{-2} Sv (0.8 rem). The inhalation consequences are calculated as follows:

5.2.1.11 Onsite Dose. The amount respirable can be calculated as follows:

Overall Airborne Release Rate:

$$(4.0 \times 10^{-6}/\text{hour} \times 1 \text{ hour}) + (3.6 \times 10^{-7}/\text{hour} \times 7 \text{ hours}) = 6.52 \times 10^{-6}$$

Amount Respirable:

$$Q(L) = 12{,}220 \text{ L} \times 6.52 \times 10^{-6} = 0.08 \text{ L respirable HLW}$$

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

D	=	Inhalation Dose (Sv)
Q	=	Amount Respirable (L)
χ/Q'	=	Atmospheric Dispersion Coeff. (onsite 8-hr release duration) (6.51 x 10^{-3} s/m^3)
R	=	Breathing Rate (light activity) (3.3 x 10^{-4} m^3/s)
C	=	Unit Liter Dose Concentration (8.1 x 10^4 Sv/L)

gives

$$D(Sv) = 0.08 \text{ L} \times 6.51 \times 10^{-3} \times 3.3 \times 10^{-4} \times 8.1 \times 10^4$$

or

$$D(Sv) = 1.4 \times 10^{-2} \text{ Sv} = 1.4 \text{ rem}$$

5.2.1.12 Offsite Dose. For the offsite receptor, inhalation over a period of 24 hours was considered. The ARRs of 4.0×10^{-6}/hour for the first hour and ARR of 3.6×10^{-7}/hour for remainder of event duration will be used to calculate the liters respirable HLW released from a surface pool of 12,220 L (3,220 gal).

Offsite Dose:

Overall Airborne Release Rate

$$(4.0 \times 10^{-6}/\text{hour} \times 1\ \text{hour}) + (3.6 \times 10^{-7}/\text{hour} \times 23\ \text{hours}) = 1.228 \times 10^{-5}$$

Amount Respirable:

$$Q(L) = 12{,}220\ L \times 1.228 \times 10^{-5} = 0.15\ L\ \text{respirable HLW}$$

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where:

χ/Q' = Atmospheric Dispersion Coeff. (offsite 24-hr release duration) (3.29×10^{-6} s/m^3)

R = Breathing Rate (24-hr average) (2.7×10^{-4} m^3/s)

gives:

$$D(Sv) = 0.15\ L \times 3.29 \times 10^{-6} \times 2.7 \times 10^{-4} \times 8.1 \times 10^{4}$$

or

$$D(Sv) = 1.0 \times 10^{-5}\ Sv = 1.0 \times 10^{-3}\ rem$$

Therefore, the combined mitigated radiation dose consequences for a transfer line leak/break ia summarized in the following table.

Table 5-1.3. Mitigated Combined Dose Consequences Resulting from Transfer Line Leaks/Breaks; Using EDE Unit Doses.

Onsite dose rem (EDE)	Offsite dose rem (EDE)
1.4 (1.4×10^{-2} Sv) (Airborne)	1.0×10^{-3} (1.0×10^{-5} Sv) (Airborne)
0.8 (0.8×10^{-2} Sv) (Direct)	Insignificant (Direct)
2.2 (2.2×10^{-2} Sv) (Combined)	1.0×10^{-3} (1.0×10^{-5} Sv) (Combined)

Both the onsite and offsite consequences are within risk-acceptance guidelines, as established in WHC-CM-4-46.

5.2.1.13 Key Assumptions Used in Analysis.

The key assumptions used in this analysis are provided in the following table.

Table 5-1.4 Key Assumptions for Transfer Line Leak/Break Analysis.

Source Term	Composite Unit Liter Dose Concentration (2/3 SST liquids, 1/3 SST solids)
Leak Duration	2 hours at 10 gpm.
Total Release Volume	12,220 L (3,228 gal)
Exposure Duration	Onsite - 8 hours Offsite - 24 hours
Mitigation Required	Transfer flow rate restricted to 38 L/min (10 gpm) MBDs performed hourly

5.3 PIPING FAILURE - SPRAY RELEASE IN PIT

The key assumptions for the spray release analysis are summarized in Table 5-2.1. The source term activity concentration for the spray release accident utilized a maximum sample activity composite of SST liquids and solids, as described above. The dose consequence results considered a double ended spray leak in the pit areas and transfer system pressure of 1.4×10^6 Pa (207 psi).

5.3.1 Radiological Consequences

An analysis of dose consequences to maximum onsite and offsite individuals, provided that cover blocks were in place, during spray release events was conducted.

Concrete cover blocks would significantly reduce the potential onsite and offsite dose consequences of spray leaks. With the cover blocks in place, the moist air inside the pit is displaced by the liquid accumulated inside the pit as the liquid is generated from the spray leak.

The flow rate of liquid through an orifice or nozzle is expressed by the following equation (Crane 1988), using the assumptions identified in Section 4.3.2.3

$$q = CA \times ((2g\Delta p)/\rho)^{1/2}$$

where

q	=	rate of flow (ft^3/s)
C	=	Flow coefficient, 0.6 for a very small diameter ratio of d/d_p
A	=	Area of orifice (d = 0.063 in; A = 2.16×10^{-5} ft^2)
g	=	Gravitational constant (32.2 ft/s^2)
Δ	=	Pressure difference across the orifice (207 lb/in^2)
ρ	=	Density of fluid (62.37 lbm/ft^3)

The rate of flow, q, is calculated to be:

$$q = 2.27 \times 10^{-3}\ ft^3/s = 3.86\ L/min\ (1.02\ gal/min)$$

For two holes, the rate of flow is calculated to be 7.72 L/min (2.04 gal/min).

For the source term it was first assumed that the spray leak continued and the air in the pit quickly became saturated; then, the volume of air displaced from the pit which contained respirable aerosols and was transported from the pit to the atmosphere, was equal to the spray leak rate; and finally, the air in the pit is saturated. The density of water vapor is 17.3 g/m^3 (1.08×10^{-3} lbm/ft^3) (*Handbook of Chemistry and Physics*, 4th Edition, 1965-1966). Thus, the quantity of displaced liquid per minute is:

$$2.04 \text{ gal/min} \times 17.3 \text{ g/m}^3 \times (1 \text{ m}^3/264.17 \text{ gal})$$

$$= 0.134 \text{ g/min}$$

This quantity of liquid per minute condensed from the vapor is equivalent to

$$0.134 \text{ g/min} \times 1 \text{ cm}^3/\text{g} \times 10^{-3} \text{ L/cm}^3 = 1.34 \times 10^{-4} \text{ L/min } (3.54 \times 10^{-5} \text{ gal/min})$$

It is assumed that this volume rate of condensed liquid contains the same concentration of radionuclides as the waste.

