ENCLOSURE 4

SHINE MEDICAL TECHNOLOGIES, LLC

SHINE MEDICAL TECHNOLOGIES, LLC OPERATING LICENSE APPLICATION RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION AND SUPPLEMENT NO. 7

FINAL SAFETY ANALYSIS REPORT CHANGE SUMMARY PUBLIC VERSION

Summary Description of Changes	**FSAR Impacts**
Administrative corrections, including correction of inconsistencies, cross references, and typographical errors.	Table 2.4-7, Section 4a2.2, Section 9a2.1, Section 9b.7, Section 13b.1
Update to remove uranium concentration instrumentation in the radioactive liquid waste storage (RLWS) system.	Section 9b.7
Update to clarify byproduct material quantities associated with the molybdenum extraction and purification system (MEPS) and iodine and xenon purification and packaging (IXP) system.	Section 9b.5
Update to clarify that major target solution vessel (TSV) off-gas system (TOGS) components are made of austenitic stainless steel.	Section 4a2.8
Update to remove the light water pool liner leak chase and associated leak chase detection system.	Section 2.4, Section 4a2.4, Section 7.3, Section 13a2.1
Update to replace target solution preparation system (TSPS) uranyl sulfate dissolution tank mechanical agitators with recirculation lines to provide tank mixing.	Figure 4b.4-3, Section 6b.3
Update to replace vacuum transfer system (VTS) knockout pot vacuum relief valves with actuated valves, consistent with engineered safety features actuation system (ESFAS) described functions.	Figure 9b.2-1
Update to correct facility nitrogen handling system (FNHS) interfaces with TSPS, primary closed loop cooling system (PCLS), target solution storage system (TSSS), quality control and analytical testing laboratories (LABS), IXP, VTS, radioactive drain system (RDS), and production facility biological shield (PFBS).	Table 4b.4-3, Table 5a2.2-3, Table 9b.5-1, Section 9b.7, Table 9b.7-4, Table 9b.7-5
Update to incorporate MEPS pneumatically driven pumps.	Table 4b.3-1, Section 9b.7, Table 9b.7-5, Figure 9b.7-6
Update to the arrangement drawing to reflect configuration changes (e.g., door between battery rooms and uninterruptible power supply system [UPSS] rooms, electrical equipment room door, and removal of radiologically controlled area [RCA] designation).	Figure 1.3-1

Summary Description of Changes	FSAR Impacts
Update to correct an inconsistency related to VTS transfers.	Table 9b.2-1
Update to clarify gas monitoring functions of the process vessel vent system (PVVS).	Section 9b.6
Update to tritium purification system (TPS) configuration, including isolation valve types.	Section 7.5, Table 7.5-2, Figure 7.5-1, Figure 9a2.7-1
Update to radiation dose estimates for irradiation unit (IU) cell walls to reflect calculation update.	Section 4a2.5
Update to the supercell shielding, supercell process description, and supercell confinement description to reflect PFBS design progression.	Section 4b.1, Section 4b.2, Figure 4b.2-2, Figure 4b.2-4, Section 6b.1
Update to decommissioning cost estimate to reflect calculation update.	Section 15.3
Update to correct inconsistencies in the nomenclature for radiation monitors.	Section 7.4, Section 7.5, Table 7.5-1, Table 7.7-1, Section 9a2.1, Section 13a2.1, Section 13a2.2, Section 13b.1, Section 13b.2
Update to the facility demineralized water system (FDWS) configuration to reflect design progression.	Section 5a2.6, Table 5a2.6-2, Figure 5a2.6-1
Update to PCLS configuration, including impacts associated with the deionizer bed and temperature element.	Figure 5a2.2-1, Section 5a2.5
Update to correct the instrument range and clarify the function of TPS tritium monitors.	Table 7.5-1, Section 9a2.7
Update to correct inconsistent RCA descriptions.	Section 1.2, Section 1.3, Figure 1.3-1, Section 4b.4, Table 4b.4-1, Section 9a2.5, Section 9b.5
Update to process integrated control system (PICS) functions related to supercell valve position indication to reflect available component functionality.	Section 7.3

A markup of FSAR changes is provided as Attachment 1.

ENCLOSURE 4
ATTACHMENT 1

SHINE MEDICAL TECHNOLOGIES, LLC

SHINE MEDICAL TECHNOLOGIES, LLC OPERATING LICENSE APPLICATION
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION AND SUPPLEMENT NO. 7

FINAL SAFETY ANALYSIS REPORT CHANGE SUMMARY
PUBLIC VERSION

FINAL SAFETY ANALYSIS REPORT MARKUP

87 pages follow

1.2 SUMMARY AND CONCLUSIONS ON PRINCIPAL SAFETY CONSIDERATIONS

This section identifies safety criteria, principal safety considerations and conclusions for the SHINE facility structures, systems, and components (SSCs). The purpose of the safety criteria for the SHINE facility is to limit adverse effects on the public and workers due to operation of the facility. These criteria are assured by designing, constructing, and operating the plant such that safety-related SSCs remain functional during normal conditions and during and following design basis events.

The accident analysis uses the most conservative operational condition or operating mode to determine potential radiological consequences. See Chapter 13 for a description of the accident analysis for the SHINE facility. Section 4a2.6 and Section 7.3 provide a description of operating modes of the irradiation unit.

1.2.1 CONSEQUENCES FROM THE OPERATION AND USE OF THE FACILITY

The primary consequences resulting from the operation of the SHINE facility are radiological. The SHINE facility produces molybdenum-99 (Mo-99) and other medical isotopes from irradiation of low enriched uranium (LEU). Within the irradiation facility (IF), the LEU in the target solution is in the form of a uranyl sulfate. In the irradiation units (IUs), the target solution is irradiated in a subcritical assembly by neutrons produced by a fusion neutron source. The irradiated target solution is then processed in the radioisotope production facility (RPF) to extract and purify the Mo-99 and other medical isotopes. Radioactive waste materials are processed and/or converted to solid wastes for shipment to off-site disposal facilities. The main production facility is designed to be a zero radioactive liquid effluent discharge facility as described in Section 11.1.

The IF and RPF within the main production facility ~~constitute the radiologically controlled area (RCA) (see~~are identified on Figure 1.3-1~~)~~. Radioactive materials are primarily present in the following locations within the SHINE facility buildings:

- Main production facility - IF
  - IU cells
  - Target solution vessel (TSV) off-gas shielded cells
  - Tritium purification system (TPS) area
  - Radiologically controlled area (RCA) ventilation equipment areas

- Main production facility - RPF
  - Target solution preparation and storage areas
  - Supercell
  - Target solution hold tanks
  - Carbon delay beds
  - Radioactive liquid waste storage tanks
  - Radioactive liquid waste immobilization (RLWI) shielded cell
  - Labs and storage rooms

- Main production facility - other areas
  - Shipping and receiving area

- Material staging building

1.3 GENERAL DESCRIPTION OF THE FACILITY

The SHINE main production facility consists of an irradiation facility (IF), radioisotope production facility (RPF), shipping and receiving area, and other areas that contain various support systems and equipment. General arrangement floor plan and section drawings of the facility showing the layout of major structures are provided in Figures 1.3-1 and 1.3-2. The SHINE facility site overview is provided in Figure 1.3-3.~~ The radiologically controlled area (RCA) of the main production facility consists of the IF and the RPF (see Figure 1.3-1).~~

1.3.1 GEOGRAPHICAL LOCATION

The SHINE facility is located on the south side of the City of Janesville corporate boundaries, in Rock County, Wisconsin. Geographical coordinates of the SHINE site are provided in Section 2.1.

1.3.2 PRINCIPAL CHARACTERISTICS OF THE SITE

The SHINE site consists of a previously undeveloped, approximately 91-acre (ac.) (36.8-hectare [ha]) parcel that has been historically farmed. Safety-related structures are located within a rectangular area located near the center of the property. The region of the SHINE site is entirely contained within Rock County, Wisconsin. The dominant land use in the region is agricultural/cultivated crops. The northern limits of the City of Beloit are located approximately 3.7 miles (mi.) (6.0 kilometers [km]) to the south. Principal characteristics of the site are further described in Chapter 2.

1.3.3 PRINCIPAL DESIGN CRITERIA, OPERATING CHARACTERISTICS, AND SAFETY SYSTEMS

The SHINE facility is licensed under 10 CFR 50. Classifications of systems, structure, and components (SSCs) of the SHINE facility are described in Section 3.1.

1.3.3.1 Principal Design Criteria

Principal design criteria for the facility are described in Section 3.1.

1.3.3.2 Operating Characteristics

The irradiation units (IUs) are operated in a batch mode with an approximate week-long operating cycle. An operating cycle includes the following steps:

- target solution transfer from the RPF to the target solution vessel (TSV),
- irradiation in the subcritical assembly for approximately 5.5 days,
- shut down, and
- transfer of the irradiated target solution to the RPF for isotope extraction.

During the irradiation in the subcritical assembly system, the target solution is maintained in a subcritical state. Operating characteristics of the IUs, including power level, are discussed in more detail in Chapter 4a2.

Figure 1.3-1 – Main Production Facility Building General Arrangement

2.4 HYDROLOGY

NUREG-1537 requires an assessment of applicable hydrologic, hydrogeologic, and solute transport risks to nuclear facilities, both during operation and post-closure. Surface water (i.e., hydrologic flows) related to rivers and streams that may impact the site are addressed herein. Stormwater runoff at the site scale is addressed under separate studies. The purpose of this chapter is to identify hydrological processes that could contribute to radioactive releases, and to characterize the parameters that describe those processes.

This section was prepared using available information including 12 months of groundwater elevation data. The elevations in this section are reported according to the North American Vertical Datum of 1988 (NAVD 88).

NUREG-1537 states that the facility design must consider leakage or loss of primary coolant to groundwater. The light water pool (LWP) provides decay heat removal from the target solution within the target solution vessel (TSV) dump tank during normal operations and extended periods of shutdown. ~~A primary coolant spill is not a credible scenario, as described in Section 3.3; however, small leakage is credible. The light water pool is designed with a leak chase to collect to enable the detection and collection of small leaks of the pool to prevent releases to groundwater. The light water pool leak chase system directs the collected leakage to a central point for monitoring.~~

The LWP is designed to mitigate the potential for leakage. The LWP stainless steel liner is closely inspected and monitored during fabrication and installation. Liner welds are inspected to ensure leak-tightness of the LWP. Liner materials are selected for corrosion resistance. There are no failure mechanisms that would degrade the liner welds in the future as there is no significant thermal cycling/fatigue, corrosion, or pressure that could initiate a leak.

Additionally, leakage of primary cooling water is credible from the primary closed loop cooling system (PCLS). Instrumentation identifies and quantifies leakage rates, including very small leaks, from the PCLS. The facility structure (FSTR) provides barriers at ground level exits, steel liners and drip pans in vaults and trenches, and water stops in construction joints below grade to prevent the release of potentially contaminated water to the environment and groundwater. Therefore, leaks in the PCLS do not result a release of primary cooling water outside of the radiologically controlled area.

The facility design provides for confinement of radioactive materials, as described in Chapter 6, and Chapter 13 describes the mitigation of loss of system integrity events. Additionally, the facility has a sanitary drains water management system that confines the postulated maximum discharge of water in the radiologically controlled area (RCA), such as from a fire system discharge, which prevents potentially contaminated water from reaching the groundwater. A radioactive drain system (RDS) also provides capture and confinement of radioactive liquids from postulated leakage or overflow events. Therefore, the required spill scenario would consider the effects of accidental releases of unspecified liquid effluents in groundwater.

2.4.1 HYDROLOGICAL DESCRIPTION

This subsection identifies the site surface water, groundwater aquifers, types of on-site groundwater use, sources of recharge, present known withdrawals and likely future withdrawals, flow rates, travel time, gradients, and other properties that affect movement of accidental

Table 2.4-7 – 100-Year ~~PMP~~Rainfall Event Values and Intensities at the SHINE Site[a]

~~PMP~~Rainfall Duration (minutes)	5	15	30	60	120	180	360	720	1440
~~PMP~~Rainfall Value (inches)	0.67	1.5	2.25	3	3.8	4.5	4.8	5.4	6
~~PMP~~Rainfall intensity (inches/hr)	8	6	4.5	3	1.9	1.5	0.8	0.45	0.25

a) The values presented in this table are used for determination of water levels at the safety-related structure resulting from the ~~local PMP~~design basis rainfall event.

Reference: Figure 2.4-10, ~~PMP~~ Rainfall Intensity-Duration-Frequency Curve.

The bounding TSV evaporation rate was calculated to be 59 lb./hr (27 kilograms per hour [kg/hr]) by assuming the following conditions:

- TOGS sweep gas supply temperature to the TSV: 77°F (25°C)
- TOGS sweep gas supply flow rate to the TSV: [ ]PROP/ECI
- TOGS sweep gas supply relative humidity: 0 percent
- TSV target solution temperature: 194°F (90°C)
- TSV headspace pressure: 10 pounds per square inch absolute (psia) (70 kPa absolute)

The bounding steady-state condensate return rate to the TSV from the recombination of hydrogen and oxygen is approximately 2.7 lbm/hr (1.2 kg/hr).

A detailed description of the TOGS can be found in Section 4a2.8.

4a2.2.1.6 TSV Operating Conditions

The normal operating conditions of the target solution in the TSV are approximately 68°F to 140°F~~)~~ (20°C to 60°C) and approximately -1 pounds per square inch gauge (psig) (-10 kPa gauge). Section 4a2.8 provides a detailed description of the TOGS operating conditions. Operating specification limits of the target solution are provided in Table 4a2.2-2.

During startup, the TSV temperature is approximately the same temperature as the primary closed loop cooling system (PCLS) due to the small amount of decay heat generation in the target solution and the negligible fission power generated during startup. The TSV and target solution are approximately the same temperature as the outlet temperature of the PCLS, nominally 68°F (20°C). The temperature control of the PCLS outlet temperature is within +/- 9°F (5°C). Therefore, the temperature of the TSV is nominally 68°F +/- 9°F (20°C +/- 5°C).

There is no mechanical mixing in the TSV. The target solution is mixed using natural convection and bubbling during irradiation. The highest heat generation occurs near the center of the solution and the TSV walls are cooled by the PCLS, creating an upward target solution flow through the center of the TSV with downward target solution flow along the walls. Non-uniformities exist in the power distribution in the TSV, void fraction within the TSV, and temperatures within the TSV. There are no expected non-uniformities in the chemical species that significantly affect reactivity. The non-uniformities above do not affect the operating limits for the target solution.

The temperature of the target solution rises from room temperature (approximately 68°F [20°C]) to approximately 122°F (50°C) during full-power irradiation. The pressure in the headspace of the TSV ranges from -2 to 0 psig (-13.8 to 0 kPa gauge) and is regulated by TOGS.

Fission product precipitation out of the target solution is small, and bounding values are described in Table 4a2.2-1. The potential precipitation has an insignificant effect on reactivity in the TSV. This precipitation may be filtered out during processing in the molybdenum extraction and purification system (MEPS) by the frits and extraction media in the extraction column.

There are no significant pH changes expected during irradiation.

The bulk void fraction within the target solution is expected to be less than 5 percent. The target solution has a negative void coefficient and increases in void lead to lower power in the TSV.

- Test coupons are located inside the TSV to verify the corrosion rate and material mechanical properties are acceptable. The test coupons are removable through an inspection opening.

4a2.4.2 LIGHT WATER POOL

4a2.4.2.1 Design of Light Water Pool

The light water pool is a concrete structure, lined with stainless steel, which is designed to withstand design basis events without the loss of liner integrity that could compromise the water retention capability of the liner. The pool is approximately 13.5 ft. x 13.5 ft. x 15 ft. deep (4.1 m x 4.1 m x 4.6 m deep). The pool volume is approximately 19,000 gallons (gal.) (72,000 liters [l]) of water. The concrete structure forming the pool and the pool liner are designed as Seismic Category I and remain functional after the design basis earthquake.

The light water pool is designed to mitigate the potential for leakage. The light water pool liner is formed by stainless steel plates welded to embed plates installed flush with the walls and floor of the concrete structure. The embed plates are attached to the concrete by concrete anchors and are supported by the safety-related reinforced concrete structure. ~~Welds that penetrate through the liner wall are monitored for leakage by the leak chase system, and the leak chase system is leak tested prior to operation of the IU cell.~~The safety-related concrete structure provides a rigid structural support for the liner during normal operation and seismic events to minimize potential stress on the liner. The stainless steel liner is closely inspected and monitored during fabrication and installation. ~~-~~The fabrication of the liner includes inspection to ensure the welds are relatively smooth and free of significant pits and crevices where accumulation of fission or activation products could occur. Liner welds are inspected to ensure leak-tightness of the light water pool and liner materials are selected for corrosion resistance. There are no identified failure mechanisms that would degrade the liner welds as there is no significant thermal cycling/fatigue, corrosion, or pressure that could initiate a leak. Based on these design features, leakage to the environment is not expected.

The light water pool has minimum acceptable water levels that are assumed for safety analysis accident scenarios for normal operation and for loss of cooling conditions. The minimum acceptable water levels for normal operation provides adequate radiological shielding and equipment cooling for TSV operation at the licensed power limit. The minimum acceptable water level for loss of cooling conditions allows for adequate heat removal from the target solution after the loss of forced cooling. Piping penetrations through the light water pool liner are either above the minimum acceptable water level in the pool or a specific evaluation is performed to determine the potential for loss of pool water through the penetration. Piping penetrations into the light water pool with the potential for siphoning below the minimum acceptable water level contain anti-siphon devices or other means to prevent inadvertent loss of pool water. ~~Should a leak in the liner develop, a leak chase system is incorporated into the design to provide indication that a leak is occurring, to capture the lost liquid to prevent release to the environment, and to ensure that the leak is less than the allowable leakage rate for the liner.~~

Under normal operating conditions, the target solution does not come in contact with the light water pool or the light water pool steel liner. The target solution is located inside the PSB, which consists primarily of the TSV, the TOGS, and the TSV dump tank. As described in Subsection 4a2.2.1.4, the PSB components are designed to be compatible with the target solution to avoid excessive corrosion and other unwanted metallurgical effects that could lead to

4a2.4.2.3 Radiological Shielding

The light water pool surrounding the TSV provides significant neutron and gamma shielding, thereby reducing the shielding requirements of the IU cell biological shield and reducing neutron activation of equipment located above the light water pool.

As noted in Section 4a2.5, neither the neutron nor gamma flux levels are high enough to threaten the integrity of the concrete structure surrounding the light water pool. Significant degradation of the shielding performance of the water only occurs if void volume results from boiling. Based on the heat generation rates for the various operational conditions, the heat capacity of the pool water and the heat transfer rate to adjacent materials, boiling of the pool water is not credible. Pool water temperature is monitored to ensure it is within the normal operating temperature range. The relatively minor loss of shielding resulting from a decrease in the pool water density as the water temperature increases was included in the shielding analysis.

The design of the light water pool and associated piping and valving prohibit configurations that could accumulate significant volumes of radiolytic gases within the bulk volume of pool water, which could result in voids that do not provide equivalent shielding.

A principal objective of the light water pool (together with the concrete biological shielding) is to ensure the projected radiation dose rates and accumulated doses in occupied areas do not exceed the limits of 10 CFR 20 and the guidelines of the as low as reasonably achievable (ALARA) program, described in Subsection 11.1.3.

4a2.4.2.4 Instrumentation

The light water pool includes instrumentation to monitor temperature and liquid level ~~along with a leak chase system to provide indication of leakage~~.

Temperature instrumentation monitors temperature within the light water pool. The normal operating temperature range of the light water pool is 50 to 95°F (10 to 35°C).

Liquid level instrumentation monitors volume changes in the light water pool. If the liquid level of the pool decreases to the low liquid level, there may be a leak in the pool liner.

Repair procedures are conducted in accordance with the radiation protection, monitoring, and response guidelines described in Section 11.1.

4a2.4.3 TECHNICAL SPECIFICATIONS

Certain material in this section provides information that is used in the technical specifications. This includes limiting conditions for operation, setpoints, design features, and means for accomplishing surveillances. In addition, significant material is also applicable to, and may be used for the bases that are described in the technical specifications.

subcritical assembly. The interior surface of the primary cooling room wall was partitioned into two-foot by two-foot sections, and the gamma flux and dose rates in each section were calculated due to the operation of the subcritical assembly and primary cooling system.

For the primary cooling room, the magnitude of the fluxes and dose rates during irradiation is:

- Average gamma flux and dose rate impinging on the interior wall: less than 3E+04 gamma/cm^2-s, less than 9E-02 rem/hr
- Peak gamma flux and dose rate impinging on the interior wall: less than 9E+04 gamma/cm^2-s, less than 3E-01 rem/hr

4a2.5.3.2 Radiation Damage

4a2.5.3.2.1 Concrete

According to the ANSI/ANS-6.4-2006, Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants*,* nuclear heating in concrete can be neglected if the incident energy fluxes are less than 1E+10 MeV per square centimeter per second (MeV/cm^2-sec) or if temperatures are maintained below 149°F (65°C) (ANSI/ANS, 2006).

During irradiation, significant neutron and gamma fluxes are created by the irradiation process in the subcritical assembly. The light water pool serves to significantly reduce the magnitude of the fluxes that reach the ICBS. The cumulative effects of the neutron and gamma fluxes from the neutron driver, SCAS, and TOGS sources have been analyzed with MCNP software, and peak energy fluxes in the concrete were found to be less than 1E+10 MeV/cm^2-sec in all areas except immediately below the TSV dump tank, which had a maximum energy flux of 6E+10. With this region of the shielding in direct contact with the light water, which has a maximum temperature of 95°F (35°C) during normal operation, heat transfer from the concrete to the pool water is sufficient to maintain the concrete temperature below the 149°F (65°C) limit. Therefore, no nuclear heating concerns exist.