If it is also conservatively assumed that the respirable release fraction is 100%, a the onsite and offsite doses for a one-third SST solids and two-thirds SST liquids source term (as described in Section 5.1) can be calculated as

Consequences (The onsite receptor is subjected to an 8-hour exposure duration).

$$1.34 \times 10^{-4} \text{ L/min} \times 480 \text{ min} = 0.064 \text{ L } (0.017 \text{ gal})$$

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

Q	=	Amount Respirable (0.064 L)
χ/Q'	=	Atmospheric Dispersion Coeff. (onsite 8-hr release duration) (6.51×10^{-3} s/m^3)
R	=	Breathing Rate (light activity) (3.3×10^{-4} m^3/s)
C	=	Unit Liter Dose Concentration (8.1×10^4 Sv/L)

gives

$$D(Sv) = 0.064 \text{ L} \times 6.51 \times 10^{-3} \times 3.3 \times 10^{-4} \times 8.1 \times 10^4$$

or

$$D(Sv) = 1.11 \times 10^{-2}\ Sv = 1.11\ rem$$

Offsite Consequences (For the offsite receptor, inhalation over a period of 24 hours was considered)

$$Q(L) = 1.34 \times 10^{-4}\ L/min \times 1{,}440\ min$$
$$= 0.193\ L\ (0.051\ gal)$$

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

Q	=	Amount Respirable (0.129 L)
χ/Q'	=	Atmospheric Dispersion Coeff. (offsite 24-hr duration) ($3.29 \times 10^{-6}\ s/m^3$)
R	=	Breathing Rate ($2.7 \times 10^{-4}\ m^3/s$)
C	=	Unit Liter Dose Concentration (8.1×10^4 Sv/L)

gives

$$D(Sv) = 0.193\ L \times 3.29 \times 10^{-6}$$
$$\times 2.7 \times 10^{-4} \times 8.1 \times 10^4$$

or

$$D(Sv) = 1.39 \times 10^{-5}\ Sv = 1.39 \times 10^{-3}\ rem$$

The consequences for both the onsite and offsite receptors are within risk acceptance guidelines for "Anticipated" events as defined in WHC-CM-4-46, see Section 7.0.

5.3.1.1 Analysis Key Assumptions. The following table provides the key asseumptions for spray analysis.

Table 5-2.1 Key Assumptions for Spray Release Analysis.

Source Term	Composite Unit Liter Dose Concentration (2/3 SST liquids, 1/3 SST solids)
Release Duration	24 hours
Total Release Volume (over 16 hours)	0.129 L (0.034 gal)
Exposure Duration	Onsite - 8 hours Offsite - 24 hours
Mitigation Required	Cover blocks in place

5.4 POOL FIRE IN THE 244-CR-003 DCRT

Two solvent fire cases were evaluated for the 244-CR-003 DCRT. For both cases, the liquid level was assumed to be at the bottom of the cylindrical section so as to maximize the quantity of air (oxygen inventory) available to react with solvent, and thereby maximize the quantity of solvent that could burn. For the first case, best estimate fire parameters were used and in the second case an extreme fire spread velocity (2 cm/s) was used to maximize computed peak pressure. Key results of the analysis are summarized in Table 5-3.1.

Table 5-3.1. Results of Thermal Hydraulic Analysis of Postulated Solvent Fire in a DCRT

Fire Case Analyzed	Peak Pressure psig (Kpa)	Mass of Solvent Burned kg	Maximum Vacuum on Cooldown psig (kPa)	Fraction of Products Leaked (Grisgsby and Postma 1995)
Best-estimate Parameters	2.6 (17.9)	1.0	-1.5 (-10.3)	0.27
Conservative Parameters	6.6 (45.5)	1.1	-1.4 (-9.7)	0.31

5.4.1 Peak Pressure Tank Structural Limit

The DCRT is designed to hold a liquid level of 14 ft (4.27 m), which is equivalent to a hydrostatic pressure of 6.1 psig (42.1 kPa), in combination with an internal gas pressure of 0.5 psig (3.5 kPa). Thus at the bottom of the tank, the operating pressure is 6.1 + 0.5 = 6.6 psig (45.5 kPa). If we were to assume the worst case: that the tank was full (46 kPa [6.6 psi] hydrostatic) yet the tank had oxygen equivalent to the ground if it were empty, then a pool fire could potetially pressurize the DCRT to 92 kPa 13.2 psi) 46 kPa (hydrostatic) and 46 kPa (peak burn)). However, this pressure will not be reached as thereis not enough oxygen in the tank to burn the quantity of solvent required to reach this pressure. Pressure vessel calculations indicate that the tank willyield at an intenral pressure of ≈724 kPa (105 psi). Therefore, a large margin between predicted peak pressure and tank rupture clearly exists.

The DCRT is made from 0.25 in. thick, type 347 stainless steel. Wall heatup caused by a postulated solvent fire is predicted to be relatively minor because of the short duration (a few minutes or less) of the fire. Wall temperatures are predicted to peak at temperatures below 200°F and therefore no significant deleterious effect on the DCRT is expected.

5.4.1.1 Solvent Smoke Leaked. Smoke generated by a solvent fire amounts to ≈15% of the mass of liquid combusted (SARR-001, Supplement [Grigsby and Postma 1995]). Using the data of Table 5-3.1 the mass released through the vent line.

$$\text{smoke released} = 1.1 \text{ kg} \times 0.15 \times 0.31 = 0.051 \text{ kg}$$

for the worst case. This quantity is amall compared to the loading limit for a single 28.3 m^3/min (1,000 cfm) HEPA filter, which amounts to ≈1.8 kg (4.0 lbm). Therefore, the small quantity of smoke released is not expected to plug the filters in the ventilation system associated with the DST and very little fire aerosol would escape to the atmosphere.

5.4.1.2 Radiological Consequences. The quantity of smoke released from the tank to the secondary confinement zone (0.051 kg) is small compared to the quantities that were assumed to leak directly to the outside atmosphere for analyzed fires in SARR-001, Supplement (Grigsby and Postma 1995). Because consequences for the analyzed fire events were within guidelines, consequences for postulated fires in a DCRT would fall far below guideline limits.

5.5 POOL FIRE IN A DOUBLE-SHEET TANK

DSTs that may receive the solvent pumped from tank 241-C-103 have the same internal diameter as tank 241-C-103, but are greater in height and have a primary steel pressure boundary that is not present in SSTs. Key features of DSTs that are important in evaluating consequences of postulated pool fires include the following.

1. Static pressure limits are estimated to be ≈80 psig (July 1990) as compared to 14 psig for SSTs (July 1994).

2. Headspace air volumes are computed to be as large as 185,800 ft^3 (5,260 m^3), or roughly double the air volume in tank 241-C-103. This larger air volume would permit more solvent to burn before the oxygen extinguishment limit was reached.

3. The DSTs are vented through relatively large pipes (12 in nominal diameter), allowing significant venting of overpressure during a postulated fire.

Solvent fire consequences were evaluated for the tank currently having the largest headspace volume of any DST, tank 241-AP-104. This tank has very little waste (68 m^3) (Hanlon 1994) and therefore a large headspace air volume, estimated to be 185,800 ft^3 (5,260 m^3). The vent path was modeled as a 12-in. (30.5 cm), Schedule 40 pipe, made of 100 ft (30.5 m) of straight pipe with two 90° elbows. The equivalent length of the vent pipe was estimated to be 182 ft

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6.0 UNCERTAINTY AND CONSERVATISM IN THE ANALYSIS

6.1 PIPING FAILURE

6.1.1 Source Term

The first conservatism for the piping failure scenarios is the source term. The source term was derived by taking the maximum concentrations of each radionuclide found in the SST liquids, solids, and, in effect, depositing them into a SST (see Appendix D). The source term was composed of 1/3 SST solids and 2/3 SST liquids in order to account for solids carryover. The amount of solids carryover is very conservative, as sluicing operations for waste retrieval hope to achieve a solids carryover of 30%. This Super Tank source term does not accurately represent the waste contents of tank 241-C-103, but is extremely conservative. A more accurate representation of the consequences associated with a release of tank 241-C-103 liquid waste is achieved by using a tank 241-C-103-specific source term.

6.1.2 Maximum Release Volume

The amount of waste released in the piping failure scenario is also very conservative. The estimated lengths of the transfer pipelines introduces extreme conservatism. Each pipeline along the route from tank 241-C-103 to the 241-ER-153 diversion box was estimated to have a length greater than actual. From the diversion box the route is dependent on the receiving DST, so a cross-site pipeline length was used. This would encompass all of the possible transfer routes to a DST within the 200 East Area. In all likelihood, the receiving DST in the 200 East Area; therefore a cross-site transfer would not be necessary and the actual length of the pipeline would not significantly reduced.

6.1.3 Leak Detection

Credit for leak detection is not taken throughout the piping failure analyses. The reasoning for this is that the conductivity probes used in leak detection are incapable of detecting organic; however, the majority of the liquid to be transferred is aqueous supernate, which is capable of being detected by conductivity probes. It is unlikely that a maximum release volume leak along the double-encased piping could occur without detection.

6.1.4 Spray Release

The model used for the srray release is very conservative. More refined models are currently being developed. However, this spray release modelis considered conservative, and therefore acceptable, at this time.

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7.0 RISK ACCEPTANCE CRITERIA

Table 7-1 provides the risk-acceptance criteria found in WHC-M-4-46.

Table 7-1. Radiological Risk Acceptance Guidelines.

Frequency Category	Frequency Range	Effective Dose Equivalent (rem)	Organ Dose Equivalent for Lens of Eye (rem)	Organ Dose Equivalent for ALL Other Organs (rem)
Offsite Guidelines				
Anticipated	$1 - 10^{-2}$	0.01 - 0.5	0.03 - 1.5	0.1 - 5
Unlikely	$10^{-2} - 10^{-4}$	0.5 - 4	1.5 - 12	5 - 40
Extremely Unlikely	$10^{-4} - 10^{-6}$	4 - 25	12 - 75	40 - 250
Onsite Guidelines				
Anticipated	$0.1 - 10^{-2}$	1 - 5	3 - 15	10 - 50
Unlikely	$10^{-2} - 10^{-4}$	5 - 25	15 - 75	50 - 250
Extremely Unlikely	$10^{-4} - 10^{-6}$	25 - 100	75 - 300	250 - 1000

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8.0 CONTROLS AND INDUSTRIAL SAFETY PRECAUTIONS

The radiological and toxicological consequences to the maximum offsite individual were found to be below the risk-acceptance guidelines. The onsite radiological consequences for a leak or break from a single-encased pipeline are not acceptable when compared to the risk-acceptance guidelines. Controls are required to limit the volumes of potential transfer line leaks (by surveillance and/or flow rate constraints). See Sections 8.2.2 and 8.2.6.

8.1 GENERAL PROCESS CONTROLS

The following are the general process controls for interim stabilization of tank 241-C-103.

1. In the event that the riser is damaged as a result of dropped equipment, gas and vapor confinement is to be maintained by using a thick torus type gasket on the riser or by installing a temporary glove bag around the damaged riser until the riser can be repaired.

2. A reading for level of flammable gas concentration shall be taken before any tank intrusive activities are performed. If the concentration is ≤25% of the LFL, operations may proceed but if the concentration exceeds 25% of the LFL, a sample shall be taken in accordance with the *Tank Farm Health and Safety Plan* (Hewitt 1994).

3. A technician from the Industrial Hygiene, Safety, and Fire Protection Organization shall be present whenever a riser is open to enforce supplied fresh air requirements, provide guidance, and monitor for toxic gases, in accordance with the requirements of the *Tank Farm Health and Safety Plan* (Hewitt 1994).

4. All lifts of greater than 1.1 kN (250 lb) shall be treated as critical lifts. This requires additional operator training and rigging inspections as described in the *Hanford Site Hoisting and Rigging Manual* (DOE-RL 1993).

8.2 TRANSFER CONTROLS

The following are the transfer process controls for interim stablization of tank 241-C-103.

1. The transfer of waste from tank 241-C-103 must be routed through a saltwell screen prior to pump initiation.

2. The transfer rate will be limited to 38 L/min (10 gpm). This is be verified by utilization of a flow meter. This control is based on an assumption of 1/3 solids carry over. This control may be revised based on additional information on the actual amount of solids carry over achieved during transfer operations.

3. If the Floway pump is used, thermal overload protection must be added prior to transfer.

4. The current drawn by the pump motor is monitored for shutdown on a current drop of more than 50%, which would indicate a loss of pump suction.

5. Megger test is required on submersible pump prior to installation.

6. All coverblocks are in place on all facilities along the transfer route (including SST pump pits, valve pits, and DCRTs) before initiating pumping and no cover blocks are removed until pumping through the affected facility is shut down. Coverblocks are properly reinstalled after maintenance activities before pumping is resumed. Surveillance is mandated once within 72 hours prior to transfer, and once every 24 hours after transfer begins for permanent covers, or once every 12 hours for temporary covers.