With regard to degradation, NUREG/CR-7171, A Review of the Effects of Radiation on Microstructure and Properties of Concretes Used in Nuclear Power Plants (NRC, 2013), provides recommended radiation exposure limits for concrete. The most limiting of the values listed are an integrated neutron fluence up to 1E+19 n/cm^2 and an integrated dose of gamma radiation up to 1E+10 rads, which have been shown to not significantly impact structural properties. Using MCNP, analysis of the maximum neutron and gamma doses to the concrete over the 30 year lifetime were < 2E+14 n/cm^2 and < ~~2~~3E+0~~8~~9 rads, respectively. Given these results, concrete radiation degradation is not significant and does not need additional design considerations.

4a2.5.3.2.2 Steel

No neutron fluxes that could result in degradation or activation of the primary cooling room shield doors are present in the primary cooling room.

4a2.5.3.3 Radiation Streaming

The ICBS requires a number of penetrations, inserts, and other features where the bulk shielding materials are reduced in thickness, or where the materials used in the penetration are less dense than the surrounding bulk material. Each such penetration is designed with well-demonstrated

4a2.8.3 TSV OFF-GAS PROCESS FLOW DIAGRAM

Figure 4a2.8-1 shows the process flow diagram of the TOGS and its major components.

4a2.8.4 TOGS MAJOR COMPONENTS AND SYSTEM INTERFACES

Table 4a2.8-1 lists the major components in the TOGS shown in Figure 4a2.8-1. The description of the components includes the design codes and standards of these TOGS components. Also provided in Table 4a2.8-1 are major dimensions of the principal TOGS components. A discussion of the favorable geometry of the TOGS components is described below in Subsection 4a2.8.5.

The TOGS components are designed based on the following TSV operating envelope and conservative design assumptions for the gas leaving the TSV headspace:

- Gas temperature: The range of temperatures for gas leaving the TSV headspace is based on the sweep gas supply temperature from TOGS and the heat transfer rate between the sweep gas and the target solution at a temperature range of 50°F (10°C) to 194°F (90°C).
- Gas pressure: -4.5 pounds per square inch gauge (psig) (-31 kilopascals [kPa] gauge) to 15 psig (103 kPa gauge).
- Steady state hydrogen production rate: up to approximately 3.8E-2 grams/second.
- Relative humidity: The relative humidity for gas leaving the TSV headspace is based on the evaporation rate of the target solution at a maximum temperature of 194°F (90°C).

The component designs are based on the normal operating envelope, anticipated transients, and conservative assumptions, and then additional design margin is included in the capacity of each of the components. The design margin applied is specific to the component being analyzed, and the amount of design margin includes consideration for the importance of that component to affecting the capacity of TOGS and the potential variability of the relevant process parameters.

Table 4a2.8-2 provides a listing of the TOGS interfaces with interconnecting systems.

The specified materials of construction of the TOGS components are chemically compatible with the evolved fission product, radiolytic, and sweep gases. Major TOGS components are made of ~~347~~austenitic stainless steel. Unlike nitric acid systems, sulfuric acid is stable under irradiation. Seals/gaskets are chemically compatible with the process fluids. This ensures that possible corrosion damage to the system is reduced. The TOGS components are designed and fabricated in accordance with the codes and standards listed in Table 4a2.8-1.

The TOGS components are designed to withstand system pressures that could occur during credible TSV power fluctuations to avoid breaching the PSB. The components are designed to withstand credible hydrogen deflagrations.

The TOGS condenses water vapor and returns the water to the TSV. This also serves to conserve water in the system. The reactivity effects of water retention in TOGS are provided in Subsection 4a2.6.1.

The VTS is one of the methods used to transfer liquids throughout the RPF. Liquid is moved in batches using tanks that have a favorable geometry for criticality safety. These tanks are collectively named lift tanks. Vacuum is applied to the destination lift tank causing liquid to flow from the source tank to the lift tank. When filled to a specified height, vacuum is broken and the tank is vented to atmospheric pressure. Liquid is then transferred to its subsequent destination through gravity, a second lift, or pumping. A detailed description of the VTS is provided in Section 9b.2.

The SNM present in the VTS is target solution and waste streams being transferred by the system. This SNM is in the form of uranyl sulfate. The maximum inventory of LEU in the system is 60 kg. This is divided between the VTS lift tanks and piping.

The components in the VTS that potentially contain uranium meet the criticality safety requirements of the criticality safety evaluation, which include geometry, interaction, and volume controls. A general description of provisions for criticality control in the VTS is described in Subsection 6b.3.2.5.

4b.1.3.10 Molybdenum Isotope Product Packaging System

4b.1.3.10.1 Process and Safety Functions

Section 9b.7 describes the process and safety functions for the MIPS.

4b.1.3.10.2 Process Description

The MIPS receives concentrated Mo-99 product solution from the MEPS and Xe-133 and I-131 product containers from the IXP system. After Mo product is purified and sampled in the purification hot cell, the Mo product bottle is capped and transferred to the packaging hot cell. Labels are applied to the product bottle and the bottle is secured into the secondary container. The secondary container is labeled and then secured into the Mo shipping cask. The cask is leak tested prior to being ~~exported~~shipped from the ~~hot cell~~facility. The packaging operations for iodine and xenon products are the same as for the Mo.

There is no significant quantity of SNM within the MIPS system. Therefore, no criticality controls are required. A more detailed description of the MIPS is provided in Section 9b.7.

4b.2.2.2 Geometry and Configuration

The general shape of the PFBS shielding elements is that of rectangular slabs comprising the walls and cover plugs.

The shield walls of the supercell shield are ~~steel~~lead and vary in thickness from approximately ~~1.~~0.75 ft. (0.~~3~~2 m) to 1.~~5~~0 ft. (0.~~5~~3 m). The walls of the RLWI shielded enclosure are concrete and vary in thickness from approximately 1.5 ft. (0.5 m) to 2.5 ft. (0.8 m). Below-grade PFBS enclosures include process tank vaults, pipe trenches, valve pits, waste drum storage bore holes, and the carbon delay bed vault. The concrete process tank and pipe trench cover plugs vary in thickness from approximately 4.5 ft. (1.4 m) to 5.5 ft. (1.7 m), the concrete carbon delay bed vault cover plug thickness is approximately 5.5 ft. (1.7 m), and the ~~steel~~lead waste drum storage cover plug thickness is approximately ~~1.7~~0.83 ft. (0.25 m). Alternative shielding materials and configurations that provide equivalent or increased shielding effectiveness may be used.

Biological shielding materials are described in Section 4b.2.3 and shield thicknesses support ALARA goals and compliance with 10 CFR 20 dose limits as described in Section 11.1. Local hot spots (e.g., penetrations, interfaces) will be measured as part of the shielding test program and will be managed appropriately according to the Radiation Protection Program (RPP), as described in Section 11.1.

Figure 4b.2-1 shows a section view through a representative auxiliary valve pit, pipe trench, and tank vault, providing a general depiction of the below-grade RPF biological shielding.

4b.2.2.2.1 Functional Design of Biological Shield

Process piping generally transitions between the RPF and IF biological shields (i.e., PFBS and irradiation cell biological shield [ICBS]) directly through below-grade piping penetrations. Auxiliary piping and unirradiated target solution piping enter the PFBS shielding through one of two auxiliary valve pits using fixed supplemental shielding and non-linear paths, as shown in Figure 4b.2-1. Shielding for the waste drum bore holes, shown in Figure 4b.2-2, utilizes a shielding gate, which interfaces with the drum transfer cart to limit streaming paths. Compensating shielding is used as needed to ensure sufficient shielding for the different gate positions. Process tank vault, pipe trench, and carbon delay bed cover plugs are not removed during routine operation, but can be removed for equipment replacement, maintenance, or inspection. Smaller access plugs are available within larger plugs for inspection purposes.

The RLWI shielded enclosure has functional design requirements for waste and equipment import and export. The liquid process wastes enter the RLWI shielded enclosure through the process piping trench, they are solidified in the cell, and the solidified waste drums exit through the RLWI drum access door. New drums enter the RLWI shielded enclosure through the same drum access door, and personnel can enter and leave the shielding via the personnel access door. Contaminated process equipment is removed via the drum access door or shield plugs. Figure 4b.2-3 shows a general depiction of the entry and exit facilities for the RLWI shielded enclosure.

The supercell has multiple functional design requirements for interfacing with the shielded area. Solid wastes exit through drum export features on the supercell. The supercell includes features to allow the import of consumables and process equipment and transfer between adjacent cells. The supercell has export features for product shipping containers. Penetrations through the hot cell work surfaces to the import and export areas have plugs that are in-place when not actively importing or exporting materials. Plugs have the same shielding capability as the bulk material they penetrate. The penetrations are designed to minimize the potential spread of contamination in accordance with the RPP. The supercell consists of multiple individual hot cells. The hot cells are equipped with manipulators. Manipulator penetrations are designed with supplemental shielding to meet ALARA goals. The hot cells are equipped with lead glass windows. The window design incorporates compensating shielding to reduce streaming at the interface of the window and the hot cell wall. Figure 4b.2-4 shows a general depiction of the entry and exit facilities from the supercell.

The biological shield and supporting structures are designed and constructed to remain intact during normal operations as well as during and following design basis accidents.

No neutron fluxes exist in the RPF that could result in activation of groundwater or soils.

4b.2.3 SHIELD MATERIALS

The RPF uses the following primary materials in different configurations to assemble the biological shield and meet the radiation exposure goals defined in Chapter 11:

- standard density (minimum 140 pounds per cubic foot [lb/ft^3]) (2.2 grams per cubic centimeter [g/cm^3]) concrete with reinforcing steel,
- lead,
- steel, and
- lead glass.

The concrete is of the ordinary type, with no special additives for shielding purposes.

The biological shielding for the tank vaults, pipe trenches, carbon delay bed vault, waste drum storage (except upper portions), and portions of the RLWI shielded enclosure is reinforced concrete. Waste drum storage bore hole upper portions (i.e., covers and compensating shielding) are ~~steel~~lead. Portions of the RLWI shielded enclosure include steel. The supercell shielding is primarily ~~steel~~lead. Lead glass windows are used for viewing purposes. Lead is used ~~primarily~~ for localized shielding around components with high activity. Alternative shielding materials and configurations that provide equivalent or increased shielding properties may be used.

4b.2.3.1 Shielding Calculations

Calculations are performed with the software package named MCNP (Monte Carlo N-Particle Transport Code). MCNP is developed and validated by Los Alamos National Laboratory (LANL) and distributed by the Radiation Safety Information Computational Center (RSICC) at Oak Ridge National Laboratory (ORNL) (LANL, 2011). MCNP uses a Monte Carlo based particle (neutrons and photons) transport method to generate a set of particle tracks through a model of the facility geometry. The Monte Carlo method generates a statistical set of results for individual particles transported through the geometry. Enough particles are simulated to obtain statistically significant results. Conservative assumptions are used to define the overall shielding properties of the concrete and reinforcing bar assuming no reinforcing bar is conservative for gamma shielding. Shielding coefficients are not used in the MCNP calculation methodology and, therefore, were not calculated. See Table 11.1-1 for source term assumptions.

Figure 4b.2-2 – Waste Bore Hole Shielding – General Arrangement (Not to Scale)

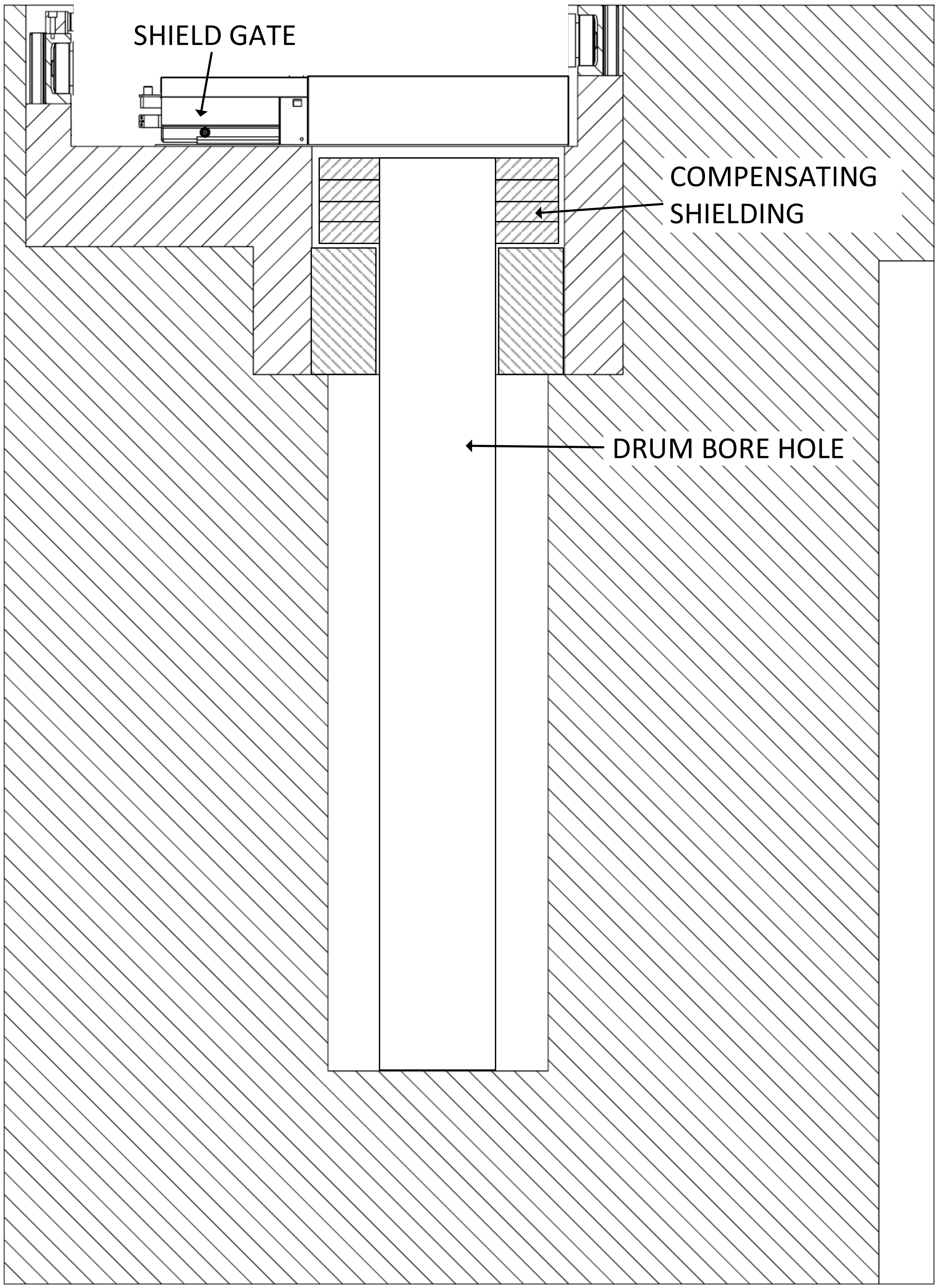


Figure 4b.2-4 – Supercell Shielding - General Arrangement (Not to Scale)

Table 4b.3-1 – MEPS Interfaces

Interfacing System	Interface Description
Vacuum transfer system (VTS)	The VTS transfers target solution to MEPS for Mo extraction and provides vacuum service for the evaporator.
Process vessel vent system (PVVS)	The MEPS interfaces with the PVVS at two locations, the vent lines from the Mo eluate hold tank and the MEPS condensate tank.
Radioisotope process facility cooling system (RPCS)	The RPCS provides cooling water to the Mo eluate evaporator condenser.
Normal electrical power supply system (NPSS)	Electrical power is provided to the extraction column feed pumps, [ ]PROP/ECI, the Mo eluate evaporator, valves, and ancillary equipment.
Radioactive liquid waste storage (RLWS)	Solutions resulting from the processing of Mo batches are discharged to the RLWS tanks.
Target solution staging system (TSSS)	Target solution batches may be returned to the target solution hold tanks following separation of Mo from the target solution.
Solid radioactive waste packaging (SRWP)	The MEPS interfaces with the SRWP system at the solid waste shielded drum interface point.
Molybdenum isotope product packaging system (MIPS)	The MEPS interfaces with the MIPS by transferring a container with the purified Mo-99 from the MEPS area of the supercell to the MIPS area of the supercell.
Engineered safety features actuation system (ESFAS)	ESFAS actuates isolation functions of the MEPS to prevent unacceptable radiological releases.
Facility nitrogen handling system (FNHS)	The FNHS provides nitrogen to operate the extraction column feed pumps [ ]PROP/ECI
Process integrated control system (PICS)	PICS allows operators to monitor MEPS parameters and control process functions.
Iodine and xenon purification and packaging (IXP)	Target solution [ ]PROP/ECI transferred to IXP from MEPS for iodine processing.
Production facility biological shield (PFBS)	The MEPS components with radiological inventories are within a hot cell to minimize worker doses.
Facility chemical reagent system (FCRS)	The FCRS provides chemical reagents to MEPS as needed.
Nitrogen purge system (N2PS)	The N2PS ventilates the MEPS tanks if normal ventilation provided by PVVS were to fail.

4b.4 SPECIAL NUCLEAR MATERIAL PROCESSING AND STORAGE

Special nuclear material (SNM) is used throughout the radioisotope production facility (RPF) radiologically controlled area (RCA) in both unirradiated and irradiated forms for the production of medical isotopes.

Molybdenum (Mo) is extracted from the irradiated SNM in the Mo extraction and purification system (MEPS) and iodine (I) is extracted from the irradiated SNM in the iodine and xenon purification and packaging (IXP) system as described in Section 4b.3. Following isotope extraction, the target solution is directed to one of the target solution hold tanks, the target solution storage tanks, or the radioactive liquid waste storage (RLWS) system. In the target solution hold tanks, sampling and adjustments to chemistry are performed as required. Target solution is stored in favorable geometry tanks that are designed to remain subcritical. Subsection 4b.4.1 discusses the processing of irradiated SNM.

The following are the major SNM processing steps:

- Dissolve uranium oxide in sulfuric acid to form target solution.
- Extract radioisotopes from irradiated target solution.
- Store and transport irradiated target solution, allowing for in-process adjustments.

The facility receives and stores new shipments of uranium metal and uranium oxide. Uranium metal is converted to uranium oxide in the uranium receipt and storage system (URSS). Uranium oxide is used to prepare unirradiated target solution. Uranium oxide is stored in uranium oxide storage canisters and is transported from the URSS to the target solution preparation system (TSPS) area. Subsection 4b.4.2 discusses the preparation of the target solution.

Shipments of SNM are received at the facility in solid form. The shipments consist of low enriched uranium (LEU), uranium metal or uranium oxide enriched to 19.75 ± 0.2 percent uranium-235 (U-235). The SNM is shipped in approved shipping containers (a general-purpose Type B fissile material shipping container). The SNM is removed from the shipping containers and stored in uranium metal storage canisters or uranium oxide storage canisters in a favorable configuration storage rack. Subsection 4b.4.2 provides more detail on the receipt and storage of unirradiated SNM.

The RPF contains uranium in multiple forms: uranium metal, uranium oxide, and uranyl sulfate. A small amount of plutonium is generated during the irradiation cycle, as described in Section 4a2.6, and is transferred to the RPF in aqueous form within the target solution. Table 4b.4-1 provides the total inventory of SNM in the ~~RCA~~main production facility. Table 4b.4-2 provides the physical and chemical forms of SNM within RPF processes. Refer to Table 4a2.2-1 for the target solution batch uranium inventory. See Table 4a2.6-2 for the target solution batch plutonium inventory. Refer to Section 4b.1 for maximum SNM inventory within each RPF process system.

The SNM processing and storage systems prevent inadvertent criticality through criticality safety controls applied to the design of tanks, process equipment, storage containers, and other components that may handle the SNM, as well as through other controls detailed in the nuclear criticality safety evaluations, as described in Section 6b.3.

Table 4b.4-1 – Special Nuclear Material Maximum Inventory in the ~~RCA~~Main Production Facility (Approximate)

Chemical Form[a]	Physical Form	Inventory[b]
Uranium metal	Solid	1030 lb. (470 kg)
Uranium oxide	Powder	310 lb. (140 kg)
Uranyl sulfate	Aqueous	4770 lb. (2170 kg)
Uranyl sulfate	Solidified	16 lb. (8 kg)
Plutonium	Aqueous, solidified	4.08 lb. (1.85 kg)
Highly enriched uranium in fission chambers	Solid	0.55 lb. (0.25 kg)

a) Uranium is low enriched uranium (LEU), unless otherwise noted.
b) Inventory mass does not include the water mass for aqueous solutions.

Table 4b.4-3 – TSSS Interfaces

Interfacing System	Interface Description
Molybdenum extraction and purification system (MEPS)	The TSSS receives solutions from MEPS.
Target solution preparation system (TSPS)	The TSSS receives target solution, makeup solution, sulfuric acid, or water from the TSPS.
Iodine and xenon purification and packaging (IXP)	The TSSS receives solution from IXP.
Vacuum transfer system (VTS)	Solutions are transferred from the TSSS via VTS.
Process vessel vent system (PVVS)	The TSSS tanks are ventilated by the PVVS for evolved radiolytic hydrogen and radiological gases.
Radioactive drain system (RDS)	The TSSS tanks have overflow connections to the RDS.
Production facility biological shield (PFBS)	The TSSS tanks are located in shielded below-grade vaults that are part of PFBS.
Normal electrical power supply system (NPSS)	TSSS equipment is supplied electric power from the NPSS.
Facility nitrogen handling system (FNHS)	The FNHS provides a nitrogen gas supply for liquid level detectors for the target solution hold tanks and target solution storage tanks. The TSSS tanks are agitated by the FNHS.
Nitrogen purge system (N2PS)	The N2PS provides ventilation to the TSSS tanks in the event of a loss of PVVS. The N2PS ventilates the TSSS via PVVS piping.
Process integrated control system (PICS)	PICS allows operators to monitor TSSS parameters.

Figure 4b.4-3 – Target Solution Preparation System Process Flow Diagram (Sheet 1 of 2)

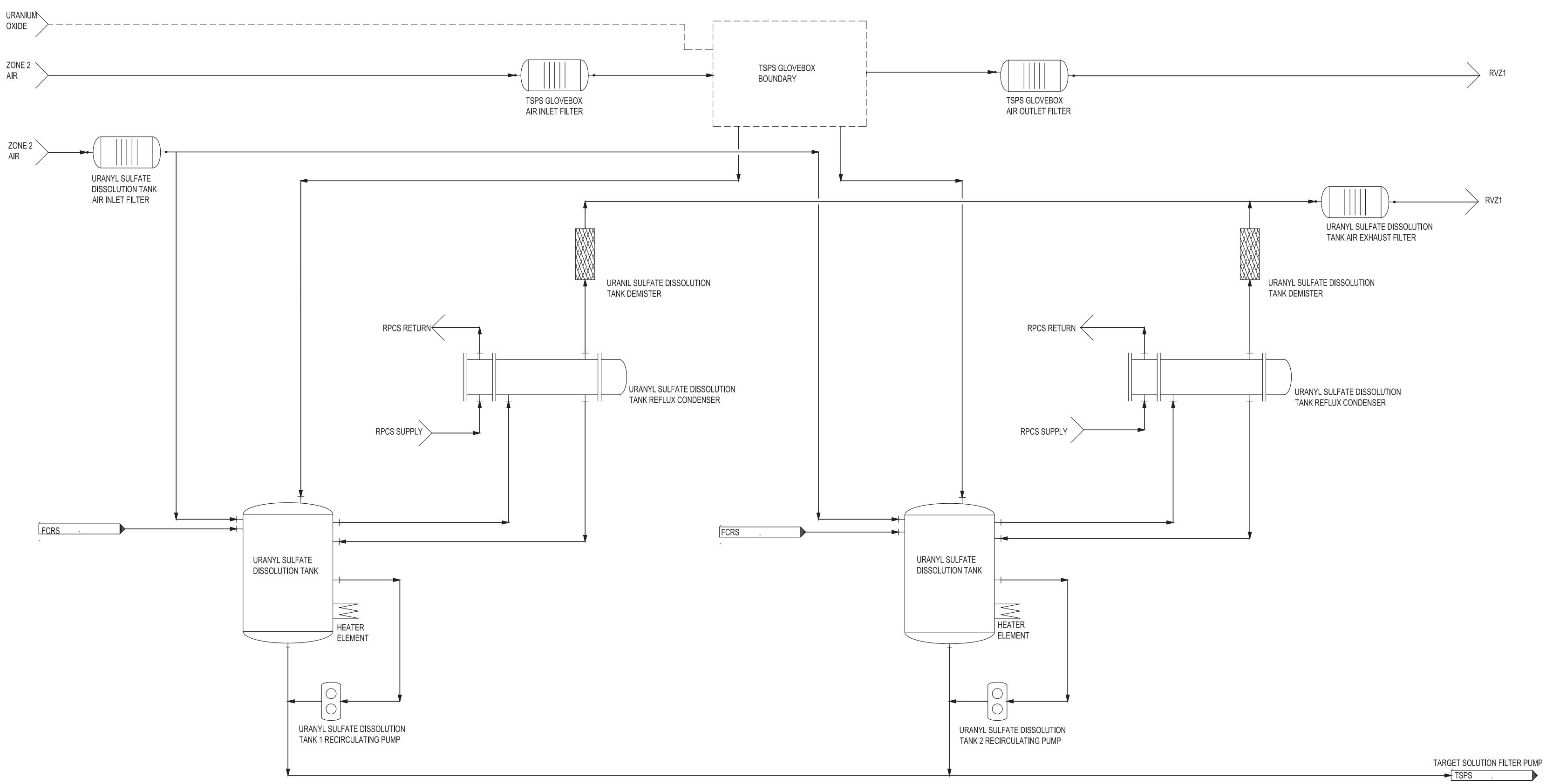
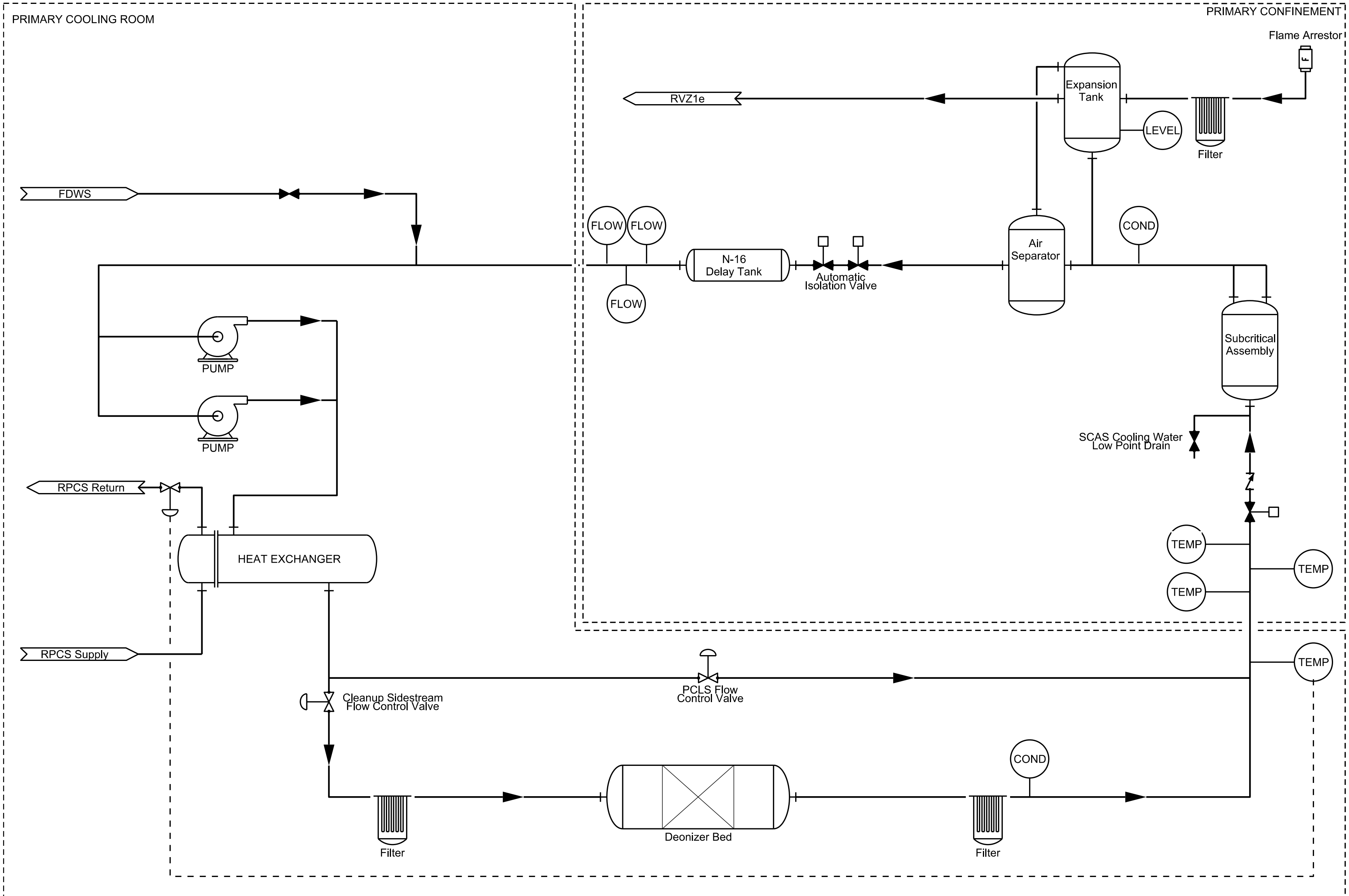


Table 5a2.2-3 – PCLS System Interfaces

System	Interface Description
Radioisotope process cooling water system (RPCS)	The RPCS interfaces with each of the eight instances of PCLS inside the radiologically controlled area (RCA). Nonsafety-related manual isolation valves are located at the interface with PCLS.
Facility demineralized water system (FDWS)	The FDWS interfaces with each of the eight PCLS cooling loops inside the RCA. The FDWS interfaces with the PCLS downstream of a FDWS vacuum breaker. Nonsafety-related manual isolation valves are located at the interface with PCLS.
Subcritical assembly system (SCAS)	The SCAS interfaces with the PCLS in each of the eight light water pools located in the irradiation facility (IF).
Normal electrical power supply system (NPSS)	The NPSS provides power to PCLS process skid, including pumps and instrumentation, located inside the IF.
Uninterruptible electrical power supply system (UPSS)	The UPSS provides the PCLS safety-related instrumentation with electrical power during normal conditions and during and following design basis events.
TSV reactivity protection system (TRPS)	The PCLS provides instrumentation for the TRPS to monitor variables important to the safe operation of the PCLS. The TRPS provides controls to the PCLS components to perform safety actuations when monitored variables exceed predetermined limits.
~~Facility nitrogen handling system (FNHS)~~	~~The FNHS provides compressed nitrogen gas to the PCLS loop pneumatic control mechanisms located inside the IF.~~
Process integrated control system (PICS)	The PICS monitors and controls the PCLS process parameters, utilizing the instrumentation and controlled components within the IF.
Radiological ventilation zone 1 (RVZ1)	The RVZ1 provides an exhaust path from the headspace of each of the eight PCLS expansion tanks. The PCLS removes radiolytic gas from the cooling water and vents it to prevent combustible gas mixtures from forming.
Radiological ventilation zone 2 (RVZ2)	The RVZ2 provides an indirect source of makeup air into the PCLS expansion tanks via the supply air provided to the IF through the primary confinement.

Figure 5a2.2-1 – Primary Closed Loop Cooling System Flow Diagram



5a2.5 PRIMARY CLOSED LOOP COOLING SYSTEM CLEANUP SIDE STREAM

5a2.5.1 DESIGN BASES AND PROCESS FUNCTIONS

The primary closed loop cooling system (PCLS) cleanup side stream maintains the required water quality limits of the PCLS.

The following are the process functions of the PCLS cleanup side stream:

- Maintain water quality to reduce corrosion and scaling; and
- Limit concentrations of particulate and dissolved contaminants that could be made radioactive by neutron irradiation to achieve as low as reasonably achievable (ALARA) goals.

The PCLS cooling water is treated to meet water quality limits discussed in Table 5a2.2-1. The cleanup components are located on a side stream through which the PCLS diverts a portion of the cooling water flow. The components that perform the PCLS cooling water treatment are located within the PCLS cleanup side stream flow path.

The PCLS cleanup side stream includes conductivity instrumentation to monitor water quality, a deionizer bed~~s~~ to remove ionic species, and filters on the inlet and outlet of the deionizer bed~~s~~ to remove particulates from the cooling water.

Maintaining the design water quality limits corrosion damage and scaling of the PCLS, the target solution vessel (TSV), and the neutron multiplier, which are components of the subcritical assembly system (SCAS). The PCLS cleanup side stream removes contaminates that could become activated and radioactive materials from the PCLS cooling water in order to meet ALARA occupational exposure goals described in Section 11.1. The PCLS cleanup side stream and its components are designed and selected so that malfunctions are unlikely. Malfunctions and leaks in the PCLS and the PCLS cleanup side streams are addressed in Subsection 5a2.2.2.

See Table 5a2.2-2 for the list of PCLS components and their functions.

The PCLS cleanup side stream components are designed and fabricated in accordance with the codes and standards listed in Table 5a2.2-2.

5a2.5.2 PCLS CLEANUP SIDE STREAM CONTROL AND INSTRUMENTATION

The PCLS cleanup side stream instrumentation is located in the primary cooling room.

Conductivity instrumentation located at the outlet of the PCLS cleanup side stream measures the conductivity within the PCLS. The pH of the PCLS cooling water is monitored through sampling of the system and analysis of the cooling water is performed by the quality control and analytical testing laboratories (LABS). Pressure, flow, temperature, conductivity, and level instrumentation monitor the operating parameters of the PCLS as discussed in Subsection 5a2.2.3.

5a2.5.3 PCLS CLEANUP SIDE STREAM COMPONENTS AND LOCATIONS

The PCLS cleanup side stream components are located in the primary cooling room, directly adjacent to the IU cells.

5a2.6 FACILITY DEMINERALIZED WATER SYSTEM

The facility demineralized water system (FDWS) provides makeup water to the primary closed loop cooling system (PCLS), radioisotope process facility cooling system (RPCS), facility chilled water system (FCHS), molybdenum extraction and purification system (MEPS) hot water loop subsystem, light water pool, and process chilled water system (PCHS). The FDWS provides a water supply to the radiological ventilation zone 2 (RVZ2) system and the facility ventilation zone 4 (FVZ4) system for humidity control. The quality control and analytical testing laboratories (LABS) and the facility chemical reagent system (FCRS) are supplied demineralized water from the FDWS. Operational cooling water loss in the PCLS and light water pool occurs gradually from radiolysis and evaporation. Water loss in the PCLS, RPCS, FCHS, MEPS hot water subsystem, and PCHS may also occur from off-normal events such as leaks or for maintenance. Makeup from the FDWS to the systems served is supplied through piping that contains backflow prevention. Transfers of makeup water from the FDWS to the cooling and heating systems are performed manually. Refer to Figure 5a2.6-1 for a flow diagram of the FDWS.

The FDWS is supplied water from the facility potable water system (FPWS). The FDWS ~~consists of~~includes a reverse osmosis (RO) skid and a RO storage tank located outside of the radiologically controlled area (RCA). The RO skid is a packaged unit that contains pre-filters, piping, valves, pumps, and RO membranes to supply RO water. The RO skid is located downstream of the backflow prevention device that acts as the system boundary between the FPWS and the FDWS. ~~A portion of t~~The demineralized water processed through the RO membrane into the RO storage tank outside of the RCA is supplied to end users outside the RCA requiring RO treated water ~~with the balance supplied~~as well as to the RO storage tank located inside the RCA. A second backflow prevention device is provided at the boundary where the FDWS enters the RCA.

The FDWS includes two recirculation loops (i.e., one inside the RCA and one outside the RCA) with two 100% capacity pumps for each recirculation loop. The two pumps are supplied water from the respective RO storage tank that has been filtered by the RO membrane on the RO skid. The pumps circulate water from the respective RO storage tank to a ring header either inside or outside the RCA and back to the respective tank. Only one of the two pumps in each recirculation loop is required to be operational for system service. Recirculated water is supplied directly to end users requiring RO-processed water, and through deionizers to other end users requiring deionized water. Table 5a2.6-1 identifies the RO-processed and deionized water end users.

The FDWS components are listed in Table 5a2.6-2, including design codes and standards.

Flow from the RO skid is controlled by level instrumentation in the RO storage tanks. Tank level is provided with high- and low-level alarms. Pressure is monitored at the outlet of the circulation pump where high- and low-level alarms are provided. Sampling and trending of the system is performed to detect malfunctions in the deionizer units and the RO skid. Sampling and trending serve to identify when replacement or repair is necessary.

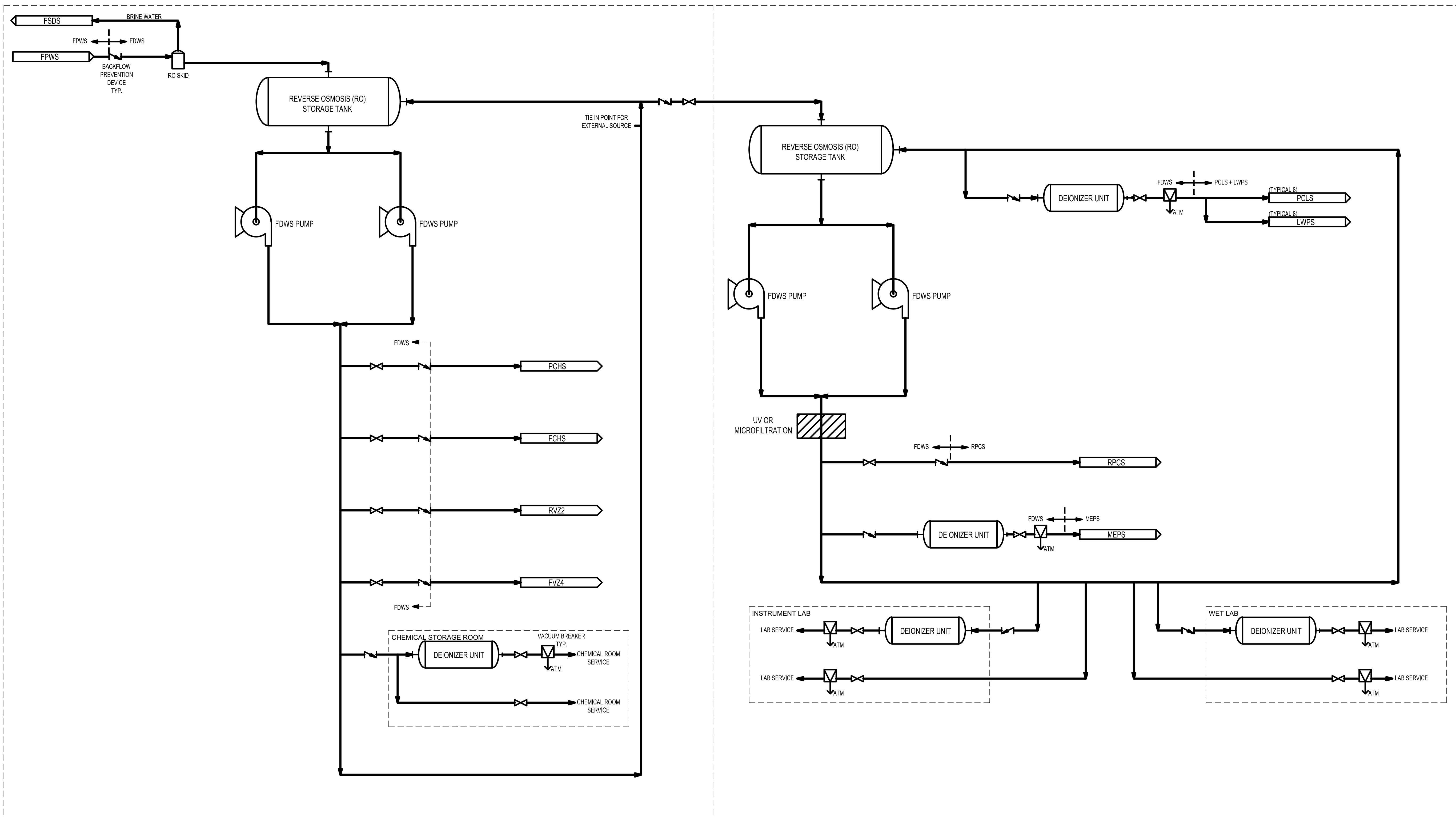
The FDWS is not safety-related. On loss of normal power, the pumps will not be operational, as the FDWS is not relied on to provide water on loss of normal power.

Table 5a2.6-2 – FDWS Components

Component	Description	Code/Standard
Facility demineralized water system (FDWS) reverse osmosis (RO) skid	The RO skid is a packaged unit that contains pre-filters, piping, valves, pumps, and RO membranes.	Note[(a)]
FDWS deionizer units	Provided to house deionization resins for the removal of contaminants and the reduction of water conductivity.	Note[(a)]
FDWS RO storage tanks	Provided to maintain adequate RO system supply volumes.	Note[(a)]
FDWS pumps	Circulates FDWS RO water through system components.	Note[(a)]
Piping components	FDWS piping.	ASME B31.9 (ASME, 2011)
Instrumentation	Provide indication of FDWS operating parameters (pressure, temperature, conductivity, flow, and level).	Note[(a)]

a) Commercially available equipment designed to standards satisfying system operation.

Figure 5a2.6-1 – Facility Demineralized Water System Flow Diagram



6b RADIOISOTOPE PRODUCTION FACILITY ENGINEERED SAFETY FEATURES

6b.1 SUMMARY DESCRIPTION

This section provides a summary of the engineered safety features (ESFs) installed in the radioisotope production facility (RPF). Table 6b.1-1 contains a summary of the ESFs and the RPF design basis accidents (DBAs) they are designed to mitigate. Table 6b.1-2 provides unmitigated and mitigated doses for the public and the worker, with one DBA selected per confinement system, to demonstrate the mitigative effects of the confinements. The same methods described in Section 13a2.2 were used to calculate the unmitigated doses, but with a leak path factor of 1 for both the worker and public. A block diagram for the RPF ESFs is provided as Figure 6b.1-1. This block diagram shows the location and basic function of the structure, system and components (SSCs) providing the ESFs in the RPF portion of the main production facility.

Confinement Systems

Confinement systems provide active and passive protection against the potential release of radioactive material to the environment during normal conditions of operations and during and after a DBA. Passive confinement is performed by physical barriers such as concrete or steel boundaries, sealed access plugs, and sealed doors. The confinement systems provide active isolation of penetrations that include process piping and heating, ventilation, and air conditioning (HVAC) systems penetrating confinement boundaries during and after certain DBAs. The process confinement boundary includes two areas: (1) the supercell confinement, which includes the extraction, purification, and packaging hot cells, the iodine and xenon purification and packaging cell, and the process vessel ventilation system (PVVS) hot cell; and (2) the below grade confinement, which confines the PVVS delay beds, the target solution hold, storage, and waste tanks, the pipe trench and valve pits, and the waste processing tanks. A detailed description of the confinement systems is provided in Subsection 6b.2.1.