7. Ensure that all leak detectors along the transfer route are operational prior to transferring waste.

8. Pressure testing of all direct buried transfer pipes is required prior to transfer.

9. MBDs are calculated at least hourly during waste transfer operations.

10. Installation of nonconductivity level measurement gauges into the 244-CR-003 DCRT and the receiving DST is required prior to transfer.

8.3 RECEIVING TANK CONTROLS (BOTH INTERMEDIARY AND DST)

The following are the receiving tank controls for interim stabilization of tank 241-C-103.

1. Watch List DSTs shall not be considered as receiver tanks.

2. DSTs must not exceed their maximum operating limits.

3. The separable organic phase is transferred to a DST with waste temperatures less than 74 °C (165 °F).

4. If the mean [TOC] is > 10 g/L (0.083 lbm/gal) at double-shell slurry feed composition, then the waste is transferred to a complexant waste receiver tank in accordance with the waste compatibility program.

5. If pH is adjusted in the DCRT, the ventilation flow through the tank is $\geq$ 0.14 m^3/min (5 cfm).

6. The active ventilation system is verified to be operable prior to any transfer operations to a DST.

9.0 CONCLUSIONS

Potential accidents and consequences for interim stabilization of tank 241-C-103 are bounded by the analyses presented in this safety analysis.

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APPENDIX A

DIRECT RADIATION DOSE CALCULATIONS

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APPENDIX A

DIRECT RADIATION DOSE CONSEQUENCES

Westinghouse Hanford Company — **Internal Memo**

From: Criticality & Radiological Analyses — 8M400-AVS-95-003
Phone: 376-8191 H4-64
Date: March 10, 1995
Subject: DIRECT RADIATION DOSE CALCULATIONS FOR WASTE TRANSFER SPILL ACCIDENTS AT TANK FARMS

To: G. R. Geschke H6-26

cc: N. J. Milliken H4-63
A. R. Ramble H4-64
J. C. Van Keuren H4-64
AVS/LB

A recalculation of the direct radiation doses for a Tank Farms waste transfer accident involving a spill of 17,000 gallons of Single Shell Tank (SST) supernate is provided as requested in Attachment 1. As indicated, the spill consisted of 2/3 SST Liquids A source term, and 1/3 SST Solids. The line-of-sight and sky-shine contributions are 70.4 and 490.0 mR/hr respectively, giving a total dose rate of approximately 560 mR/hr at 100 m. It is understood that these results will be used in a topical report concerning organic liquid layer removal and interim stabilization activities in Tank C-103.

Attachment 2 discusses the accident scenario, documents the calculation methods, and describes the MICROSHIELD and MICROSKYSHINE computer code models used to estimate the direct dose from the spills. Attachments 3 and 4 contain the computer code output files.

If you have any questions or need further assistance, please do not hesitate to call me at 376-8191.

A. V. Savino
Senior Engineer

ajg

Attachments 4

Concurrence: A. L. Ramble, Manager, Criticality & Radiological Analyses — Date 3/10/95

Attachment 1

From: G R (Ryan) Geschke at ~WHC276 1/31/95 2:49PM (1204 bytes: 26 ln)
To: Anthony V Savino at ~WHC46
cc: John C Van Keuren at ~WHC188, Alan L Ramble at ~WHC210, Nancy J Milliken at
~WHC150
Subject: Direct Radiation Doses
------------------------------- Message Contents

Tony,

Per our conversation earlier today:

Please arrange and schedule a recalculation of direct radiation doses for the SAR-065 Tank Farms waste transfer accidents involving:

1) A waste surface pool of 12,275 gallons of the new SST Liquids A source term.

These calculations are the same as previously done within your organization, with the revised source term, and are to be used for a topical report concerning organic liquid layer removal and interim stabilization activities in C-103.

The TPCN for this effort is N2E1G.

I understand that this effort may take through the end of the week.

If you have any questions, feel free to call.

Thanks,

Ryan

[1] From: G R (Ryan) Geschke at ~WHC276 2/2/95 11:53AM (1148 bytes: 21 ln)
To: Anthony V Savino at ~WHC46
cc: G R (Ryan) Geschke
Subject: Direct Radiation Dose Calc Change #2
------------------------------- Message Contents

Tony,

Please disregard the message sent to you earlier today. The correct volume to be calculated is given below.

I sent you a ccmail on 1/31/95, requesting a calculation of the direct radiation doses for a waste transfer accident involving a spill of SST supernate.

Since that time, it has been decided that changes involving the amount of the spill may also need to be evaluated. The calculations involving the 12,275 gal spill are still valid. A spill of 17,000 gallons is also a credible scenario, and I would like this evaluated to accompany the previous spill.

The source term remains SST Liquids A for both spills.

If you have any questions, feel free to call

Ryan G.
372-1744

Attachment 2

1.0 Gamma Ray Dose Rate Calculation for Waste Transfer Line Breaks

A postulated waste transfer line break results in a spill of radioactive material to the ground. Some of the spilled radioactive material becomes resuspended and transported downwind, which results in an inhalation dose to workers and the public. Workers are also exposed to direct radiation from the contaminated ground. This report addresses the calculation of the direct gamma-radiation dose rate for an onsite individual located 100 m from the edge of a 64,345 L (17,000 gal) supernate spill. Line-of-sight and sky-shine contributions were calculated using the MICROSHIELD and MICROSKYSHINE computer codes, respectively. Section 2.0 contains a description of the calculational methods used in MICROSHIELD and MICROSKYSHINE. Section 3 provides a description of the assumptions used to model the radioactive spill using these computer codes, and presents the results of these calculations.

2.0 Descripton of MICROSHIELD and MICROSKYSHINE Methods

2.1 MICROSHIELD Methods

MICROSHIELD Version 4 (Grove 1992) was used to calculate the line-of-sight dose rate. MICROSHIELD models the radioactive source as a group of differential point isotropic sources. It uses the point kernel method to estimate the contribution to the detector response from the each of the differential sources. The basic equation used by MICROSHIELD to describe the detector response (i.e., the dose rate) from a differential source is as follows:

$$D = \frac{S_o \, B \, e^{-\mu x}}{K \, 4 \, \pi \, x^2}$$

where, D is the dose rate from the differential source for gammas in a particular energy group, S_o is the source strength for that energy group (gammas/sec), B is the buildup factor, which is a function of the gamma energy, source and/or shield material, and the source to detector distance x, and K is the flux-to-dose conversion factor which is a function of the gamma energy.