The accidents for which confinement is credited are described in detail in Section 13b.1 and listed in Table 6b.1-1. The accident sequences in the RPF which require confinement are related to the release of radioactive liquids and gases from irradiated target solution, waste streams, or processing streams.

The RPF confinement systems remain operational during and following any of the DBAs, including seismic events and loss of off-site power. Active components which comprise portions of the confinement boundaries are designed to fail safe on a loss of actuating power and maintain the integrity of the confinement boundaries.

A listing of the automatic isolation valves included in the confinement boundaries is provided in Section 7.4 and Section 7.5.

Process Vessel Ventilation System Isolation

The PVVS is equipped with isolation valves that actuate to confine and extinguish fires, which may occur in the PVVS carbon guard beds or carbon delay beds. These isolation functions are described in detail in Subsection 6b.2.2. The PVVS is described in detail in Section 9b.6.

target solution toward the FCRS reagent vessels. An isolation valve is installed between the FCRS and upper vacuum lift tanks that is administratively closed during target solution processing, and a check-valve also exists to prevent inadvertent flow of target solution to the reagent vessels.

Precipitation due to the inadvertent addition of caustic reagents requires application of the DCP to prevent criticality accidents. The volume of caustic reagents and the sequence of column washes is administratively controlled to prevent potential precipitate formation. Additionally, a column frit filter prevents downstream transfer of any potential solid precipitates.

6b.3.2.4 Target Solution Preparation System

The TSPS produces uranyl sulfate solution, referred to as target solution, from uranium oxide powder. The uranium oxide powder is dissolved in sulfuric acid to produce uranyl sulfate. Hydrogen peroxide may be used as a catalyst in this process, forming uranyl peroxide as an intermediate. A process overview is provided in Figure 6b.3-4.

The uranium oxide powder is manually transferred from the uranium receipt and storage system (URSS) to the TSPS glovebox. The powder is stored and handled in sealed cans which are opened inside the glovebox. The oxide powder is then metered and poured into the dissolution tanks. The dissolution tank is then charged with hydrogen peroxide (if used) and sulfuric acid in sequence to produce the final uranyl sulfate product. The tanks are ~~mechanically~~ agitated and heated during the process to ensure proper dissolution. The tanks themselves are favorable geometry vessels with a controlled diameter to protect against potential criticality.

Once the dissolution process is complete, the tank contents are pumped through a filter into the target solution preparation tank and can then be transferred into the TSSS. The target solution preparation tank is a favorable-geometry annular tank like those found in the TSSS and RLWS.

Because the dissolution process evolves heat and water vapor, the off-gas from the process flows through a reflux condenser which condenses the vapor and returns it to the dissolution tank. The reflux condenser is cooled by the radioisotope process cooling system (RPCS). The glovebox and reflux condenser are vented to the facility radiological ventilation system.

Criticality Safety Basis

The NCSE for the TSPS shows that the entire process will remain subcritical under normal and credible abnormal conditions.

The TSPS is subject to two sets of criticality safety limits. Portions of the system contain oxide powder in both dry and wet (partially-dissolved) conditions, and the remainder of the system contains uranyl sulfate. The uranium concentration in the uranyl sulfate may be higher in this system than in the rest of the facility due to the nature of the process.

Under normal process conditions, the mass of uranium oxide is controlled to less than the optimally-moderated, fully-reflected critical mass for uranium oxide of oxide per canister, and only a single oxide canister is permitted in the glovebox at any given time. High efficiency particulate air (HEPA) filters are favorable geometry within the single parameter limit and installed on the glovebox to prevent significant buildup of oxide powder outside of the glovebox

Monitoring and Alarms

The PICS receives input and provides alarms for LWPS pool level~~,~~ and LWPS pool temperature~~, and LWPS pool leak chase level~~ for each IU.

Control Functions

None

Interlocks

None

7.3.1.1.5 Neutron Driver Assembly System

The NDAS is the source of neutrons used to generate the neutron fluxes required to create medical isotopes in the TSV. The NDAS produces neutrons by colliding a deuterium (D) ion beam with tritium (T) gas. The NDAS is directly controlled by a vendor-provided nonsafety-related control system. The NDAS is described in Section 4a2.3.

Monitoring and Alarms

The NDAS is directly monitored by a vendor-provided nonsafety-related control system. The NDAS control system monitors deuterium-tritium (DT) neutron yield, beam current, target pressure, leakage indications, various system voltages, currents and temperatures, and feedback from vacuum pumps and other system components.

The NDAS control system provides a subset of these monitored parameters and the status of the system (System Off, Vacuum, Prepared, Standby, or Beam On) to the PICS for display on the PICS workstations and generation of alarms.

Control Functions

The NDAS control system allows the operator to manually adjust (e.g., focus or direct) the deuterium beam by changing voltages and currents applied to various solenoid magnets. The NDAS control system also allows the operator to control the ion source by adjusting microwave power, current, and voltage to manually start and stop various system auxiliaries (e.g., vacuum pumps, blowers, cooling pumps), and to open and close NDAS system valves.

The local NDAS control station is only used for maintenance and commissioning activities for an NDAS unit installed in an IU, or for an NDAS unit located in the NDAS service cell.

The operator uses PICS to provide signals to manually open or close the neutron driver HVPS breakers to meet TRPS mode transition criteria and allow the beam to be energized. The operator is able to use the PICS to manually open and close individual valves that are capable of being actuated by TRPS as described in Subsection 7.3.1.3.11.

operator is able to use the PICS local supercell control stations to manually open and close individual valves and manually start or stop individual components unless operation is prevented by interlocks, permissives, or active sequences. Components that are capable of being actuated by ESFAS are controlled by PICS as described in Subsection 7.3.1.3.11.

The supercell control system is used by the operator to manually control hot cell (non-process) functions.

Interlocks and Permissives

The PICS provides permissives and interlocks to:

- Prevent initiation of a target solution extraction sequence if the associated IU from where solution is being transferred is not in Mode 4.
- Prevent opening of any of the supercell reagent feed isolation valves while a target solution extraction sequence is in progress.
- Prevent alignment of MEPS three-way valves in a way that could misdirect fluid and challenge the operation of system check valves.
- ~~Prevent operation of the extraction feed pump if more than one target solution discharge valve is open (i.e., valves used to direct post-extraction target solution to the IXP hot cell, or a target solution staging system [TSSS] or radioactive liquid waste storage [RLWS] tank).~~
- Stop or prevent from starting system pumps when discharge pressure is above an allowable limit ~~or when the pump discharge flow path is isolated~~.

Indication to the operator is provided on the PICS operator workstation displays when an interlock or permissive is bypassed.

7.3.1.2.2 Molybdenum Isotope Product Packaging System

The MIPS is located in two hot cells of the supercell (packaging areas 1 and 2) and is used to package isotopes received from the MEPS and IXP, as described in Subsection 9b.7.1.

Monitoring and Alarms

PICS monitors the weight of the Mo-99 product from the MEPS and the weight of the Xe-133 and I-131 products from the IXP system. No alarms are provided.

Control Functions

The supercell control system is used by the operator to manually control hot cell (non-process) functions.

Interlocks and Permissives

None

7.3.1.2.3 Iodine and Xenon Purification and Packaging System

The IXP is located in a hot cell of the supercell (IXP area) and is used to extract and purify isotopes of iodine and xenon. The IXP is described in Subsection 4b.3.1.

Monitoring and Alarms

The PICS receives input from the ESFAS and provides alarms for the position of the IXP three-way valves (Subsection 7.5.4.1.17).

The PICS directly monitors and provides alarms for IXP eluate hold tank level, [ ]PROP/ECI, xenon cryotrap temperature, and various other system temperatures and pressures. The PICS also monitors the weight of samples obtained from various processes, but no alarms are provided.

The PICS also provides alarms for automatic or manual IXP Alignment Actuations described in Subsection 7.5.3.1.

Control Functions

The tasks performed by the operator for the IXP are manual. The operator is able to use the PICS local supercell control stations to manually open and close individual valves and manually start or stop individual components unless operation is prevented by interlocks, permissives, or active sequences. Components that are capable of being actuated by ESFAS are controlled by PICS as described in Subsection 7.3.1.3.11.

The supercell control system is used by the operator to manually control hot cell (non-process) functions.

Interlocks and Permissives

The PICS provides permissives and interlocks to:

- Prevent opening of any of the supercell reagent feed isolation valves while an IXP target solution supply valve is open.
- Prevent alignment of IXP three-way valves in a way that could misdirect fluid and challenge the operation of system check valves.
- ~~Prevent operation of the B and C extraction feed pumps if more than one target solution discharge valve is open (i.e., valves used to direct post-IXP recovery target solution to a TSSS or RLWS tank).~~
- [ ]PROP/ECI

Indication to the operator is provided on the PICS operator workstation displays when an interlock or permissive is bypassed.

7.3.1.2.4 Process Vessel Vent System

The process vessel vent system (PVVS) provides ventilation of tanks and vessels located in the RPF that may contain radioactive solutions in order to mitigate the potential buildup of hydrogen open the PVVS inlet and outlet valves and start the PVVS reheater for the redundant carbon guard bed train.

- Open the carbon guard bed bypass valves if both carbon guard bed train PVVS inlet valves are closed.
- Isolate flow from the PVVS condensate tank on high level in the first uranium liquid waste tank.
- Isolate flow from the PVVS condensate tank on high level in the liquid waste blending tanks.
- ~~Prevent from starting or stop the PVVS condensate pump when all PVVS condensate pump discharge valves are closed.~~

Indication to the operator is provided on the PICS operator workstation displays when an interlock or permissive is bypassed.

7.3.1.2.5 Vacuum Transfer System

Target solution transfer activities occur throughout the main production facility in order to remove irradiated solution from the TSV dump tank, extract isotopes, and return target solution to an IU. These activities are accomplished by the VTS and target solution staging system (TSSS). The VTS consists of vacuum pumps and a vacuum buffer tank located in a hot cell of the supercell (co-located with the PVVS in the PVVS area) and lift tanks, as described in Subsection 9b.2.5.

Monitoring and Alarms

The PICS receives input from the ESFAS and provides alarms for the VTS vacuum header liquid detection switches (Subsection 7.5.4.1.8).

The PICS directly monitors and provides alarms for vacuum system pressure, individual VTS lift tank level switches, VTS vacuum buffer tank level switches, target solution sample line level switches, and status feedback information from the VTS vacuum pumps.

The PICS also provides alarms for automatic or manual VTS Safety Actuation described in Subsection 7.5.3.1.

Control Functions

The operator is able to use the PICS to manually open and close individual valves and manually start or stop individual components unless operation is prevented by interlocks, permissives, or active sequences. Components that are capable of being actuated by TRPS or ESFAS are controlled by PICS as described in Subsection 7.3.1.3.11.

When initiated by the operator, the PICS starts or stops the VTS by enabling or disabling the vacuum system pressure control loop.

The PICS automatically starts and stops the second of two VTS vacuum pumps to maintain vacuum system pressure within an allowable range.

The supercell control system is used by the operator to manually control hot cell (non-process) functions.

7.4.4.1.13 High TOGS Condenser Demister Outlet Temperature

The high TOGS condenser demister outlet temperature signal protects against adverse effects on TOGS instrumentation and zeolite beds, causing them to fail to perform their safety functions (Subsection 13a2.1.9.2, Scenario 1). The signal is generated by TRPS when a TOGS condenser demister outlet temperature input exceeds the high level setpoint. TOGS condenser demister outlet temperature is measured independently for both TOGS Train A and TOGS Train B. The TOGS condenser demister outlet temperature signal is measured with a temperature interface on three different channels, one for each TRPS division. When two-out-of-three or more TOGS condenser demister outlet temperature inputs exceed the allowable limit, an IU Cell Safety Actuation and an IU Cell Nitrogen Purge are initiated.

7.4.4.1.14 ESFAS Loss of External Power

The ESFAS loss of external power signal is an anticipatory protection against the impending loss of TOGS blowers and recombiners after the runtime of that equipment on the UPSS has been exceeded (Subsection 13a2.1.9.2, Scenario 1). The signal is generated by ESFAS and provided to each of the eight TRPS subsystems when ESFAS senses a loss of external (i.e., normal) power being provided to the UPSS as described in Subsection 7.5.4.1.19. TRPS does not receive the loss of external power signal from ESFAS until three minutes after the external power loss. The ESFAS loss of external power signal is measured with a discrete input signal on two different channels, one for each Division A and Division B of TRPS. When an ESFAS loss of external power signal is active, the division receiving the discrete signal initiates an IU Cell Nitrogen Purge.

7.4.4.1.15 High RVZ1e IU Cell Radiation

The high RVZ1e IU cell radiation signal protects against a breach in the primary system boundary (Subsection 13a2.1.4.2, Scenario 4; and Subsection 13a2.1.9.2, Scenario 2). The high RVZ1e IU cell radiation is measured on the exhaust of the PCLS expansion tank located in each IU cell. The signal is generated by TRPS when an RVZ1e IU cell radiation input exceeds the high level setpoint. The RVZ1e IU cell radiation is measured with an analog interface on three different channels, one for each division of TRPS. When two-out-of-three or more RVZ1e IU cell radiation channels exceed the allowable limit, an IU Cell Safety Actuation is initiated.

7.4.4.1.16 TSV Fill Isolation Valve Fully Closed

A TSV fill isolation valve fully closed signal protects against the inadvertent addition of target solution to the TSV (Subsection 13a2.1.2.2, Scenario 6). The TSV fill isolation valve fully closed position indication is received by the TRPS as a discrete input from redundant position indicating limit switches on two different channels for each valve. When one-out-of-two or more TSV fill isolation valve fully closed signals are no longer active for either of the TSV fill isolation valves, an IU Cell Safety Actuation is initiated. IU Cell Safety Actuation on TSV fill isolation valves fully closed is only active when the IU cell is undergoing irradiation (Mode 2).

7.4.4.1.17 ESFAS IU Cell TPS Actuation

An ESFAS IU Cell TPS Actuation protects against release of tritium events in the TPS (Subsection 13a2.1.6.2, Scenario 3; and Subsection 13a2.1.12.2, Scenario 1). The actuation signal is generated by ESFAS and provided to only the affected TRPS subsystems when the

Subsection 7.5.4 addresses the specific variables that provide input into the ESFAS, the instrument range for covering normal and accident conditions, the accuracy for each variable, the analytical limit, and response time. The conditions or operating modes applicable to each variable monitored by the ESFAS are described in the technical specifications.

7.5.3.1 Safety Functions

The ESFAS is a plant level control system not specific to any operating unit or process, configured as shown in Figure 7.1-3 The facility operating conditions applicable to each automatic ESFAS safety function listed in this subsection are specified in the technical specifications.

7.5.3.1.1 Supercell Area 1 (PVVS Area) Isolation

Supercell Area 1 (PVVS Area) Isolation is relied upon as a safety-related control for radioactivity release scenarios similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3), and to provide for a consistent confinement strategy for all ten cells of the supercell.

A Supercell Area 1 (PVVS Area) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 1 (PVVS area) inlet isolation dampers
- Deenergize RVZ1 supercell area 1 (PVVS area) outlet isolation dampers
- VTS Safety Actuation which returns the VTS to atmospheric pressure

The ESFAS initiates a Supercell Area 1 (PVVS Area) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 1 (PVVS ~~area~~) radiation
- RCA Isolation

7.5.3.1.2 Supercell Area 2 (Extraction Area A) Isolation

Supercell Area 2 (Extraction Area A) Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3, Scenarios 1, 2, 3, and 13).

A Supercell Area 2 (Extraction Area A) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 2 (extraction area A) inlet isolation dampers
- Deenergize RVZ1 supercell area 2 (extraction area A) outlet isolation dampers
- MEPS A Heating Loop Isolation
- VTS Safety Actuation

The ESFAS initiates a Supercell Area 2 (Extraction Area A) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 2 (extraction ~~area~~ A) radiation
- RCA Isolation

7.5.3.1.3 Supercell Area 3 (Purification Area A) Isolation

Supercell Area 3 (Purification Area A) Isolation is relied upon as a safety-related control for radioactivity release scenarios similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3), and to provide for a consistent confinement strategy for all ten cells of the supercell.

A Supercell Area 3 (Purification Area A) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 3 (purification area A) inlet isolation dampers
- Deenergize RVZ1 supercell area 3 (purification area A) outlet isolation dampers

The ESFAS initiates a Supercell Area 3 (Purification Area A) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 3 (purification ~~area~~ A) radiation
- RCA Isolation

7.5.3.1.4 Supercell Area 4 (Packaging Area 1) Isolation

Supercell Area 4 (Packaging Area 1) Isolation is relied upon as a safety-related control for radioactivity release scenarios similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3), and to provide for a consistent confinement strategy for all ten cells of the supercell.

A Supercell Area 4 (Packaging Area 1) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 4 (packaging area 1) inlet isolation dampers
- Deenergize RVZ1 supercell area 4 (packaging area 1) outlet isolation dampers

The ESFAS initiates a Supercell Area 4 (Packaging Area 1) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 4 (packaging ~~area~~ 1) radiation
- RCA Isolation

7.5.3.1.5 Supercell Area 5 (Purification Area B) Isolation

Supercell Area 5 (Purification Area B) Isolation is relied upon as a safety-related control for radioactivity release scenarios similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3), and to provide for a consistent confinement strategy for all ten cells of the supercell.

A Supercell Area 5 (Purification Area B) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 5 (purification area B) inlet isolation dampers
- Deenergize RVZ1 supercell area 5 (purification area B) outlet isolation dampers

The ESFAS initiates a Supercell Area 5 (Purification Area B) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 5 (purification ~~area~~ B) radiation
- RCA Isolation

7.5.3.1.6 Supercell Area 6 (Extraction Area B) Isolation

Supercell Area 6 (Extraction Area B) Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3, Scenarios 1, 2, 3, and 13).

A Supercell Area 6 (Extraction Area B) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 6 (extraction area B) inlet isolation dampers
- Deenergize RVZ1 supercell area 6 (extraction area B) outlet isolation dampers
- MEPS B Heating Loop Isolation
- VTS Safety Actuation

The ESFAS initiates a Supercell Area 6 (Extraction Area B) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 6 (extraction ~~area~~ B) radiation
- RCA Isolation
- Supercell Area 10 (IXP area) Isolation

7.5.3.1.7 Supercell Area 7 (Extraction Area C) Isolation

Supercell Area 7 (Extraction Area C) Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3, Scenarios 1, 2, 3, and 13).

A Supercell Area 7 (Extraction Area C) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 7 (purification area C) inlet isolation dampers
- Deenergize RVZ1 supercell area 7 (purification area C) outlet isolation dampers
- MEPS C Heating Loop Isolation
- VTS Safety Actuation

The ESFAS initiates a Supercell Area 7 (Extraction Area C) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 7 (extraction ~~Area~~ C) radiation
- RCA Isolation
- Supercell Area 10 (IXP area) Isolation

7.5.3.1.8 Supercell Area 8 (Purification Area C) Isolation

Supercell Area 8 (Purification Area C) Isolation is relied upon as a safety-related control for radioactivity release scenarios similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3), and to provide for a consistent confinement strategy for all ten cells of the supercell.

A Supercell Area 8 (Purification Area C) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 8 (purification area C) inlet isolation dampers
- Deenergize RVZ1 supercell area 8 (purification area C) outlet isolation dampers

The ESFAS initiates a Supercell Area 8 (Purification Area C) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 8 (purification ~~area~~ C) radiation
- RCA Isolation

7.5.3.1.9 Supercell Area 9 (Packaging Area 2) Isolation

Supercell Area 9 (Packaging Area 2) Isolation is relied upon as a safety-related control for radioactivity release scenarios similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3), and to provide for a consistent confinement strategy for all ten cells of the supercell.

A Supercell Area 9 (Packaging Area 2) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 9 (packaging area 2) inlet isolation dampers
- Deenergize RVZ1 supercell area 9 (packaging area 2) outlet isolation dampers

The ESFAS initiates a Supercell Area 9 (Packaging Area 2) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 9 (packaging ~~area~~ 2) radiation
- RCA Isolation

7.5.3.1.10 Supercell Area 10 (IXP Area) Isolation

Supercell Area 10 (IXP Area) Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3, Scenarios 4, 5, 6, and 7).

A Supercell Area 10 (IXP Area) Isolation initiates the following safety functions:

- Deenergize RVZ2 supercell area 10 (IXP area) inlet isolation dampers
- Deenergize RVZ1 supercell area 10 (IXP area) outlet isolation dampers
- Supercell Area 6 (extraction area B) Isolation
- Supercell Area 7 (extraction area C) Isolation

The ESFAS initiates a Supercell Area 10 (IXP Area) Isolation based on the following variable or safety actuation:

- High RVZ1 supercell area 10 (IXP ~~area~~) radiation
- RCA Isolation

7.5.3.1.18 TPS Train A Isolation

TPS Train A Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for external events (Subsection 13a2.1.6, Scenario 3), and for facility specific tritium purification system events (Subsection 13a2.1.12, TPS Scenario 1).