MICROSHIELD numerically solves the above equation for each differential source and gamma energy group, and adds the contributions from these sources to obtain the overall detector response from the entire source. MICROSHIELD Version 4 uses buildup factors from ANSI-6.4.3 (ANSI 1991). Grove (1992) and its references provide further detail on the equations and methods used in MICROSHIELD Version 4 to calculate dose rates.

2.2 MICROSKYSHINE Methods

MICROSKYSHINE (Grove 1987) was used to calculate the skyshine dose rate. It calculates the gamma-ray skyshine radiation dose rates from point, monoenergetic, isotropic sources. The code uses line-beam response functions which give the absorbed dose rate in air as a function of distance from a point isotropic source emitting photons at angles up to 180 degress from the source-detector axis. Specifically, a point-kernel technique is used to compute the response functions for 12 source energies and 20 beam directions. The detector response accounts for direct scattering as well as contributions from annihilation photons which may also be generated as a result of pair production interactions if the photon (gamma) energy is greater than 1.02 MeV. To account for buildup of secondary photons as the photons travel from the source to the detector, the uncollided dose is multiplied by appropriate buildup factors. The total dose per photon at the detector is then calculated by integrating the direct scattering and annihilation photon contributions over energy, source to detector distance, and scattering angle. Total interaction coefficient data were taken from Hubbell (1982) and pair-production interaction coefficient data were taken from Storm and Israel (1967). The Klein-Nishina free-electron model was used for the differential scattering cross section (Chilton 1984). Buildup factors for air are approximated using the geometric-progression formulation described in Harima (1983). Grove (1987) and its references provide further detail on the equations and methods used in MICROSKYSHINE to calculate dose rates.

3.0 MICROSHIELD and MICROSKYSHINE Models used for the 17,000 gal Supernate Spill

This section addresses the modeling of the 17,000 gallon spill. The entire volume of the spill was assumed to soak the ground to a depth of one foot. However, the radioactivity was assumed to be uniformly distributed within the top five centimeters due to filtration of the supernate by the soil which results in the radioactive particles becoming attached to the soil particles (WHC 1992). In a previous study (WHC 1992) it was found that the soil porosity and the soil contamination depth have little effect on the computed dose rates because the activity is so close to the surface. The radius of the spill, which was assumed to be circular, is calculated using the following equation:

$$\text{Volume of Spill} = \pi \times R^2 \times H \times f_v$$

where, R (m) is the radius of the spill, H (m) is the assumed soaking depth of the spill (0.3048 m or 1 ft), and f_v is the soil porosity (0.3). Solving for the above equation for the spill radius results in the following equation:

$$R = \text{sqrt}\left\{ \frac{64.345\ m^3}{\pi \times 0.3048\ m \times 0.3} \right\}$$

where, the spill volume is 64,345 L (64.345 m^3). This results in a spill radius of 14.97 m.

The source term for the spill was assumed to consist of soil with a porosity of 30%, a soil density of 1.6 g/cc, and a supernate density of 1.0 g/cc. Since MICROSHIELD and MICROSKYSHINE do not include "dirt" in their material libraries, "dirt" is modeled as concrete (which is included in both code libraries) with a density of 1.6 g/cc. This has been found to be a reasonable approximation since the elemental composition of concrete and dirt are similar. Since the dirt occupies only 70% of the source volume, a density of 1.12 g/cc (1.6 g/cc x 0.7) was used for the dirt in the source term. The supernate is assumed to fill the void (30%) present in the soil. Therefore, the supernate in the source term was modeled as water with a density of 0.3 g/cc, since the supernate density is 1 g/cc and it fills 30% of the volume. The radionuclides for the source term were derived assuming a composite containing 2/3 of the "SST Liquids A," and 1/3 of the "SST Solids" maximum sample activity concentrations from Section 3.4.1.1 of SAR-065 (Milliken 1995). The activity concentrations for this mixture includes 4.0E10 Bq/L (1.0 Ci/L) of Cs-137, 1.8E8 Bq/L (4.9E-3 Ci/L) Co-60, 2.2E9 Bq/L (6.0E-2 Ci/L) of Eu-154 , and 2.1E6 Bq/L (5.7E-5 Ci/L) of Eu-155. The following summarizes the input used in the MICROSHIELD and MICROSKYSHINE models:

Source Term Model:

Activity: Cs-137 activity in the spill = 2.60E15 Bq (4.0E10 Bq/L x 64,345 L), which results in an activity of 2.5E15 Bq Ba-137m (Ba-137m is the Cs-137 daughter product). Similarly, there are activities of 1.1E13 Bq Co-60, 1.4E14 Bq Eu-154, and 1.4E11 Bq Eu-155.

Geometry: 14.97 m radius circular pool with a depth of 5 cm.

Material: Dirt (concrete) with a 1.12 g/cc density, and water with a 0.3 g/cc density.

Receptor: 1.5 m high receptor located 100 m from the nearest edge of the circular pool. The uncontaminated surrounding soil is modeled as dirt with a 1.6 g/cc density in MICROSHIELD. MICROSKYSHINE does not model the surrounding soil.

Integration Parameters: MICROSHIELD - the cylindrical source was divided into 16 radial, 16 circumferential, and 10 axial kernels or segments. MICROSKYSHINE - the cylindrical source was divided into 5 radial, 5 circumferential, and 5 axial kernels or segments.

The MICROSHIELD and MICROSKYSHINE code outputs are included in Attachments 3 and 4, respectively.

3.1 Line-of-Sight and Sky-shine Dose Rate Results for the 17,000 gal Supernate Spill

The calculated line-of-sight and sky-shine contributions were 70.4 and 490.0 mR/hr respectively, giving a total dose rate of approximately 560 mR/hr. The shielding effect of the surrounding uncontaminated soil and the oblique view angle of the receptor were accounted for in the MICROSHIELD model. In the MICROSKYSHINE model a wall with a small height (1.0 m) was required between the contaminated ground the edge of the spill. This wall was required to prevent the code from calculating direct line-of-sight dose contributions, since those dose contributions were accounted for in the MICROSHIELD model.

Note that these results are conservative in that the MICROSHIELD "line of sight dose rate" includes a dose rate contribution from air scatter through the buildup factors used, and the MICROSKYSHINE results also account for air scatter, although to a lesser extent for large angles of scatter. This "double counting" for the air scatter contribution to the direct dose rate was not easy to quantify, however, so the MICROSHIELD and MICROSKYSHINE results were considered to be additive.

5.0 References

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Attachment 3

MICROSHIELD OUTPUT

MicroShield 4.00 - Serial #4.00-00386

Westinghouse Hanford Co.

Page	: 1	File Ref:	________
DOS File:	SSTRYAN2.MS4	Date:	___/___/___
Run Date:	March 3, 1995	By:	________
Run Time:	7:29 p.m. Friday	Checked:	________
Duration:	0:01:52		

Case Title: 1/3 SST Liq A, 2/3 SST Sol Spill for C-103 - 17,000 gal

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and	inches
Dose point coordinate X:	11497.0	377.0	2.4
Dose point coordinate Y:	155.0	5.0	1.0
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	5.0	0.0	2.0
Cylinder radius:	1497.0	49.0	1.4
Side Clad:	10000.0	328.0	1.0

Source Volume: 3.52017e+7 cm^3   1243.14 cu ft.   2.14814e+6 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Transition Shield	Side Clad Shield
Air		0.00122	
Concrete	1.12		1.6
Water	0.3		

BUILDUP

Method: Buildup Factor Tables
The material reference is Transition

INTEGRATION PARAMETERS

	Quadrature Order
Radial	16
Circumferential	16
Axial (along Z)	10

SOURCE NUCLIDES

Nuclide	curies	microCi/cm^3	Nuclide	curies	microCi/cm^3
Ba-137m	6.7568e+004	1.9194e+003	Co-60	2.9730e+002	8.4455e+000
Eu-154	3.7838e+003	1.0749e+002	Eu-155	3.7838e+000	1.0749e-001

Page : 2
DOS File: SSTRYAN2.MS4
Run Date: March 3, 1995
Run Time: 7:29 p.m. Friday
Title : 1/3 SST Liq A, 2/3 SST Sol Spill for C-103 - 17,000 gal

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

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.1	5.668e+013	4.402e+000	1.259e+002	6.734e-003	1.926e-001
0.2	9.561e+012	3.064e+000	4.422e+001	5.408e-003	7.805e-002
0.4	9.988e+011	1.229e+000	8.879e+000	2.396e-003	1.730e-002
0.5	3.031e+011	5.740e-001	3.415e+000	1.127e-003	6.702e-003
0.6	2.261e+015	6.082e+003	3.111e+004	1.187e+001	6.073e+001
0.8	5.460e+013	2.556e+002	1.055e+003	4.861e-001	2.006e+000
1.0	5.407e+013	3.885e+002	1.384e+003	7.162e-001	2.551e+000
1.5	6.563e+013	1.023e+003	2.882e+003	1.721e+000	4.848e+000
TOTAL:	2.503e+015	7.758e+003	3.661e+004	1.481e+001	7.043e+001

Attachment 4

MICROSKYSHINE OUTPUT

MicroSkyshine
=============
(Criticality & Radiological Analyses - 1.16-007)

Page: 1	File Ref: ________
File: SSTRYAN2.SKY	Date: __/__/__
Run: 7:26 p.m.	By: ________
: March 3, 1995	Checked: ________

CASE: 2/3 SST Liq A, 1/3 SST Sol Spill for C103 - 17,000 gal

GEOMETRY: Vertical cylinder area source behind a wall

DIMENSIONS (meters):

Distance between wall and detector...........	X	99.
Depth of source behind wall..................	Y	1.
Offset of detector...........................	Z	0.
Depth of dose point..........................	H	-0.5
Distance between center of source and wall...	R1	15.97
Thickness of cover slab......................	T1	0.
Thickness of second shield...................	T2	0.
Radius of source.............................	W	14.97
Height of source.............................	L	0.05

INTEGRATION PARAMETERS:

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

MATERIAL DENSITIES (g/cc):

Ambient air: .0012

Material	Cover Slab	Lower Shield	Volume Source
Air			
Water			0.3
Concrete			1.12

Iron
Lead
Zirconium
Urania

Buildup factor based on: AIR.

Page 2

CASE: 2/3 SST Liq A, 1/3 SST Sol Spill for C103 - 17,000 gal

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies
Ba-137m	6.7568e+04	Co-60	2.9730e+02
Eu-154	3.7838e+03	Eu-155	3.7838e+00

RESULTS:

Group #	Energy (mev)	Activity (photons/sec)	Dose point rads/photon	Dose rate (mr/hr)
1	1.29	6.448e+13	4.528e-20	1.204e+01
2	1.04	5.147e+13	4.726e-20	1.003e+01
3	.78	5.575e+13	4.515e-20	1.038e+01
4	.66	2.261e+15	4.794e-20	4.469e+02
5	.45	1.009e+12	4.957e-20	2.062e-01
6	.40	2.932e+11	4.839e-20	5.850e-02
7	.24	9.243e+12	4.575e-20	1.744e+00
8	.20	3.180e+11	4.364e-20	5.724e-02
9	.12	5.668e+13	3.607e-20	8.430e+00
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	2.500e+15		4.899e+02

8M400-AVS-95-003

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: Internal Memo from A. V. Savino to G. R. Geschke, "DIRECT RADIATION DOSE CALCULATIONS FOR WASTE TRANSFER SPILL ACCIDENTS AT TANK FARMS," 8M400-AVS-95-001, dated March 6, 1995.

Scope of Review: Entire Document

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

J C Van Keuren   J C Van Keuren   3/10/95

Reviewer (Printed Name and Signature)   Date

Any notes and/or comments should be attached.

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APPENDIX B

TOXICOLOGICAL CONSEQUENCES

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APPENDIX B

TOXICOLOGICAL CONSEQUENCES

1.0 PIPING FAILURE - TRANSFER LINE LEAK/BREAK

The worst-case pipeline leak or break accident could potentially result in a surface pool of 64,352 L (17,000 gal) of waste liquid. Using an airborne release rate of 4.0×10^{-6}/h (1×10^{-9}/s), applicable for waste surface pools, and windspeeds to 13.4 m/s (30 mi/h) found in *Recommended Values and Technical Bases for Airborne Release Fraction, Airborne Release Rates, and Respirable Fractions for Materials from Accidents in DOE Fuel Cycles, Ex-Reactor Facilities* (Mishima 1993), the constant release rate for a waste surface pool of this size is

$$64{,}352 \text{ L} \times (1.0 \times 10^{-9}/\text{s}) = 6.4 \times 10^{-5} \text{ L/s}.$$

Windspeeds higher than 13.4 m/s (30 mi/h) result in greater atmospheric dispersion and are not expected to result in greater toxicological exposures.

The methodology used in WHC-SD-WM-SAR-011, *Hazard Identification and Evaluation for the D Cell Cerium Coverglass Replacement* (WHC 1994) is used to determine toxicological consequence acceptability. Values <1.0 that result from application of this methodology meet the toxicological risk-acceptance guidelines. The consequence for this accident scenario, assuming single-shell liquids waste and an accident frequency rate of $>1.0 \times 10^{-2}$ events/yr, is

$$6.4 \times 10^{-5} \text{ L/s} \times 1.0 \times 10^{4} = 0.64$$

for an maximum onsite individual and

$$6.4 \times 10^{-5} \text{ L/s} \times 6.3 = 4.0 \times 10^{-4}$$

for a maximum offsite individual.