A TPS Train A Isolation initiates the following safety functions:

- Deenergize TPS train A glovebox pressure control exhaust isolation valves
- Deenergize vacuum/impurity treatment subsystem (VAC/ITS) train A process vent ITS isolation valves (TPS train A ITS isolation valves)
- Deenergize TPS train A helium ~~air operated valve (AOV)~~ supply isolation valve
- ~~Deenergize TPS train A helium solenoid operated valve (SOV) supply isolation valve~~
- Deenergize RVZ2 TPS room supply isolation dampers
- Deenergize RVZ2 TPS room exhaust isolation dampers
- Deenergize VAC/ITS train A process vent vacuum isolation valves (TPS train A vacuum isolation valves)
- Deenergize IU Cell 1 TPS Actuation
- Deenergize IU Cell 2 TPS Actuation

The ESFAS initiates a TPS Train A Isolation based on the following variables or safety actuation:

- High TPS IU cell 1 target chamber supply pressure
- High TPS IU cell 2 target chamber supply pressure
- High TPS IU cell 1 target chamber exhaust pressure
- High TPS IU cell 2 target chamber exhaust pressure
- High TPS confinement A tritium
- RCA Isolation
- Facility master operating permissive

7.5.3.1.19 TPS Train B Isolation

TPS Train B Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for external events (Subsection 13a2.1.6, Scenario 3), and for facility specific tritium purification system events (Subsection 13a2.1.12, TPS Scenario 1).

A TPS Train B Isolation initiates the following safety functions:

- Deenergize TPS train B glovebox pressure control exhaust isolation valves
- Deenergize VAC/ITS train B process vent ITS isolation valves (TPS train B ITS isolation valves)
- Deenergize TPS train B helium ~~AOV~~ supply isolation valve
- ~~Deenergize TPS train B helium SOV supply isolation valve~~
- Deenergize RVZ2 TPS room supply isolation dampers
- Deenergize RVZ2 TPS room exhaust isolation dampers
- Deenergize VAC/ITS train B process vent vacuum isolation valves (TPS train B vacuum isolation valves)
- TRPS IU Cell 3 TPS Actuation

- TRPS IU Cell 4 TPS Actuation
- TRPS IU Cell 5 TPS Actuation

The ESFAS initiates a TPS Train B Isolation based on the following variables or safety actuation:

- High TPS IU cell 3 target chamber supply pressure
- High TPS IU cell 4 target chamber supply pressure
- High TPS IU cell 5 target chamber supply pressure
- High TPS IU cell 3 target chamber exhaust pressure
- High TPS IU cell 4 target chamber exhaust pressure
- High TPS IU cell 5 target chamber exhaust pressure
- High TPS confinement B tritium
- RCA Isolation
- Facility master operating permissive

7.5.3.1.20 TPS Train C Isolation

TPS Train C Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for external events (Subsection 13a2.1.6, Scenario 3), and for facility specific tritium purification system events (Subsection 13a2.1.12, TPS Scenario 1).

A TPS Train C Isolation initiates the following safety functions:

- Deenergize TPS train C glovebox pressure control exhaust isolation valves
- Deenergize VAC/ITS train C process vent ITS isolation valves (TPS train C ITS isolation valves)
- Deenergize TPS train C helium ~~AOV~~ supply isolation valve
- ~~Deenergize TPS train C helium SOV supply isolation valve~~
- Deenergize RVZ2 TPS room supply isolation dampers
- Deenergize RVZ2 TPS room exhaust isolation dampers
- Deenergize VAC/ITS train C process vent vacuum isolation valves (TPS train C vacuum isolation valves)
- TRPS IU Cell 6 TPS Actuation
- TRPS IU Cell 7 TPS Actuation
- TRPS IU Cell 8 TPS Actuation

The ESFAS initiates a TPS Train C Isolation based on the following variables or safety actuation:

- High TPS IU cell 6 target chamber supply pressure
- High TPS IU cell 7 target chamber supply pressure
- High TPS IU cell 8 target chamber supply pressure
- High TPS IU cell 6 target chamber exhaust pressure
- High TPS IU cell 7 target chamber exhaust pressure
- High TPS IU cell 8 target chamber exhaust pressure
- High TPS confinement C tritium
- RCA Isolation
- Facility master operating permissive

7.5.4.1 Monitored Variables and Response

Table 7.5-1 identifies specific variables that provide input into the ESFAS and includes the instrument range for covering normal and accident conditions, the accuracy for each variable, the analytical limit, and response time. A discussion of each variable (signal input) and the system response is provided in this section.

7.5.4.1.1 High RVZ1/2 RCA Exhaust Radiation

The high RVZ1~~/~~ and RVZ2 RCA exhaust radiation signals protect~~s~~ against confinement leakage or accidents that could potentially result in excess radiation doses to the workers or to the public (Subsection 13b.1.2.3, Scenarios 8, 10, 11, 12, and 16). ~~The~~A signal is generated by ESFAS when an RVZ1~~/~~ or RVZ2 RCA exhaust radiation input exceeds ~~the~~its high level setpoint. ~~The~~ RVZ~~V~~1~~/~~ and RVZ2 RCA exhaust radiation is measured ~~by~~using an analog interface on three different channels in RVZ1 and three different channels in RVZ2, one channel of each type for each division of ESFAS. When two-out-of-three or more high RVZ1 or two-out-of-three or more high RVZ2 RCA exhaust radiation channels are active, then an RCA Isolation is initiated.

7.5.4.1.2 High RVZ1 Supercell Radiation (PVVS Cell)

The high RVZ1 supercell area 1 (PVVS) radiation signal protects against hot cell equipment leakage or an accident that could potentially result in excess radiation doses to the workers or to the public. The signal is used to indicate potential radioactivity releases in the PVVS cell similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3). The signal is generated by ESFAS when an RVZ1 supercell area 1 (PVVS ~~cell~~) radiation input exceeds the high level setpoint. ~~The~~ RVZ1 supercell area 1 (PVVS) radiation is measured ~~by~~using an analog interface on three different channels, one for each division of ESFAS. When two-out-of-three or more high RVZ1 supercell area 1 (PVVS) radiation channels are active, then a Supercell Isolation for ~~that~~ area 1 and a VTS Safety Actuation are initiated.

7.5.4.1.3 High RVZ1 Supercell Radiation (MEPS Extraction Cells)

The high RVZ1 supercell area 2/6/7 (extraction A/B/C) radiation signals protect~~s~~ against hot cell equipment leakage or an accident that could potentially result in excess radiation doses to the workers or to the public (Subsection 13b.1.2.3, Scenarios 1, 2, 3, and 13) for their respective hot cells. ~~The~~A signal is generated by ESFAS when an ~~MEPS~~ RVZ1 supercell area 2/6/7 (extraction A/B/C) ~~cell~~ radiation input exceeds ~~the~~its high level setpoint. ~~The~~ RVZ1 supercell area 2/6/7 (extraction A/B/C) radiation is measured ~~by~~using an analog interface on two different channels per area, one for each Division A and Division B of ESFAS. When one-out-of-two or more high RVZ1 supercell area 2/6/7 (extraction A/B/C) radiation channels are active (for a single area), then a Supercell Isolation for that area, MEPS Heating Loop Isolation, and VTS Safety Actuation are initiated.

7.5.4.1.4 High RVZ1 Supercell Radiation (IXP Extraction Cell)

The high RVZ1 supercell area 10 (IXP) radiation signal protects against hot cell equipment leakage or an accident that could potentially result in excess radiation doses to the workers or to the public (Subsection 13b.1.2.3, Scenarios 4, 5, 6, and 7). The signal is generated by ESFAS when an RVZ1 supercell area 10 (IXP) ~~extraction cell~~ radiation input exceeds the high level setpoint. ~~The~~ RVZ1 supercell area 10 (IXP) radiation is measured ~~by~~using an analog interface on two different channels, one for each Division A and Division B of ESFAS. When one-out-of-two or more high RVZ1 supercell area 10 (IXP) radiation channels are active, then a Supercell Isolation for ~~that~~ area 10 and a VTS Safety Actuation are initiated.

7.5.4.1.5 High RVZ1 Supercell Radiation (Purification and Packaging Cells)

The high RVZ1 supercell area 3/4/5/8/9 (purification A/B/C and packaging 1/2) radiation signals protect~~s~~ against hot cell equipment leakage or an accident that could potentially result in excess radiation doses to the workers or to the public for their respective hot cells. The signal ~~is~~ are used to indicate potential radioactivity releases in the purification or packaging cells similar to those described in Chapter 13 for RPF critical equipment malfunction events (Subsection 13b.1.2.3). ~~The~~A signal is generated by ESFAS when an RVZ1 supercell area 3/4/5/8/9 (purification A/B/C or packaging 1/2) ~~cell~~ radiation input exceeds ~~the~~its high level setpoint. ~~The~~ RVZ1 supercell area 3/4/5/8/9 (purification A/B/C and packaging 1/2) radiation is measured ~~by~~using an analog interface on two different channels per area, one for each Division A and Division B of ESFAS. When one-out-of-two or more high RVZ1 supercell area 3/4/5/8/9 (purification A/B/C and packaging 1/2) radiation channels are active (for a single area), then a Supercell Isolation for that area is initiated.

7.5.4.1.6 High MEPS Heating Loop Conductivity

The high MEPS heating loop conductivity signal protects against leakage of high radiation solutions into the heating water loop, which is partially located outside the supercell shielding and could potentially result in an excess dose to the workers (Subsection 13b.1.2.3, Scenario 14). The signal is generated by ESFAS when a MEPS heating loop conductivity input exceeds the high level setpoint. The MEPS heating loop conductivity is measured by an analog interface on two different channels, one for each Division A and Division B of ESFAS. MEPS heating loop conductivity is measured in three locations (MEPS A, B, and C). When one-out-of-two or more high MEPS heating loop conductivity channels are active in a given heating loop (A, B, or C), then a MEPS Heating Loop Isolation is initiated for that heating loop.

7.5.4.1.7 High PVVS Carbon Delay Bed Exhaust Carbon Monoxide

The high PVVS carbon delay bed exhaust carbon monoxide signal protects against a fire in the PVVS delay bed (Subsection 13b.1.2.5, Scenario 1). The signal is generated by ESFAS for the associated carbon delay bed group (Group 1, 2, or 3) when a carbon delay bed exhaust carbon monoxide input exceeds the high level setpoint. The PVVS carbon delay bed exhaust carbon monoxide is measured with an analog interface on two different channels, one for each Division A and Division B of ESFAS. When one-out-of-two or more high PVVS carbon delay bed exhaust carbon monoxide channels are active, then a Carbon Delay Bed Isolation for the affected group is initiated.

7.5.4.1.8 VTS Vacuum Header Liquid Detection Switch

The VTS vacuum header liquid detection switch signal protects against an overflow of the vacuum lift tanks to prevent a potential criticality event as described in Subsection 6b.3.2.5. The VTS vacuum header liquid detection switch signal is received by the ESFAS as a discrete input from a liquid detection switch on two different channels, one for each Division A and Division B of

ESFAS. When one-out-of-two or more (Division A and Division B) VTS vacuum header liquid detection switch signals are active, then a VTS Safety Actuation is initiated.

7.5.4.1.9 RDS Liquid Detection Switch

The RDS liquid detection switch signal detects leakage or overflow from other tanks and piping (Subsection 13b.1.2.3, Scenarios 8, 10, 11, 12, and 16). The RDS liquid detection switch signal is received by the ESFAS as a discrete input from a liquid detection switch on two different channels, one for each Division A and Division B of ESFAS. When one-out-of-two or more RDS liquid detection switch signal channels are active, then a VTS Safety Actuation is initiated.

7.5.4.1.10 High TPS IU Cell 1/2/3/4/5/6/7/8 Target Chamber Exhaust Pressure

The high TPS IU Cell 1/2/3/4/5/6/7/8 target chamber exhaust pressure signal protects against a break in the tritium exhaust lines in the IU cell (Subsection 13a2.1.6.2, Scenario 3 and Subsection 13a2.1.12.2, TPS Scenario 3). The signal is generated by ESFAS when a target chamber exhaust pressure input exceeds the high level setpoint. The TPS IU Cell 1/2/3/4/5/6/7/8 target chamber exhaust pressure is measured with an analog interface on two different channels, one for each Division A and Division B of ESFAS. When one-out-of-two or more TPS IU Cell 1/2/3/4/5/6/7/8 target chamber exhaust pressure inputs exceed the allowable limit, the appropriate TPS Train A/B/C Isolation is initiated.

7.5.4.1.11 High TPS IU Cell 1/2/3/4/5/6/7/8 Target Chamber Supply Pressure

The high TPS IU Cell 1/2/3/4/5/6/7/8 target chamber supply pressure signal protects against a break in the tritium supply lines in the IU cell (Subsection 13a2.1.6.2, Scenario 3 and Subsection 13a2.1.12.2, TPS Scenario 3). The signal is generated by ESFAS when a target chamber supply pressure input exceeds the high level setpoint. The TPS IU Cell 1/2/3/4/5/6/7/8 target chamber supply pressure is measured with an analog interface on two different channels, one for each Division A and Division B of ESFAS. When one-out-of-two or more TPS IU Cell 1/2/3/4/5/6/7/8 target chamber supply pressure inputs exceed the allowable limit, the appropriate TPS Train A/B/C Isolation is initiated.

7.5.4.1.12 High TPS Exhaust to Facility Stack Tritium

The high TPS exhaust to facility stack tritium signal protects against a release of tritium from the TPS glovebox pressure control exhaust and VAC/ITS process vent exhaust into the facility ventilation systems (Subsection 13a2.1.12.2, TPS Scenario 3 and TPS Scenario 4). The signal is generated by ESFAS when a TPS exhaust to facility stack tritium input exceeds the high level setpoint. The TPS exhaust to facility stack tritium is measured with an analog interface on three different channels, one for each division of ESFAS. When two-out-of-three or more high TPS exhaust to facility stack tritium channels are active, then a TPS Process Vent Actuation is initiated.

7.5.4.1.13 High TPS Confinement Tritium

The high TPS confinement A/B/C tritium signals protect~~s~~ against a release of tritium from TPS equipment into the associated TPS glovebox (Subsection 13a2.1.12.2, TPS Scenario 1). ~~The~~A signal is generated by ESFAS when a TPS confinement A/B/C tritium input exceeds ~~the~~its high level setpoint. There is an independent and separate tritium measurement for each of the three

TPS trains. ~~The~~ TPS confinement tritium concentration is measured ~~with~~using an analog interface on two different channels per glovebox, one for each Division A and Division B of ESFAS. When one-out-of-two or more high TPS confinement A/B/C tritium channels are active (for a particular glovebox), then a TPS Train A Isolation, TPS Train B Isolation, or TPS Train C Isolation is initiated for the respective TPS train.

7.5.4.1.14 TRPS IU Cell Nitrogen Purge

The TRPS IU cell nitrogen purge signal protects against a loss of hydrogen mitigation capabilities in the irradiation units (Subsection 13a2.1.2.2, Scenario 5 and Subsection 13a2.1.9.2, Scenario 1). The signal is generated by an affected TRPS subsystem and provided to the ESFAS when the TRPS initiates an IU Cell Nitrogen Purge, as described in Subsection 7.4.3.1.2. The TRPS IU cell nitrogen purge signal is transmitted as a discrete input from the TRPS on two different channels, one for each Division A and Division B of ESFAS. When a TRPS IU cell nitrogen purge signal is active, then an ESFAS IU Cell Nitrogen Purge is initiated.

7.5.4.1.15 Low PVVS Flow

The PVVS flow signal protects against loss of hydrogen mitigation capabilities in the RPF (Subsection 13a2.1.6.2, Scenario 7). The signal is generated by ESFAS when a PVVS flow input exceeds the low level setpoint. The PVVS flow is measured with an analog interface on three different channels, one for each division of ESFAS. When two-out-of-three or more low PVVS flow channels are active, then an RPF Nitrogen Purge is initiated.

7.5.4.1.16 MEPS Extraction Column Three-Way Valves Misaligned

The MEPS extraction column three-way valves misalignment signal protects against a misalignment of the extraction column upper and lower three-way valves, degrading one of the barriers preventing misdirection of chemical reagents or target solution (Subsection 13b.1.2.3, Scenario 15). The MEPS extraction column upper and lower three-way valve position indication is received by the ESFAS as a discrete input from redundant position indicating limit switches on two different channels, one for each Division A and Division B of ESFAS, for each three-way valve. When two-out-of-two MEPS extraction column upper and lower three-way valve position indications indicate they are energized, then an Extraction Column Alignment Actuation for that area is initiated.

7.5.4.1.17 IXP Three-Way Valves Misaligned

The IXP three-way valves misalignment signal protects against a misalignment of the upper and lower three-way valves, degrading one of the barriers preventing misdirection of chemical reagents or target solution. The signal is used to detect scenarios similar to a MEPS extraction column three-way valve misalignment as described in Subsection 13b.1.2.3, Scenario 15.The IXP three-way valve position indication is received by the ESFAS as a discrete input from redundant position indicating limit switches on two different channels, one for each Division A and Division B of ESFAS, for each three-way valve. When two-out-of-two IXP three-way valve position indications indicate they are energized, then an IXP Alignment Actuation is initiated.

Table 7.5-1 – ESFAS Monitored Variables
(Sheet 1 of 6)

Variable	Analytical Limit	Logic	Range	Accuracy	Response Time
RVZ1 RCA exhaust radiation	60x background radiation	2/3↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
RVZ2 RCA exhaust radiation	60x background radiation	2/3↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 1 (PVVS~~ area~~) radiation	60x background radiation	2/3↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 2 (extraction ~~area~~ A) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 3 (purification ~~area~~ A) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 4 (packaging ~~area~~ 1) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 5 (purification ~~area~~ B) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 6 (extraction ~~area~~ B) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 7 (extraction ~~area~~ C) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 8 (purification ~~area~~ C) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 9 (packaging ~~area~~ 2) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds
~~S~~RVZ1 supercell area 10 (IXP~~ area~~) radiation	60x background radiation	1/2↑	10^{-7} to 10^{-1} µCi/cc	20 percent	15 seconds

Table 7.5-1 – ESFAS Monitored Variables
(Sheet 4 of 6)

Variable	Analytical Limit	Logic	Range	Accuracy	Response Time
TPS IU cell 7 target chamber supply pressure	8 psia	1/2↑	0 to 19.5 psia	1 percent	10 seconds
TPS IU cell 8 target chamber supply pressure	8 psia	1/2↑	0 to 19.5 psia	1 percent	10 seconds
TPS confinement A tritium	1000 Ci/m^3	1/2↑	~~0.00~~1 to 50,000 Ci/m^3	10 percent	5 seconds
TPS confinement B tritium	1000 Ci/m^3	1/2↑	~~0.00~~1 to 50,000 Ci/m^3	10 percent	5 seconds
TPS confinement C tritium	1000 Ci/m^3	1/2↑	~~0.00~~1 to 50,000 Ci/m^3	10 percent	5 seconds
PVVS flow	5.0 scfm	2/3↓	1-20 scfm	3 percent	0.5 seconds
TSPS dissolution tank 1 level switch signal	Active	1/2↑	Active/Inactive	Discrete input signal	1 second
TSPS dissolution tank 2 level switch signal	Active	1/2↑	Active/Inactive	Discrete input signal	1 second
TRPS IU cell 1 nitrogen purge signal	Active	1/1↑	Active/Inactive	Discrete input signal	500 ms
TRPS IU cell 2 nitrogen purge signal	Active	1/1↑	Active/Inactive	Discrete input signal	500 ms
TRPS IU cell 3 nitrogen purge signal	Active	1/1↑	Active/Inactive	Discrete input signal	500 ms
TRPS IU cell 4 nitrogen purge signal	Active	1/1↑	Active/Inactive	Discrete input signal	500 ms
TRPS IU cell 5 nitrogen purge signal	Active	1/1↑	Active/Inactive	Discrete input signal	500 ms
TRPS IU cell 6 nitrogen purge signal	Active	1/1↑	Active/Inactive	Discrete input signal	500 ms

Table 7.5-2 – Fail Safe Component Positions on ESFAS Loss of Power
(Sheet 2 of 2)

IXP FNHS supply valve
IXP liquid nitrogen supply valve
TPS train A glovebox pressure control exhaust isolation valves
TPS train A ITS isolation valves
TPS train A helium ~~AOV~~ supply isolation valve
~~TPS train A helium SOV supply valve~~
TPS train A vacuum isolation valves
TPS train B glovebox pressure control exhaust isolation valves
TPS train B ITS isolation valves
TPS train B helium ~~AOV~~ supply isolation valve
~~TPS train B helium SOV supply valve~~
TPS train B vacuum isolation valves
TPS train C glovebox pressure control exhaust isolation valves
TPS train C ITS isolation valves
TPS train C helium ~~AOV~~ supply isolation valve
~~TPS train C helium SOV supply valve~~
TPS train C vacuum isolation valves
N2PS PVVS north header valves
N2PS PVVS south header valves
TSPS RPCS supply cooling valves
TSPS RPCS return cooling valve

FAIL-SAFE POSITION: OPEN

RVZ1 exhaust train 1 blower breakers
RVZ1 exhaust train 2 blower breakers
RVZ2 exhaust train 1 blower breakers
RVZ2 exhaust train 2 blower breakers
RVZ2 supply train 1 blower breakers
RVZ2 supply train 2 blower breakers
VTS vacuum transfer pump 1 breakers
VTS vacuum transfer pump 2 breakers
VTS vacuum break valves
PVVS blower bypass valves
PVVS carbon guard bed bypass valves
PVVS carbon delay bed group 1 outlet isolation valves
PVVS carbon delay bed group 2 outlet isolation valves
PVVS carbon delay bed group 3 outlet isolation valves
MEPS A extraction feed pump breakers
MEPS B extraction feed pump breakers
MEPS C extraction feed pump breakers
N2PS IU cell header valves
N2PS RPF header valves