Thus, the toxicological risk-acceptance guidelines are met.

2.0 PIPING FAILURE - SPRAY RELEASE IN PIT

A mitigated spray release from the waste transfer system, from a covered pump or valve pit, would result in a release of 6.4×10^{-2} L (1.7×10^{-2} gal) over an 8 hour period or 2.2×10^{-6} L/s at a constant release rate.

The methodology, as described in WHC-SD-WM-SAR-011, is used to determine toxicological consequence acceptability. Values <1.0 that result from application of this methodology meet the toxicological risk-acceptance guidelines. The consequence for this accident scenario, assuming single-shell liquids waste and an accident frequency rate of >1.0 x 10^{-2}/y is

$$(2.2 \times 10^{-6} \text{ L/s}) \times (1.0 \times 10^{4}) = 2.2 \times 10^{-2}$$

for a maximum onsite individual and

$$(2.2 \times 10^{-6} \text{ L/s}) \times (6.3) = 1.4 \times 10^{-5}$$

for a maximum offsite individual.

Thus, the toxicological risk-acceptance guidelines are met.

3.0 POOL FIRE IN DOUBLE-CONTAINED RECEIVER TANK

The quantity of smoke released from the tank to the secondary confinement zone (0.051 kg [0.11 lbm]) is small compared to the quantities that are assumed to leak directly to the outside atmosphere for analyzed fires in *Safety Analysis of Exothermic Reaction Hazards Associated With the Organic Liquid Layer in Tank 241-C-103*, WHC-SD-SARR-001, Supplement (WHC 1995). Because toxicological consequences for the analyzed fire events are within guidelines, the toxicological consequences for postulated fires in a double-contained receiver tank would fall far below guideline limits.

4.0 POOL FIRE IN DOUBLE-SHELL TANK

Toxicological consequences for double-shell tank solvent fires are predicted to fall beneath the guidelines as well. The combined concentrations of P_2O_5, CO, and NO_2 total 0.52 of guideline limits for an onsite receptor for postulated solvent fires in tank 241-C-103 (WHC 1995). Multiplying this value by 1.6 yields a combined exposure concentration that is 0.83 of the onsite exposure guideline. For offsite receptors, the combined exposure concentration is calculated to amount to $1.6 \times 9 \times 10^{-4} = 1.4 \times 10^{-3}$ of the guideline limit.

5.0 REFERENCES

Mishima, 1993, *Recommended Values and Technical Bases for Airborne Release Fraction, Airborne Release Rates, and Respirable Fractions for Materials from Accidents in DOE Fuel Cycles, Ex-Reactor Facilities*, DOE-DD-BK-0013-93, Westinghouse Hanford Company, Richland, Washington.

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APPENDIX C

DESIGN-BASIS EARTHQUAKE

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APPENDIX C

DESIGN-BASIS EARTHQUAKE

Two accident scenarios are analyzed in this appendix: a pipe rupture between tank 241-C-103 and the 244-CR-003 double-contained receiver tank resulting in a release of 5.7×10^5 L (1.5×10^5 gal) to the soil, and an unmitigated spray release. The spray release is assumed to occur for a period of 24 hours. This time duration is a general estimate for the response time to shut down the transfer pump if an earthquake were to occur.

1.0 PIPE RUPTURE BETWEEN 241-C-103 AND 244-CR-003

The pipe rupture between tank 241-C-103 and the double-contained receiver tank is a concern because it is possible that an earthquake occurs during a transfer, the transfer line breaks, and the pump remains pumping at its maximum flowrate. It is assumed that the entire liquid contents of tank 241-C-103 is leaked to the environment. This volume is estimated at 5.7×10^5 L (1.5×10^5 gal).

2.0 ONSITE DOSE CONSEQUENCES

The onsite receptor is assumed to be exposed to the spill for a maximum of 8 hours. Using the methodology established in Section 5.0 of the main document, the exposure is

$$(4.0 \times 10^{-6}/\text{hour} \cdot 1 \text{ hour}) + (3.6 \times 10^{-7}/\text{hour} \cdot 7 \text{ hours}) = 6.52 \times 10^{-6}$$

for an overall airborne release rate and

$$Q(L) = 5.7 \times 10^5 \text{ L} \times 6.52 \times 10^{-6} = 3.72 \text{ L respirable HLW}$$

for the amount respirable

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

D	=	inhalation dose (Sv)
Q	=	amount respirable (3.72 L)
χ/Q	=	atmospheric dispersion coeff. (onsite) (6.51×10^{-3} s/m^3)
R	=	breathing rate (light activity) (3.3×10^{-4} m^3/s)
C	=	unit liter dose concentration (8.1×10^4 Sv/L)

gives

$$D(Sv) = 3.72\ L \times 6.51 \times 10^{-3} \times 3.3 \times 10^{-4} \times 8.1 \times 10^{4}$$

or

$$D(Sv) = 0.65\ Sv = 65\ rem.$$

Because this dose consequence is well above the risk-acceptance guidelines for unlikely events, the direct radiation dose consequences need not be calculated.

3.0 OFFSITE DOSE

For the offsite receptor, inhalation over a period of 24 hours is considered. Using the methodology described in Section 5.0, the exposure is

$$(4.0 \times 10^{-6}/\text{hour} \cdot 1\ \text{hour}) + (3.6 \times 10^{-7}/\text{hour} \cdot 23\ \text{hours}) = 1.2 \times 10^{-5}$$

for the overall airborne release rate and

$$Q(L) = 5.7 \times 10^{5}\ L \times 1.2 \times 10^{-5} = 6.84\ L\ \text{respirable HLW}$$

for the amount respirable

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

χ/Q = atmospheric dispersion coeff. (offsite) (3.29×10^{-6} s/m^3)
R = breathing rate (offsite) (2.7×10^{-4} m^3/s)

gives

$$D(Sv) = 6.84\ L \times 3.29 \times 10^{-6} \times 2.7 \times 10^{-4} \times 8.1 \times 10^{4}$$

or

$$D(Sv) = 4.9 \times 10^{-4} \text{ Sv} = 0.049 \text{ rem.}$$

The inhalation dose consequences for the offsite receptor are acceptable. The direct radiation dose consequences are deemed insignificant (Section 5.0) due to the distance of the offsite receptor from the spill. The time required to reach an offsite exposure of 5 x 10^{-3} Sv 0.5 mrem) is approximately 3.9 years.