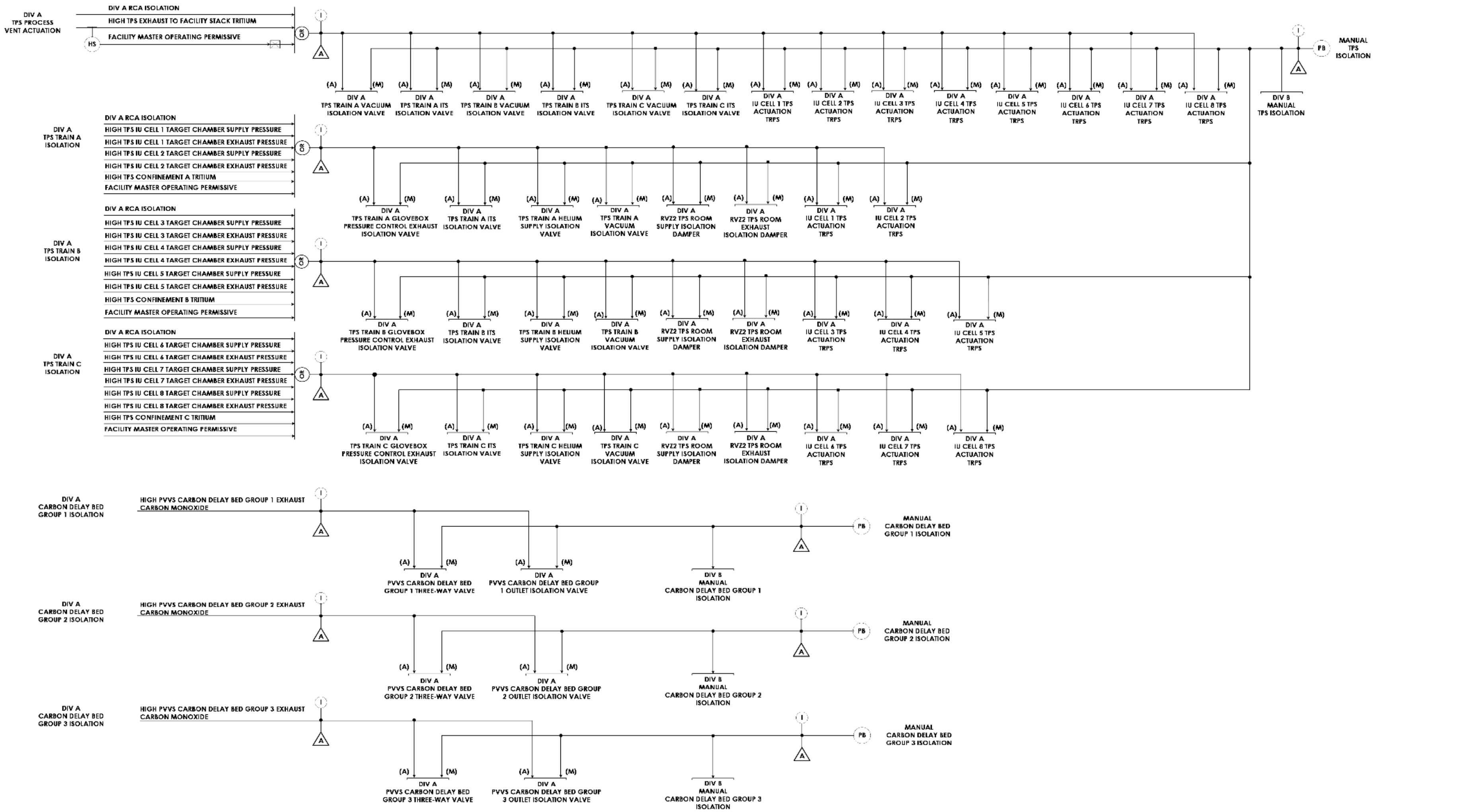
FAIL-SAFE POSITION: SUPPLYING

PVVS carbon delay bed group 1 three-way valves
PVVS carbon delay bed group 2 three-way valves
PVVS carbon delay bed group 3 three-way valves

FAIL-SAFE POSITION: DISCHARGING

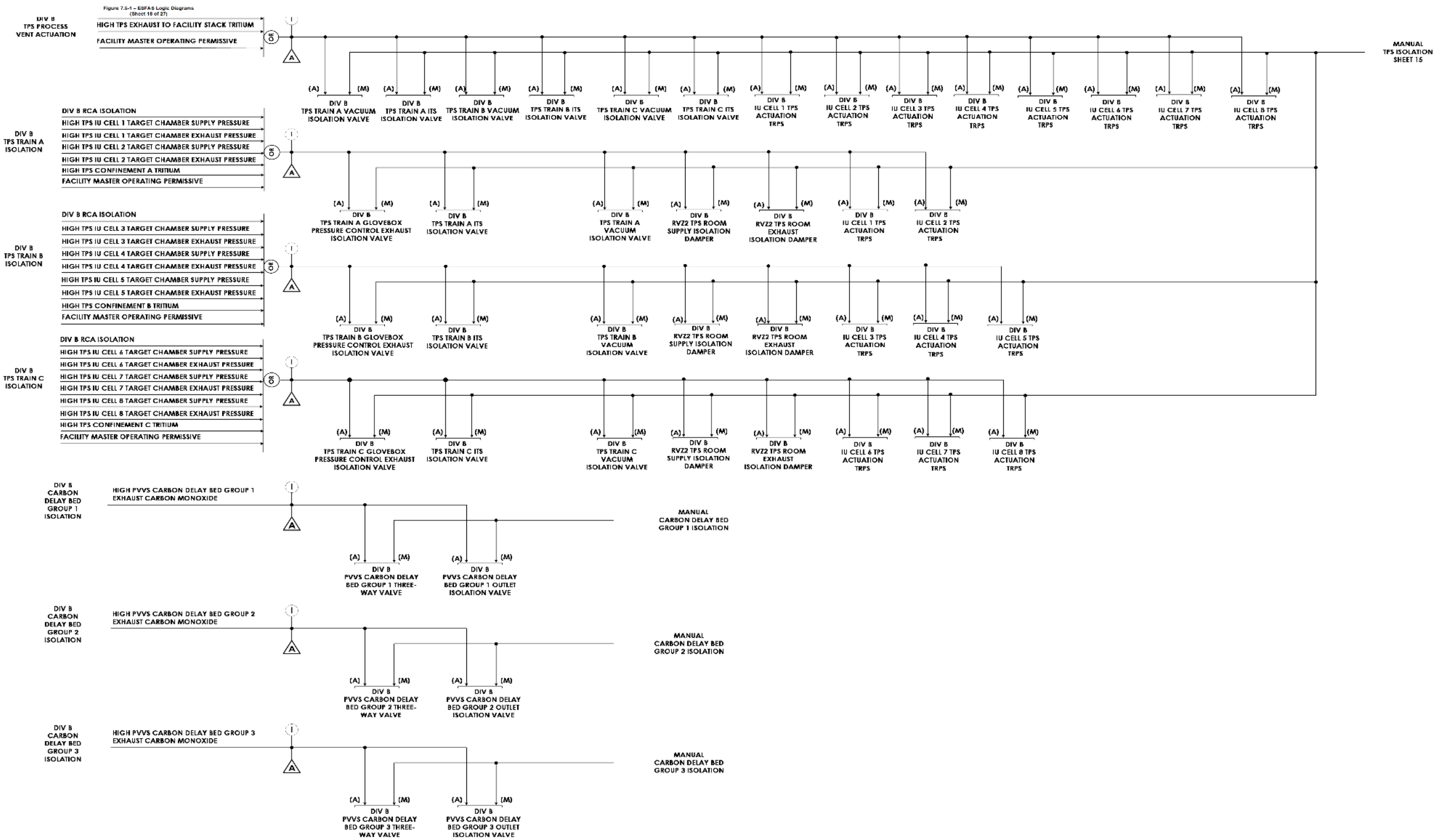
MEPS area A lower three-way valve
MEPS area A upper three-way valve
MEPS area B lower three-way valve
MEPS area B upper three-way valve
MEPS area C lower three-way isolation valve
MEPS area C upper three-way isolation valve
IXP upper three-way valve
IXP lower three-way valve

Figure 7.5-1 – ESFAS Logic Diagrams
(Sheet 14 of 27)



Safety Actuation

Figure 7.5-1 – ESFAS Logic Diagrams
(Sheet 19 of 27)



Safety Actuation

Figure 7.5-1 – ESFAS Logic Diagrams
(Sheet 22 of 27)

Table 7.7-1 – Safety-Related Process Radiation Monitors (Sheet 1 of 4)

Unit	Monitored Material	Monitored Location	Unit Location	Function	Total Available Channels	Minimum Required Channels	Operability Requirements
1	Fission products	~~S~~RVZ1 supercell area 1 (PVVS) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from process vessel ventilation cell (input to ESFAS)	3	2	Whenever PVVS, VTS, or N2PS is operating and hot cell isolation dampers are not closed
2	Fission products	~~S~~RVZ1 supercell area 2 (extraction A) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from extraction cell A (input to ESFAS)	2	2	Whenever target solution or radioisotope products are present in the hot cell and hot cell isolation dampers are not closed
3	Fission products	~~S~~RVZ1 supercell area 3 (purification A) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from purification cell A (input to ESFAS)	2	2	
4	Fission products	~~S~~RVZ1 supercell area 4 (packaging 1) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from packaging cell 1 (input to ESFAS)	2	2	Whenever radioisotope products are present in the hot cell and hot cell isolation dampers are not closed
5	Fission products	~~S~~RVZ1 supercell area 5 (purification B) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from purification cell B (input to ESFAS)	2	2	
6	Fission products	~~S~~RVZ1 supercell area 6 (extraction B) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from extraction cell B (input to ESFAS)	2	2	Whenever target solution or radioisotope products are present in the hot cell and hot cell isolation dampers are not closed
7	Fission products	~~S~~RVZ1 supercell area 7 (extraction C) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from extraction cell C (input to ESFAS)	2	2	Whenever target solution or radioisotope products are present in the hot cell and hot cell isolation dampers are not closed

Table 7.7-1 – Safety-Related Process Radiation Monitors (Sheet 2 of 4)

Unit	Monitored Material	Monitored Location	Unit Location	Function	Total Available Channels	Minimum Required Channels	Operability Requirements
8	Fission products	~~S~~RVZ1 supercell area 8 (purification C) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from purification cell C (input to ESFAS)	2	2	Whenever radioisotope products are present in the hot cell and hot cell isolation dampers are not closed
9	Fission products	~~S~~RVZ1 supercell area 9 (packaging 2) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from packaging cell 2 (input to ESFAS)	2	2	
10	Fission products	~~S~~RVZ1 supercell area 10 (IXP) exhaust ventilation	Supercell exterior	Detect elevated radiation levels from iodine and xenon purification cell (input to ESFAS)	2	2	
11	Fission products	RVZ1 RCA exhaust	Mezzanine (RPF general area)	Detect elevated radiation levels from RVZ1 RCA exhaust (input to ESFAS)	3	2	Whenever facility operations are not secured or RVZ isolation dampers are not closed
12	Fission products	RVZ2 RCA exhaust	Mezzanine (RPF general area)	Detect elevated radiation levels from RVZ2 RCA exhaust (input to ESFAS)	3	2	
13	Tritium	TPS confinement A atmosphere	TPS room	Detect elevated tritium concentration in tritium purification system confinement (input to ESFAS)	2	2	Whenever tritium is present in the TPS confinement in gaseous form
14	Tritium	TPS confinement B atmosphere	TPS room	Detect elevated tritium concentration in tritium purification system confinement (input to ESFAS)	2	2	Whenever tritium is present in the TPS confinement in gaseous form

Table 7.7-1 – Safety-Related Process Radiation Monitors (Sheet 3 of 4)

Unit	Monitored Material	Monitored Location	Unit Location	Function	Total Available Channels	Minimum Required Channels	Operability Requirements
15	Tritium	TPS confinement C atmosphere	TPS room	Detect elevated tritium concentration in tritium purification system confinement (input to ESFAS)	2	2	Whenever tritium is present in the TPS confinement in gaseous form
16	Tritium	TPS exhaust to facility stack	TPS room	Detect elevated tritium concentration in tritium purification system exhaust to RVZ1e (input to ESFAS)	3	2	Whenever tritium is present in the TPS exhaust to RVZ1e in gaseous form and TPS confinement isolation devices are not closed
17	Fission products	RVZ1e IU cell 1 primary closed loop cooling system (PCLS) expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 1 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4
18	Fission products	RVZ1e IU cell 2 PCLS expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 2 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4
19	Fission products	RVZ1e IU cell 3 PCLS expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 3 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4
20	Fission products	RVZ1e IU cell 4 PCLS expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 4 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4
21	Fission products	RVZ1e IU cell 5 PCLS expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 5 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4

Table 7.7-1 – Safety-Related Process Radiation Monitors (Sheet 4 of 4)

Unit	Monitored Material	Monitored Location	Unit Location	Function	Total Available Channels	Minimum Required Channels	Operability Requirements
22	Fission products	RVZ1e IU cell 6 PCLS expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 6 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4
23	Fission products	RVZ1e IU cell 7 PCLS expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 7 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4
24	Fission products	RVZ1e IU cell 8 PCLS expansion tank exhaust	Cooling room	Detect elevated radiation levels from IU 8 PCLS expansion tank exhaust (input to TRPS)	3	2	Modes 1 through 4

During upset conditions, affected sections of the RVZ1e, RVZ2s, and RVZ2e ventilation systems are isolated as required for the specific event or indication. Bubble tight dampers close, based on detection of radiation more than 60 times normal background radiation levels. The RVZ1e supply flow path to the supercell includes nonsafety-related HEPA and carbon filters. The RVZ1e exhaust flow path from the supercell includes nonsafety-related HEPA filters and safety-related carbon filters. The remaining RVZ1e flow paths that exhaust confinements for fission products contain nonsafety-related HEPA and carbon filters. The RVZ1e safety-related, redundant bubble-tight dampers are situated as near to the confinement boundary as practical.

The IU cell exhaust flow path of RVZ1e provides ventilation of the IU cell and TOGS cell via the PCLS expansion tank headspace. This path is equipped with radiation monitoring instrumentation and redundant isolation valves. Between the RVZ1e IU cell radiation instrumentation and RVZ1e IU cell isolation valves is an isolation lag tank. If the RVZ1e IU cell radiation measurements exceed 60 times normal background radiation, the TSV reactivity protection system (TRPS) initiates an IU Cell Safety Actuation, which closes the RVZ1e IU cell isolation valves. The isolation lag tank provides an exhaust gas delay time greater than the closing time of the valves.

Upon loss of power, loss of signal, or ESFAS initiation of confinement, dampers seal the affected confinement areas within 30 seconds.

The RVZ1r fan coil units (FCUs) are capable of continuous operations. The RVZ1r recirculates, and cools air within the IU cell and TOGS cell. The IU cell and TOGS cell are established as low leakage boundaries.

RVZ2e fans are capable of continuous operation. RVZ2e exhausts the various normally occupiable rooms within the RCA as well as fume hoods, filters the air via HEPA filter banks and discharges to the facility stack. Exhaust headers are maintained at a negative pressure by the VFD. Negative pressure is maintained in the ductwork to control contamination and maintain pressure gradients. The exhaust from RVZ2 areas collects in the RVZ2 system duct header and then is drawn through final HEPA filters and carbon adsorbers prior to discharge to the exhaust stack.

During normal operation, ventilation zone 2 areas are maintained at negative pressure with respect to RVZ3 airlocks. The speed of the RVZ2e exhaust fans is controlled to maintain a negative pressure setpoint in the RVZ2e exhaust header. Minimum airflow will be maintained during normal system operation.

RVZ2s AHUs are capable of continuous operation. Ventilation zone 2 areas are directly supplied air via the RVZ2s AHUs. The AHUs supply conditioned, 100 percent outside air. Each AHU contains filters, pre-heat and cooling coils, and supply fans. The supply system includes redundant AHUs. If a single AHU fails, the standby AHU will start automatically. The AHUs normally supply a constant volume of conditioned air to RVZ2 areas.

The RVZ2s supply duct contains safety-related automatic isolation dampers controlled by ESFAS. These dampers are located at the RCA boundary.

RVZ2r AHUs are capable of continuous operation. The RVZ2r AHUs further condition the air in the RCA general area to comfort levels.

water flow rates in response to signals sent to the load instrumentation. A flow control valve is maintained on the system bypass line and is controlled by input signals from FCHS controller inputs made by chiller supply, RVZ2s, and FVZ4 modulating flow control valves.

Each pump's VFD status is monitored by local chiller equipment for fault status and motor amps. When the FCHS controller registers that a pump is not running, and a stop command has not been issued from the control panel, an alarm is generated at the control panel and the standby pump is automatically started.

Local chiller equipment monitors differential pressures across each chiller and the chillers' running status. Upon communication of a fault alarm, an FCHS controller isolates that chillers' modulating flow control valve and issues a start command to the back-up chiller. System pumps respond accordingly to the loading of the chillers via a local controller. Chiller fault alarms on multiple chillers initiates an automatic shutdown of the system through an FCHS controller.

The system maintains alarms monitored by PICS and displays them at operator workstations for system volumes out of range.

9a2.1.3.4 Radiation Protection

There are no radiation contamination hazards associated with the FCHS.

9a2.1.3.5 Instrumentation and Controls

Instrumentation monitors the system for off-normal conditions and signal alarms as required. FCHS controls are nonsafety-related.

The FCHS provides the necessary output signal to the PICS for the monitoring of ~~heating~~chilled water temperatures, pressures, and flow rates.

9a2.1.3.6 Inspection and Testing

The FCHS testing requirements for water piping, pipe supports, and valves are in accordance with ASME B31.9, Building Services Piping (ASME, 2017). Hydrostatic tests are performed in accordance with Section 937.3 of ASME B31.9 (ASME, 2017). Visual welding inspections are performed on piping and piping supports in accordance with ASME B31.9 (ASME, 2017).

9a2.1.3.7 Technical Specifications

There are no technical specification parameters associated with the FCHS.

9a2.1.4 FACILITY HEATING WATER SYSTEM

The facility heating water system (FHWS) is a hydronic hot water heating system configured in a variable primary flow piping arrangement.

9a2.5 POSSESSION AND USE OF BYPRODUCT, SOURCE, AND SPECIAL NUCLEAR MATERIAL

This section applies to the possession and use of byproduct, source, and special nuclear material (SNM) within the irradiation facility (IF). Refer to Section 9b.5 for the discussion of possession and use of byproduct, source, and special nuclear material in the radioisotope production facility (RPF).

The IF is designated as a radiologically controlled area ~~as shown in Figure 1.3-1~~. Radiation protection program controls and procedures, including the as low as reasonably achievable (ALARA) program, applicable to the IF are described in Section 11.1. Radioactive waste management is discussed in Section 11.2. A discussion of the Security Plan is provided in Section 12.8. Discussion of the Emergency Plan is included in Section 12.7. Fire protection details applicable to the IF are described in Section 9a2.3. Technical Specifications include limits that apply to the possession, management, and use of byproduct, source, and SNM.

9a2.5.1 BYPRODUCT MATERIAL

The SHINE facility is designed to generate byproduct materials (e.g., molybdenum-99) for use as medical isotopes. Byproduct materials within the IF include fission and activation products generated during irradiation unit (IU) operations, as well as tritium which is used within the neutron driver assembly system (NDAS) to create deuterium-tritium fusion reactions as described in Section 4a2.1.

The tritium purification system (TPS) controls the distribution and processing of tritium for the NDAS as described in Section 9a2.7. The quantity of tritium within the facility is described in Table 11.1-5. The types and quantities of fission and activation byproduct materials, as well as the systems where these byproduct materials are located, are discussed in Section 11.1.

Additionally, up to eight (alpha, neutron) neutron sources (e.g., Am-241/Be) with combined strength up to [ ][SRI] are used, one in each IU, for IU start-up operations, as described in Section 4a2.2.

9a2.5.2 SOURCE MATERIAL

Source materials in the IF include the depleted uranium (DU) within TPS and the natural uranium neutron multiplier within the subcritical assembly. The DU within TPS is used as storage beds for tritium gas as described in Section 9a2.7. The use of source material within the neutron multiplier is described in Section 4a2.2. SHINE uses up to 330 lbs (150 kg) of DU and 51,000 lbs. (23,000 kg) of natural uranium for these purposes.

9a2.5.3 SPECIAL NUCLEAR MATERIAL

Special nuclear material (SNM) in the IF includes low enriched uranium (LEU) within the target solution vessel (TSV). LEU is irradiated to produce molybdenum-99 by fission within the IF. During this process, plutonium is generated in the target solution and the neutron multiplier. Up to [ ][PROP/ECI] of LEU are used in the IF to support facility operations. The total LEU inventory for the radioisotope production facility is discussed in Section 9b.5.

TPS process equipment and tubing is designed and fabricated with low leakage rate requirements to ensure low tritium leakage to the glovebox atmosphere or IF. Tritium is supplied to the NDAS at sub-atmospheric pressure which reduces leakage potential.

Evaluation of accidents involving releases of tritium from the TPS is discussed in Subsection 13a2.1.12.

9a2.7.1.7 Instrumentation and Controls

The process integrated control system (PICS) provides normal monitoring and control of process variables and control components not important to the safe operation of the TPS. Section 7.3 provides a detailed description of the PICS.

The ESFAS monitors the TPS exhaust to facility stack and TPS confinements for tritium. If the tritium concentration in the TPS exhaust to facility stack exceeds 1 Ci/m^3, the ESFAS initiates a TPS Process Vent Actuation. If the tritium concentration in one of the TPS confinements exceeds 1,000 Ci/m^3, the ESFAS initiates a TPS Train Isolation for the affected train. The ESFAS also initiates a TPS Train Isolation when the TPS target chamber supply or exhaust pressure for an IU cell exceeds 8 psia, indicating a breach in the tritium boundary. Section 7.5 provides a detailed description of the ESFAS.

Additional tritium monitors on the SEC provide nonsafety-related monitoring for chronic sources (leakage and permeation) during normal operations.

9a2.7.1.8 Technical Specifications

Certain material in this subsection provides information that is used in the technical specifications. This includes limiting conditions for operation, setpoints, design features, and means for accomplishing surveillances. In addition, significant material is also applicable to, and may be used for the bases that are described in the technical specifications.

9a2.7.2 NEUTRON DRIVER ASSEMBLY SYSTEM SERVICE CELL

The NDAS service cell (NSC) is a dedicated work area provided to support the staging, commissioning, maintenance, and disposal of a single NDAS unit. The NSC provides additional space for maintenance activities that are difficult or impossible to perform when an NDAS is installed in an IU cell.

9a2.7.2.1 Design Bases

The NSC accommodates commissioning, maintenance, and disposal activities for the operational lifetime of each NDAS.

9a2.7.2.2 System Description

The NSC is a roofless room formed by a shared wall with the [ ]SRI on the north, an exterior building wall on the east, a wall facing the laydown area on the south, and a wall on the west. The NSC contains a service pit to allow installation of a dedicated target for NDAS beam testing. Outside of the NSC, there is sufficient space (either in the laydown area outside the NSC or on the roof of the TPS room) for placement of a control station, high voltage power supply,

Figure 9a2.7-1 – TPS Process Flow Diagram

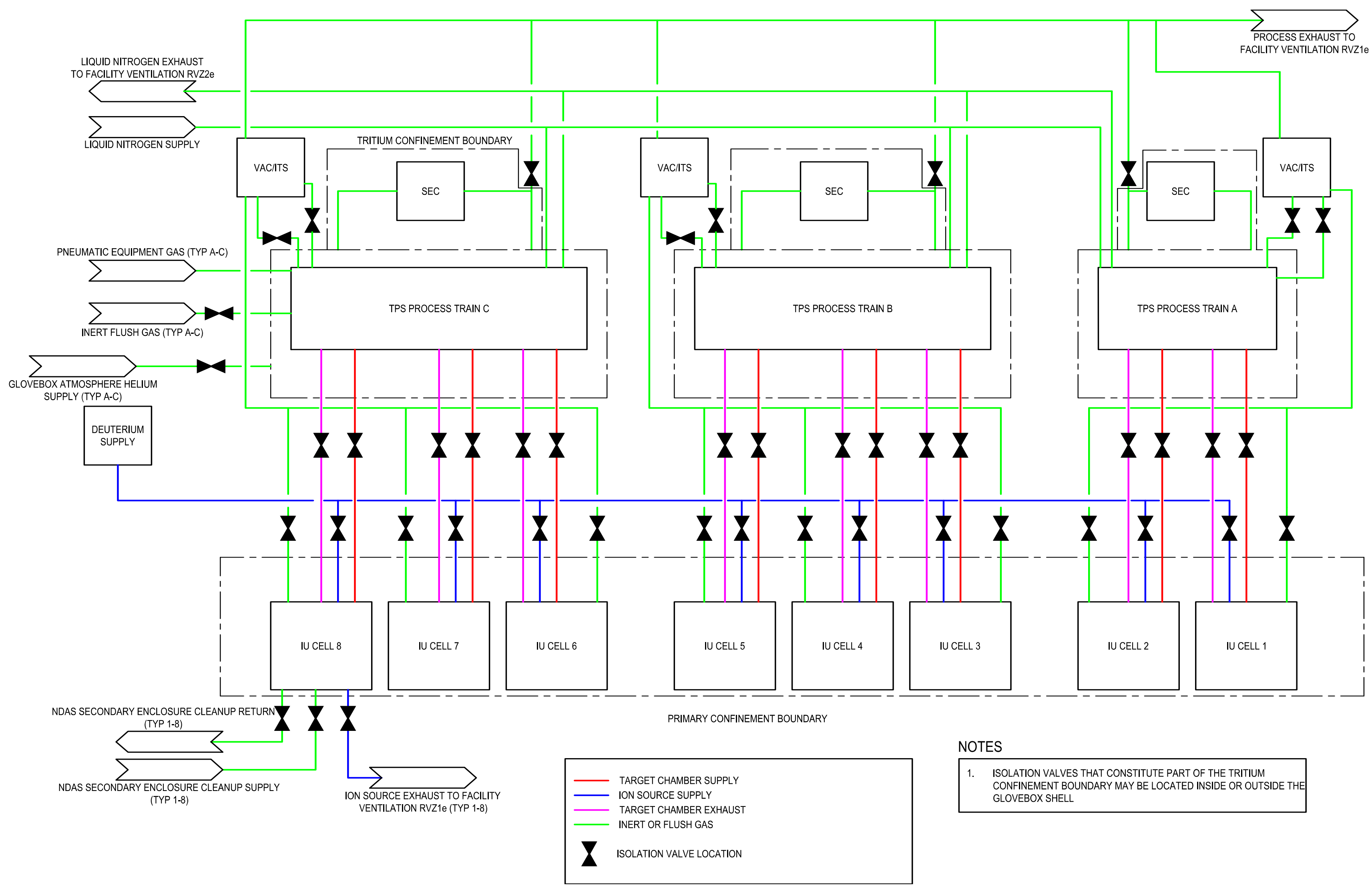
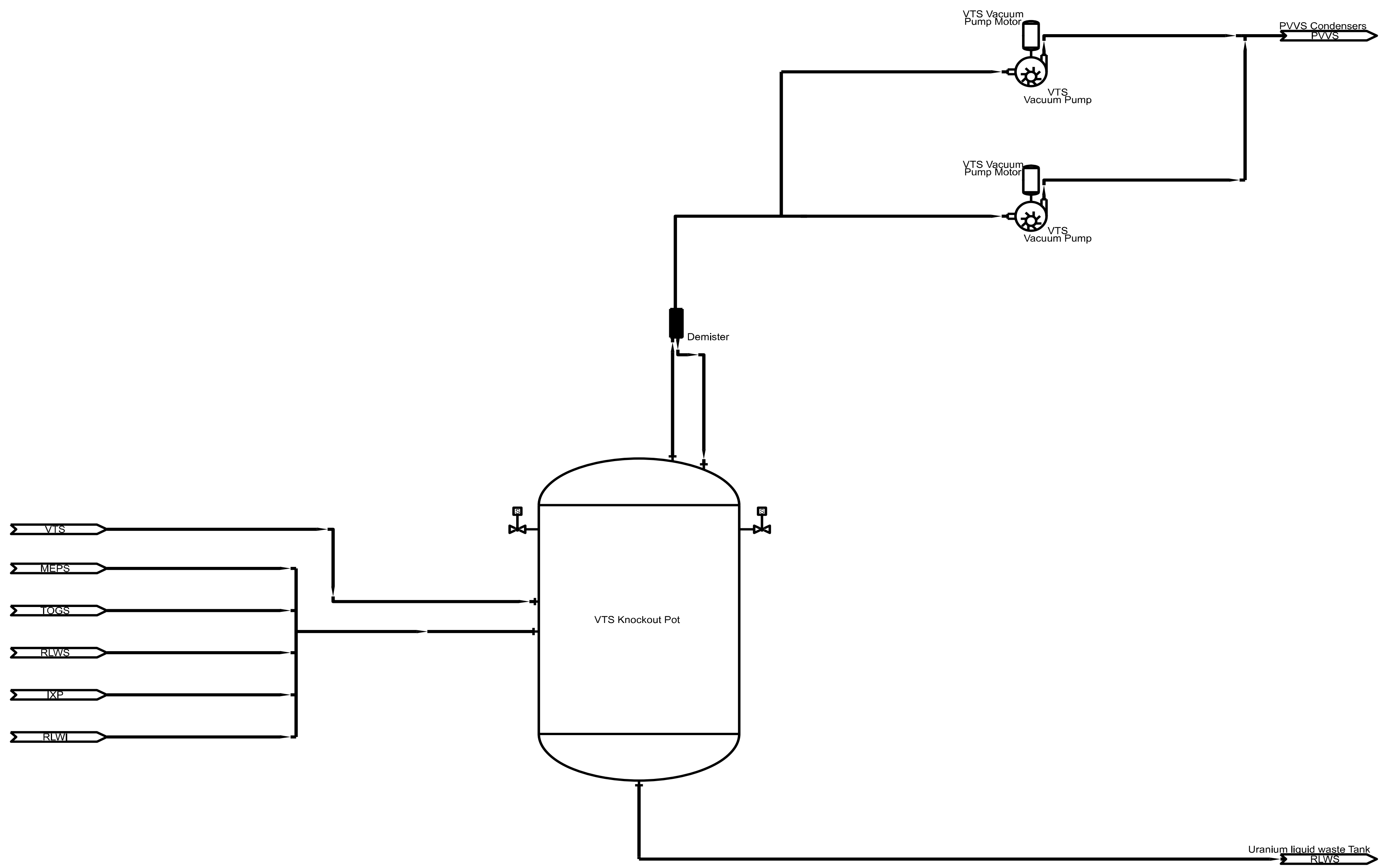


Table 9b.2-1 – Liquid Transfers Using Vacuum Lift Method

Lift	Description
Target solution vessel (TSV) dump tank to molybdenum extraction and purification system (MEPS)	Target solution is transferred from the TSV dump tank to the MEPS using two stages of lift tanks. Extraction lower lift tanks and extraction upper lift tanks. Extraction lower lift tanks are located in hold tank valve pits and extraction upper lift tanks are located in the extraction hot cells.
Target solution hold tank to TSV	Target solution is transferred from the target solution hold tank to the TSV via the TSV fill lift tank. A dedicated TSV fill lift tank is provided for each irradiation unit (IU) cell. Excess target solution in the lift tank when the TSV fill has been completed is drained back to the target solution hold tank.
Between target solution staging system (TSSS) tanks	Target solution may be transferred between TSSS tanks using the target solution storage lift tank. The target solution storage lift tank is located in one of the extraction hot cells.
TSSS tanks to first uranium liquid waste tank	Target solution may be transferred from a TSSS tank to the first uranium liquid waste tank using the ~~liquid waste~~target solution storage lift tank. The ~~liquid waste~~target solution storage lift tank is located in one of the extraction hot cells.
First uranium liquid waste tank to target solution storage tank	Solution may be transferred from the first uranium liquid waste tank to a target solution storage tank using the liquid waste lift tank. The liquid waste lift tank is located in one of the extraction hot cells.
Between uranium liquid waste tanks	Liquid waste is transferred between the uranium liquid waste tanks using the liquid waste lift tank. The liquid waste lift tank is located in one of the extraction hot cells.
Radioactive drain system (RDS) sump tank to first uranium liquid waste tank	Liquid in the RDS sump tank may be transferred to a target solution storage tank using a two-stage lift through the RDS lower lift tank and the liquid waste lift tank. The RDS lower lift tank is located in one of the RDS sump tank vaults and the liquid waste lift tank is located in one of the extraction hot cells.
RDS sump tank to target solution storage tank	Liquid in the RDS sump tank may also be transferred to a target solution storage tank using a two-stage lift through the RDS lower lift tank and liquid waste lift tank. The RDS lower lift tank is located in one of the RDS tank vaults and the liquid waste lift tank is located in one of the extraction hot cells.

Figure 9b.2-1 – Vacuum Transfer System Process Flow Diagram
(Sheet 6 of 6)



9b.5 POSSESSION AND USE OF BYPRODUCT, SOURCE, AND SPECIAL NUCLEAR MATERIAL

This section applies to the possession and use of byproduct, source, and special nuclear material (SNM) in the radioisotope production facility (RPF). The possession and use of byproduct, source, and SNM within the irradiation facility (IF) is described in Section 9a2.5.

The RPF is designated as a radiologically controlled area (RCA) ~~as shown in Figure 1.3-1~~. Radiation Protection Program controls and procedures, including the as low as reasonably achievable (ALARA) Program, applicable to the RPF, are described in Section 11.1. Radioactive waste management is discussed in Section 11.2. A discussion of the Security Plan is provided in Section 12.8. Details of the Emergency Plan are described in Section 12.7. Fire protection details applicable to the RPF are described in Section 9a2.3. Technical Specifications include limits that apply to the possession, management, and use of byproduct, source, and SNM.

The SHINE facility design and procedures ensure that personnel exposures to radiation, including ingestion or inhalation, do not exceed limiting values in 10 CFR 20 and are consistent with the ALARA Program, as described in Section 11.1.

9b.5.1 BYPRODUCT MATERIAL

The SHINE facility is designed to generate byproduct materials (e.g., molybdenum-99) for use as medical isotopes. Byproduct materials within the RPF include fission and activation products generated during irradiation unit (IU) operations. Target solution, containing byproduct and SNM, is transferred from the IF to the RPF for processing. Specific byproduct materials are separated (e.g., molybdenum, iodine) from the irradiated target solution as described in Subsection 4b.3.1.

The systems in which byproduct material may be present in the RPF include:

- The radioactive drain system (RDS), as described in Subsection 9b.7.6. The RDS contains radioactive liquids which contain byproduct materials collected in the event of a leak, spill, or overflow, and routes these liquids to a controlled location.
- The radioactive liquid waste storage (RLWS) system, as described in Subsection 9b.7.4. The RLWS system provides receipt, mixing, and storage for aqueous radioactive wastes containing byproduct materials generated by processing operations within the RCA.
- The radioactive liquid waste immobilization (RLWI) system, as described in Subsection 9b.7.3. The RLWI immobilizes liquid radioactive wastes which contain byproduct materials generated by processing operations within the RCA.
- The process vessel vent system (PVVS), as described in Subsection 9b.6.1. The PVVS collects and treats off-gases containing byproduct materials from each RPF tank containing irradiated solutions, VTS vacuum pump discharge, and from the target solution vessel (TSV) off-gas system (TOGS).
- The molybdenum isotope product packaging system (MIPS), as described in Subsection 9b.7.1. The MIPS receives finished products (e.g., molybdenum-99, iodine-131, xenon-133) in their product bottles and places them in the applicable shipping container.
- The solid radioactive waste packaging (SRWP) system, as described in Subsection 9b.7.5. The SRWP system packages solid waste containing byproduct materials for shipment and disposal.

- The quality control and analytical testing laboratories (LABS), as described in Subsection 9b.5.4. The LABS analyze samples containing byproduct materials taken from various locations throughout the SHINE process.
- The target solution staging system (TSSS), as described in Subsection 4b.1.3.5. The TSSS is a set of tanks and piping used to provide staging and storage of irradiated target solution containing byproduct materials.
- The vacuum transfer system (VTS) as described in Subsection 9b.2.5. The VTS provides transfer of radioactive liquids containing byproduct materials throughout the RPF and also provides vacuum service to the MIPS and the TOGS.
- The molybdenum extraction and purification system (MEPS) as described in Subsection 4b.3.1. The MEPS extracts molybdenum from irradiated target solution and prepares a concentrated form of molybdenum.
- The iodine and xenon purification and packaging (IXP) system as described in Subsection 4b.3.1. The IXP extracts iodine from an acidic solution following target solution irradiation.

The types and quantities of byproduct materials within the main production facility are discussed in Section 11.1.

9b.5.1.1 Byproduct Materials Extraction and Purification

Extraction and purification of byproduct materials occur in the MEPS and IXP. The MEPS and the IXP are described in Subsection 4b.3.1. The primary byproduct material separated in the MEPS is molybdenum-99. The primary byproduct materials separated in the IXP are iodine-131 and xenon-133. A batch of molybdenum-99 is up to ~~[~~ 5000 Ci~~]PROP/ECI~~ and up to 8 batches of molybdenum-99 may be produced a week. ~~A batch~~The maximum amount of iodine-131 shipped per week is ~~up to [~~ 2000 Ci~~]PROP/ECI and up to 8 batches of iodine-131 may be produced a week~~. ~~A batch~~The maximum amount of xenon-133 shipped per week is ~~up to [~~ 2000 Ci~~]PROP/ECI and up to 8 batches of xenon-133 may be produced a week~~.

9b.5.2 SOURCE MATERIAL

Source material is not normally possessed or used within the RPF. There is a potential for radioactive waste containing source material to be processed within the RPF. This may include IF components such as tritium storage beds (i.e., depleted uranium) or neutron multipliers. The types and quantities of source material within these components are described in Section 9a2.5. Radioactive waste management is discussed in Section 11.2.

9b.5.3 SPECIAL NUCLEAR MATERIAL

SNM in the RPF includes low enriched uranium (LEU) as well as plutonium generated in irradiated target solution located in systems throughout the RPF. The systems in which SNM may be present in the RPF are:

- The target solution preparation system (TSPS), as described in Subsection 4b.4.2. The TSPS is used to prepare LEU uranyl sulfate solution.
- The RDS, as described in Subsection 9b.7.6. The RDS contains liquids containing SNM collected in the event of a leak, spill, or overflow, and routes these liquids to a controlled location.

Table 9b.5-1 – Quality Control and Analytical Testing Laboratories System Interfaces (Sheet 2 of 2)

System	Interface Description
Facility demineralized water system (FDWS)	- The FDWS provides deionized water to the LABS for sample preparation. - The FDWS provides deionized water to each of the laboratory deionized water point of use locations. - The FDWS provides water to each emergency eyewash and shower located in the LABS.
Solid radioactive waste processing (SRWP) system	The SRWP system collects, transports, and packages for shipment solid radioactive waste from the LABS including, but not limited to, laboratory glassware, personal protective equipment, and immobilized liquid waste.
Process integrated control system (PICS)	The PICS monitors exhaust air flow rate from each fume hood and actuates a local alarm upon low flow conditions.
Stack release monitoring system (SRMS)	The LABS provide sample analysis for the SRMS.
Continuous air monitoring system	The LABS provide sample analysis for the CAMS.
Facility nitrogen handling systems (FHNS)	The FNHS provides nitrogen gas supply for low pressure utility and analytical tasks. The FNHS provides liquid nitrogen to dewars to supply the needs of the instrument laboratory.

~~Redundant gas analyzers monitor the hydrogen concentration upstream of the guard beds. The~~Carbon monoxide gas analyzers are used to monitor the operation of the delay beds and to monitor carbon monoxide concentrations in the bed effluent.

Flow instrumentation is used to monitor the flow rate of air from ventilation zone 2 into the RPF tanks and vessels ventilated by PVVS. The PICS alerts operators on low flow. Flow instrumentation is used to monitor the flow rate of air from the RPF tanks and vessels to the condensers. The system is designed to maintain this flow rate above the minimum required to maintain hydrogen levels below the LFL.

Pressure instrumentation is provided to monitor performance of the HEPA filters.

9b.6.1.5 Radiological Protection and Criticality Control

PVVS processes are performed within the production facility biological shield (PFBS) hot cells and below-grade vaults, which supports compliance with the as low as reasonably achievable (ALARA) objectives and 10 CFR 20 dose limits. Section 11.1 provides a description of the radiation protection program, and Section 4b.2 provides a detailed description of the PFBS.

There are no credible mechanisms by which to create a criticality hazard in the PVVS. As described in Subsection 6b.3.1.6, there are no identified criticality safety controls for the PVVS.

9b.6.1.6 Technical Specifications

Certain material in this subsection provides information that is used in the technical specifications. This includes limiting conditions for operation, setpoints, design features, and means for accomplishing surveillances. In addition, significant material is also applicable to, and may be used for the bases that are described in the technical specifications.

9b.6.2 NITROGEN PURGE SYSTEM

The N2PS provides a backup supply of sweep gas to each irradiation unit (IU) and to all tanks normally ventilated by the PVVS during a loss of normal power or loss of normal sweep gas flow. The off-gas resulting from the nitrogen purge is treated by passive PVVS filtration equipment prior to being discharged to the stack, as discussed in Subsection 9b.6.1.2. The nitrogen supply pressure is regulated to overcome the pressure drop through pipe fittings, PVVS filtration components, and the facility stack. The N2PS is safety-related and Seismic Category I. A description of system interfaces is provided in Table 9b.6-3.

9b.6.2.1 Design Bases

The design bases of the N2PS include:

- Ensure safe shutdown by preventing detonations or deflagrations from potential hydrogen accumulation in the IUs and RPF processes during deviations from normal conditions; and
- Remain functional during and following design basis events.

The safety function of the RLWS system is to prevent inadvertent criticality through design of equipment in accordance with the criticality safety evaluation. A description of provisions for criticality control in the RLWS system is provided in Subsection 6b.3.2.2.

9b.7.4.4 Instrumentation and Control

Valve position indicators and temperature~~,~~ and level~~, and uranium concentration~~ instrumentation provide remote indication of operating state of the RLWS tanks. Output of valve position indicators and other instrumentation is provided to the remotely-located PICS.

9b.7.4.5 Technical Specifications

Certain material in this section provides information that is used in the technical specifications. This includes limiting conditions for operation, setpoints, design features, and means for accomplishing surveillances. In addition, significant material is also applicable to, and may be referenced by, the bases that are described in the technical specifications.

9b.7.5 SOLID RADIOACTIVE WASTE PACKAGING SYSTEM

9b.7.5.1 Design Bases

The design bases function of the solid radioactive waste packaging (SRWP) system is to collect, segregate, and stage for shipment, solid radioactive wastes from the IF and RPF in accordance with the radioactive waste management program.

9b.7.5.2 System Description

The SRWP system consists of equipment designed and specified to collect and package solid radioactive waste from systems throughout the IF and RPF without limiting the normal operation or availability of the facilities. Solid waste may include dry active waste (DAW), spent ion exchange resin, and filters and filtration media. The SRWP system also inventories materials entering and exiting the facility structure storage bore holes as the supercell imports and exports them.

Table 11.2-1 includes a summary of the estimated annual waste stream and Table 11.1-10 includes a description of radioactive sources. Tables 11.2-2 through 11.2-4 present the waste methodology associated with the disposal of neutron drivers, spent columns, and process glassware, respectively.

Table 9b.7-3 identifies the systems which interface with the ~~SWRP~~SRWP system.