4.0 SPRAY RELEASE FROM TRANSFER SYSTEM

This accident postulates that a design-basis earthquake occurs during pumping operations and a spray leak develops in a pit. It is assumed that the pumping operation continues and credit for the cover blocks can no longer be taken. The duration of this accident is assumed to be 24 hours before a response team can shut down the transfer pump.

It is assumed that there are two 0.16 cm (0.063 in) holes in the transfer pipe, and that the pressure is 1.4 x 10^{6} Pa (207 psi). As calculated in Section 5.3, the amount of liquid released per minute is 7.72 L/min (2.04 gal/min). The onsite receptor is assumed to be exposed for 8 hours, and the offsite for 24 hours.

5.0 ONSITE CONSEQUENCES

For the onsite consequences, the amount respirable is

$$7.72 \text{ L/min} \times 480 \text{ min} = 3{,}705.6 \text{ L (979 gal)}$$

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

Q	=	amount respirable (3,705.6 L)
χ/Q	=	atmospheric dispersion coeff. (onsite 8-hr release duration) (6.51 x 10^{-3} s/m^3)
R	=	breathing rate (light activity) (3.3 x 10^{-4} m^3/s)
C	=	unit liter dose concentration (8.1 x 10^{4} Sv/L)

gives

$$D(Sv) = 3{,}705.6\ L \times 6.51 \times 10^{-3} \times 3.3 \times 10^{-4} \times 8.1 \times 10^{4}$$

or

$$D(Sv) = 645\ Sv = 64{,}500\ rem.$$

6.0 OFFSITE CONSEQUENCES

The offsite receptor is exposed to the event for 24 hours. The amount respirable is

$$7.72\ L/min \times 1440\ min = 11{,}117\ L\ (2{,}937\ gal)$$

using

$$D(Sv) = Q(L) \times \chi/Q'(s/m^3) \times R(m^3/s) \times C(Sv/L)$$

where

Q = amount respirable (11,117 L)
χ/Q = atmospheric dispersion coeff. (offsite 24-hr release duration) ($3.29 \times 10^{-6}\ s/m^3$)
R = breathing rate (24-hr average) ($2.7 \times 10^{-4}\ m^3/s$)
C = unit liter dose concentration (8.1×10^{4} Sv/L)

gives

$$D(Sv) = 11{,}117\ L \times 3.29 \times 10^{-6} \times 2.7 \times 10^{-4} \times 8.1 \times 10^{4}$$

or

$$D(Sv) = 0.8\ Sv = 80\ rem.$$

7.0 ACCIDENT FREQUENCY

The frequency of a design-basis earthquake (Safety Class 2 and 3) is estimated at 1×10^{-3}/yr. The maximum pumping duration (assuming 11.4 L/min [3 gpm] flow from tank 241-C-103 to DCRT and 76 L/min [20 gpm] flow from double-contained receiver tank to double-shell tank) is calculated as 960 hours. This results in a total time of 1.1×10^{-1} years. No credit is taken for equipment with a safety class greater than 3; therefore, all equipment is expected to fail in the worst case. The probability of an earthquake during pumping is determined to be 1.1×10^{-4}. Therefore, the frequency for this event falls between the Unlikely and Extremely Unlikely categories, as established by WHC-CM-4-46. This frequency value is conservative because it assumes the longest possible pumping duration. If a submersible pump is used throughout the system (38 L/min [20 gpm]), the pumping duration is reduced to 250 hours, or 2.85 x 10^{-2} years. The probability of an earthquake during pumping would then become 2.85 x 10^{-5}, or Extremely Unlikely.

The above dose consequences are also very conservative. It is not expected that pumping would continue until all of the liquid contents from tank 241-C-103 are released. Both accidents assure that the pump sustains the seismic event and continues to operate while the piping fails. Also, the source term in the spray release scenario includes a 33.3% carryover of solids. The offsite consequences associated with a liquid-only source term are calculated as 0.011 Sv (1.1 rem).

A design-basis earthquake would likely result in a breach of a transfer line as compared to a small diameter hole. Therefore, it is more probable that a surface pool would be released to the environment than a spray release. The onsite consequences assume that the onsite receptor is exposed for an 8 hour duration. Onsite personnel are likely to evacuate, thus greatly reducing their exposure time.

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APPENDIX D

SOURCE TERM ISOTOPES AND QUANTITIES

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APPENDIX D

SOURCE TERM ISOTOPES AND QUANTITIES

Table D-1 Accident Source Term Unit-Liter-Dose Values (2 sheets)
(Based on Maximum Sample Activity Composite Source Terms)

Nuclide	Nuclide Dose Contributions and ULD for Composites, Sv per liter inhaled (Davis 1994)	
	SST Liquids[a]	SST Solids
^{14}C	5.9×10^{-5}	7.0×10^{-5}
^{60}Co	5.3×10^{-2}	3.1×10^{1}
^{79}Se	0.0	4.5×10^{-5}
^{90}Sr	1.5×10^{2}	1.1×10^{5}
^{90}Y	5.2	3.9×10^{3}
^{99}Tc	4.7×10^{-3}	3.4
^{106}Ru	4.3×10^{-4}	3.1×10^{-2}
^{125}Sb	1.8×10^{-4}	9.2×10^{-1}
^{129}I	4.7×10^{-4}	3.0×10^{-1}
^{134}Cs	1.6×10^{-3}	3.2×10^{-2}
^{137}Cs	2.0×10^{2}	6.5×10^{2}
^{144}Ce	4.3×10^{-6}	1.6×10^{-4}
^{147}Pm	0.0	0.0
^{154}Eu	4.0	5.1×10^{2}
^{237}Np	0.0	4.7×10^{3}
^{238}Pu	9.8	2.0×10^{4}
^{239}Pu[b]	6.7×10^{2}	5.2×10^{4}
^{241}Pu	1.0×10^{2}	7.8×10^{3}
^{241}Am	9.6	4.4×10^{4}
^{242}Cm	0.0	0.0
^{244}Cm	0.0	0.0
^{155}Eu	0.0	7.1×10^{-2}
ULD[c]	1.1×10^{3}	2.4×10^{5}

NOTE: 1 Sv = 1.0×10^{2} rem
[a]SST liquids excluding six noninterim stabilized tanks (C-106, C-107, T-104, U-105, U-107, U-109).
[b]The ^{239}Pu nuclide contribution also includes ^{240}Pu.
[c]ULD values are given for each composite in terms of committed effective dose equivalent (Sv) per unit-liter of waste inhaled at the location of the maximum onsite/offsite individual.

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