9b.7.5.3 Operational Analysis and Safety Function

Solid radioactive waste is collected in segregated containers. Containers may be sorted for potentially non-contaminated waste. Contaminated waste is sealed, labeled, and transported to the material staging building for characterization, documentation, and staging for shipment. Solid wastes potentially having high levels of radioactivity are collected and transported to the material staging building in shielded casks.

Shielding and radiological protection is not required for the FPWS and the FPWS contains no SNM.

The FPWS is nonsafety-related.

9b.7.7.4 Instrumentation and Control

The FPWS hot water supply is equipped with automatic temperature controls capable of adjustments.

9b.7.7.5 Technical Specifications

There are no technical specification parameters associated with the FPWS.

9b.7.8 FACILITY NITROGEN HANDLING SYSTEM

9b.7.8.1 Design Bases

The facility nitrogen handling system (FNHS) is designed to supply liquid and compressed gaseous nitrogen to systems inside the RCA. The FNHS gaseous piping is designed, constructed, and tested in accordance with the ASME B31.9, Building Services Piping (ASME, 2011b). The FNHS liquid nitrogen piping is designed, constructed, and tested in accordance with ASME B31.3, Process Piping (ASME, 2013). The FNHS vaporizers, receivers, and bulk liquid nitrogen tanks are designed, constructed, and tested to the ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels (ASME, 2010). The balance of the equipment included in the FNHS is commercially available and is designed to standards satisfying the system operation.

The design basis of the FNHS includes:

- Provide nitrogen gas at the pressures and flow rates to operate sampling equipment in the RLWS system, ~~the RDS, the TSSS,~~ the MEPS, ~~and the target solution preparation system (TSPS)~~the IXP system, and the VTS.
- Provide nitrogen gas supply in the RDS and the TSSS for liquid level detectors for system tanks.
- Provide nitrogen gas for sparging and mixing of tanks in the RLWS, the TSSS, the MEPS, the RDS, and the IXP system.
- Provide liquid and gaseous nitrogen to the TPS. Gaseous nitrogen is used by the TPS to operate pneumatic equipment. Liquid nitrogen is supplied to the TPS cryopumps and the thermal cycling absorption process (TCAP) isotope separation columns.
- Provide liquid nitrogen in dewars to the IXP system and the instrument laboratory for equipment cooling.
- Provide nitrogen gas to the TOGS for pressure regulation.
- Provide nitrogen gas to the ~~PCLS and the~~ FFPS for pneumatic control mechanisms.
- Provide nitrogen gas to the MEPS pneumatic pumps for operating the pumps.
- Provide nitrogen gas to the LABS for low pressure utility and analytical tasks.
- Provide nitrogen gas to the PFBS for supercell isolation dampers.

The FNHS is not relied upon to prevent accidents that could cause undue risk to the health and safety of the workers and the public or to control or mitigate the consequences of such accidents.

Table 9b.7-4 – Radioactive Drain System Interfaces

Interfacing System	Interface Description
Process vessel vent system (PVVS)	PVVS provides the RDS sump tanks with ventilation to mitigate hydrogen accumulation in the tank headspace.
Nitrogen purge system (N2PS)	The N2PS provides a source of sweep gas to mitigate hydrogen accumulation in RDS sump tanks in the event of a failure of PVVS to provide the sweep gas.
Facility nitrogen handling system (FNHS)	The FNHS provides a nitrogen gas supply for liquid level detectors for the RDS sump tanks. The FNHS provides compressed gas to the RDS sump tanks for solution agitation.
Target solution staging system (TSSS)	The RDS provides capacity to collect solution from the target solution hold tanks and the target solution storage tanks that results from overflow of these tanks.
Radioactive liquid waste storage (RLWS) system	The RDS provides capacity to collect solution from the uranium liquid waste tanks that results from overflow of these tanks.
Vacuum transfer system (VTS)	The VTS provides liquid transfer out of the RDS tanks.
Engineered safety features actuation system (ESFAS)	ESFAS monitors tank level sensors and mitigates potential sources of leaks.
Process integrated control system (PICS)	The RDS system provide measurement signals to the PICS of sump tank levels as well as tank temperature.
Normal electrical power supply system (NPSS)	The RDS is powered by the NPSS.
Uninterruptible power supply system (UPSS)	The UPSS supplies electrical power to leak detection equipment that is part of the RDS in the event that normal electrical power is lost.
Process facility biological shield (PFBS)	The PFBS provides shielding from sources of radiation in RDS to ensure that accumulated doses in occupied areas do not exceed defined limits. The RDS collects solution from drip pans located in the supercell, valve pits, tank vaults, and trenches that have the potential to contain liquid that requires favorable geometry.
Quality control and analytical testing laboratories (LABS)	LABS measure properties of solution from the RDS.

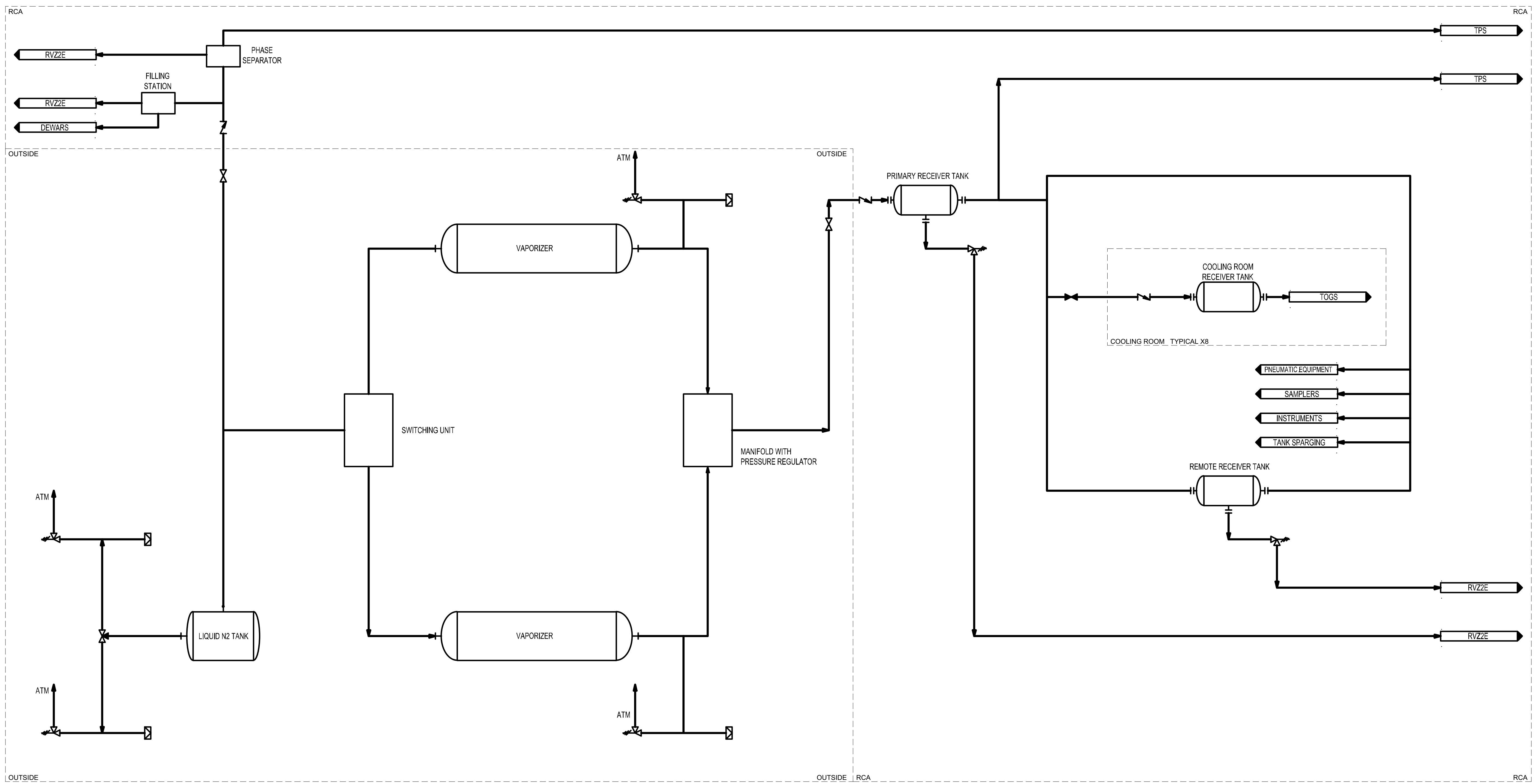
Table 9b.7-5 – Facility Nitrogen Handling System Interfaces (Sheet 1 of 2)

Interfacing System	Interface Description
Quality control and testing analytical laboratories (LABS)	The FNHS provides liquid nitrogen to dewars to supply the needs of the instrument laboratory. The FNHS provides a nitrogen gas supply for low pressure utility and analytical tasks.
Facility fire detection and suppression system (FFPS)	The FNHS provides nitrogen gas to pneumatic actuators for the pre-action fire system.
Iodine and xenon purification and packaging (IXP) system	The FNHS provides ~~a~~ nitrogen gas ~~supply line~~ for product bottle sparging and sampling equipment. The FNHS portable dewars, containing liquid nitrogen, interface with the IXP cryotraps to cool system components.
Molybdenum extraction and purification system (MEPS)	The FNHS provides nitrogen gas to MEPS pneumatic pumps. The FNHS provides nitrogen gas to sampling equipment maintained by the MEPS.
~~Primary closed loop cooling system (PCLS)~~	~~The FNHS maintains nitrogen gas supply to PCLS nitrogen operated valves in each of the cooling rooms.~~
Radioactive drain system (RDS)	~~The FNHS provides nitrogen gas to sampling equipment maintained by the RDS.~~ The FNHS provides nitrogen gas to facilitate sparging and mixing operations in the RDS sump tanks. The FNHS provides a nitrogen gas supply for liquid level detectors in the RDS sump tanks.
Radioactive liquid waste storage (RLWS) system	The FNHS provides nitrogen gas to sampling equipment maintained by the RLWS. The FNHS provides nitrogen gas to facilitate sparging and mixing operations in the uranium liquid waste tanks. The FNHS provides a nitrogen gas supply for liquid level detectors in the liquid waste blending tanks, uranium liquid waste tanks, and liquid waste collection tanks.
Tritium purification system (TPS)	The FNHS provides liquid nitrogen directly piped to the TPS. The FNHS provides nitrogen gas for the operation of pneumatic equipment.
Target solution vessel (TSV) off-gas system (TOGS)	The FNHS maintains nitrogen gas supply to each of the TOGS skids through a penetration made in each cooling room.
~~Target solution preparation system (TSPS)~~	~~The FNHS provides nitrogen gas to sampling equipment maintained by the TSPS~~

Table 9b.7-5 – Facility Nitrogen Handling System Interfaces (Sheet 2 of 2)

Interfacing System	Interface Description
Target solution staging system (TSSS)	~~The FNHS provides nitrogen gas to sampling equipment maintained by the TSSS.~~ The FNHS provides nitrogen gas to facilitate sparging and mixing operations in the target solution hold tanks and target solution storage tanks. The FNHS provides a nitrogen gas supply for liquid level detectors in the target solution hold tanks and target solution storage tanks.
Vacuum transfer system (VTS)	The FNHS provides nitrogen gas to sampling equipment maintained by the VTS.
Production facility biological shield (PFBS)	The FNHS provides nitrogen gas to isolation dampers maintained by the supercell.

Figure 9b.7-6 – FNHS Process Flow Diagram



A failure of the PSB between the TSV and the PCLS may be caused by excessive corrosion of PSB components. This failure generally results in water in-leakage to the primary system from the PCLS. The water in-leakage fills the TSV dump tank, TSV, and TOGS with a mixture of target solution and PCLS water. Potential consequences of the flooding of the PSB include an inadvertent criticality within TOGS or deflagration of hydrogen gas in the TSV headspace or TOGS due to insufficient sweep gas flow. Criticality in the TOGS is prevented by the favorable geometry of the TOGS components, as discussed in Section 4a2.8.

Consequences related to hydrogen deflagrations are described in Subsection 13a2.2.9.

~~Defense-in-depth~~DID protections are present to help prevent a failure of the PSB between the TSV and PCLS, which include:

- control of solution pH through target solution sampling in the target solution hold tank;
- a 30-year corrosion allowance in the PSB component design;
- chemistry monitoring of the PCLS to limit corrosion (see Section 5a2.5).

Scenario 3 – Failure of the RPCS-to-PSB Interface

A failure of the RPCS pressure boundary in the TOGS may be caused by excessive corrosion of the PSB in a TOGS condenser. This failure results in water in-leakage to the primary system from the RPCS. The water in-leakage fills the TSV dump tank, TSV, and TOGS with a mixture of target solution and RPCS water. Potential consequences of the flooding of the PSB include an inadvertent criticality in TOGS or deflagration of hydrogen gas in the TSV headspace or TOGS due to insufficient sweep gas flow. Criticality in the TOGS is prevented by the favorable geometry of the TOGS components, as discussed in Section 4a2.8.

Consequences related to hydrogen deflagrations are discussed in Subsection 13a2.1.9.

Scenario 4 – Failure of the TSV-to-PCLS Pressure Boundary Resulting in Target Solution Leakage to the PCLS

Leakage from the primary system into the PCLS due to a failure of the PSB between the TSV and the PCLS is an additional concern. This failure results in: (1) a potential release of target solution into the primary cooling room with potential for higher dose to workers or the public, or (2) a criticality accident in PCLS equipment. Normally the PCLS is at higher pressure than the TSV, so water will flow from the PCLS into the TSV. However, once pressure equilibrium is established, target solution could leak into the PCLS. The protections in place to prevent and mitigate a failure of the PSB between the TSV and PCLS are PCLS isolation supply and return valves, radiation detection on the RVZ1e exhaust from the PCLS expansion tank, and redundant isolation dampers on the RVZ1e exhaust from the PCLS expansion tank. Target solution leakage into the PCLS will result in radioactive gases entering the PCLS expansion tank, flowing past the RVZ1e IU cell radiation ~~detection~~monitors in the RVZ1e exhaust duct, and initiating an IU Cell Safety Actuation including isolation of the PCLS isolation valves and the RVZ1e exhaust duct.

As ~~defense-in-depth~~DID, the failure of the pressure boundary may first result in in-leakage and overflow into the TSV dump tank, which is detected with the level detection in the TSV dump tank. The TRPS then closes the PCLS isolation valves and RVZ1e isolation dampers, stopping potential transfer of target solution to the PCLS and reducing the source of water that could enter the PSB, and isolating the ventilation exhaust from the IU cell.

intact during normal operation as well as during ~~design basis earthquake~~DBE and ~~design basis accident~~DBA events. Penetrations through the light water pool liner are above the minimum water level. ~~The light water pool is also equipped with a leak chase system to detect leaks.~~

Flooding caused by external events is discussed in Subsection 13a2.1.6.

Dynamic Effects

Process systems in the main production facility operate at low temperatures (i.e., generally less than 200°F [93°C], except for the TOGS hydrogen recombination components) and low pressures (i.e., less than 100 psig [689 kPa gauge]), which are not subject to dynamic effects as are found in high energy systems. As needed, safety-related systems are protected from the dynamic effects related to equipment failure and external events. No consequences result from dynamic effects interactions in the main production facility.

Human Intervention Interactions

Human interventions can cause adverse system interactions because of the single common control room at the main production facility. Operators are able to control multiple systems within the IF and the RPF from the control room. Operator errors may occur including performing control operations on the wrong system, failing to perform required actions, or performing actions out of sequence.

Maintenance is performed as a normal scheduled activity and as a response to emergent equipment problems. Maintenance may occur during all modes of operation, including while irradiation or processing activities are in progress. Errors that occur during maintenance activities can cause failures in operating systems such as support systems. Maintenance errors may be detected upon return to service through post-maintenance testing. However, undetected errors may result in system failures at some later point in time.

Human intervention interactions as accident scenario initiating events are described in other sections in this chapter as applicable and are not evaluated further in this section.

13a2.1.11.3 Accident Consequences

The system interactions described in the preceding sections do not result in radiological consequences. Accident consequences resulting from system interactions that are referenced to other subsections in Chapter 13 are evaluated in those subsections.

Further discussion regarding system interaction events described in this section is provided in Subsection 13a2.2.11.

13a2.1.12 FACILITY-SPECIFIC EVENTS

Several accident scenarios that are unique to the IF and have the potential for inadvertent radiation exposure to workers or members of the public were evaluated. Facility-specific accident scenarios are associated with the NDAS, the TPS, and potential IF damage resulting from heavy load drops.

13a2.1.12.1 Identification of Causes, Initial Conditions, and Assumptions

General scenario descriptions for events involving the NDAS, TPS, and heavy load drop include causes of each scenario.

For accident scenarios involving the NDAS, the following initial conditions and assumptions apply:

- The NDAS contains the bounding inventory of tritium gas for full power.
- The NDAS pressure vessel contains the maximum inventory of sulfur hexafluoride (SF_6) gas.
- The primary confinement boundary for an affected IU cell is operable, including the RVZ1e IU cell radiation ~~detection~~monitors and isolation valves.

For accident scenarios involving the TPS, the following initial conditions and assumptions apply:

- The TPS glovebox confinement is operable, including the confinement isolation valves.
- The glovebox atmosphere is inerted with helium.
- Automatic isolation valves are installed in the system to isolate sections of the system to minimize system release.
- Leakage of tritium from the glovebox enclosure or the external piping is detected by the continuous airborne monitoring system (CAMS) or other leakage detection systems to provide alarms for facility personnel evacuation.
- The TPS-NDAS interface lines contain the maximum inventory of tritium gas.

For accident scenarios involving heavy load drops, the following initial conditions and assumptions apply:

- An IU cell is in maintenance with the IU cell shielding plug removed and the TSV and NDAS empty, or
- An IU cell is in service with IU cell shielding plug in place.

13a2.1.12.2 General Scenario Descriptions

Neutron Driver Assembly System Event Descriptions

There are four scenarios that are specific to the operation of the NDAS in the IF. These scenarios are: (1) inadvertent exposure to neutrons within the IU, (2) inadvertent exposure to neutrons in the NDAS service cell (NSC), (3) catastrophic failure of the NDAS, and (4) an NDAS vacuum boundary failure.

<u>NDAS Scenario 1 – Inadvertent Exposure to Neutrons within the IU</u>

Inadvertent exposure to neutrons may be caused by operation of a neutron driver while personnel are in the IU cell, such as during maintenance or assembly/disassembly activities, inadvertent access to an IU cell during irradiation operations, or failure to properly install IU cell shielding following access. An operator error which results in the neutron driver becoming energized with nearby personnel or without adequate shielding results in a significant neutron dose to workers. Operator error is the most likely cause of inadvertent exposure to neutrons within the IU.

Because the postulated reduction in cooling events do not exceed any design limits or cause damage to the PSB, there is no radiation source term.

13a2.2.3.6 Radiological Consequences

Because the postulated reduction in cooling events do not exceed any design limits or cause damage to the PSB, there are no radiological consequences to workers or the public from a reduction in cooling event.

13a2.2.4 MISHANDLING OR MALFUNCTION OF TARGET SOLUTION

The bounding scenario analyzed as a ~~design basis accident (~~DBA~~)~~ for mishandling or malfunction of target solution is a loss of the PSB integrity which results in a release of target solution into the IU cell. This scenario is described in Subsection 13a2.1.4.2 as Scenario 1b.

13a2.2.4.1 Initial Conditions

The TSV is operating at 110 percent of its design power limit at the time of the initiating event. Additional initial accident conditions are described in Subsection 13a2.1.4.1.

13a2.2.4.2 Initiating Event

The accident sequence is initiated by a catastrophic loss of PSB integrity. Potential causes of the initiating event are discussed in Subsection 13a2.1.4.1.

13a2.2.4.3 Sequence of Events

It is assumed that the primary confinement boundary is intact and performs a mitigation function with respect to radionuclide transport from the IU cell to the IF. The primary confinement boundary components are designed to maintain their integrity under postulated accident conditions and are maintained in accordance with the facility configuration management and maintenance requirements.

1. A failure of the PSB leads to mixing of irradiated target solution with the IU cell light water pool.
2. Radioactive material enters the gas space above the light water pool and is confined by the primary confinement boundary, which is described in Section 6a2.2.
3. Some radioactive material is transported into the IF through minor leakage paths around penetrations in the confinement boundary.
4. Detection of airborne radiation in RVZ1e via the RVZ1e IU cell radiation monitors actuates the primary confinement boundary isolation valves and an IU trip within 20 seconds of detection. A sufficient time delay is provided by the holdup volume in RVZ1e to prevent radioactive gases from exiting through RVZ1e prior to isolation.
5. The radioactive material is then dispersed throughout the IF and exits the facility to the environment through building penetrations.
6. Detection of high radiation in the RCA actuates ventilation dampers between the RCA and the environment and minimizes the transport of radioactive material to the environment.
7. Personal dosimeters, local radiation alarms, and alarms in the facility control room notify facility personnel of radiation leakage.

8. Facility personnel evacuate the immediate area upon actuation of the radiation alarms.

No operator actions are taken or required to reach a stabilized condition or to mitigate dose consequences.

Following the failure of the PSB, it is assumed that the MAR is instantly well-mixed with the light water pool. Gases immediately evolve out of the pool and into the IU cell gas space. For the purposes of the accident analysis, it is assumed that the N2PS is operating and causes pressurization of the IU cell. Radiation transport is driven by pressure-driven flow between the IU cell and the IF. Reduction in the MAR occurs during the release due to adsorption of iodine onto the IU cell walls and other surfaces until equilibrium conditions are established. The majority of the MAR is transported to the IF through leakage through the primary confinement boundary. Transport to the environment occurs through leakage around penetrations in the RCA boundary.

Safety Controls

The safety controls credited for mitigation of the dose consequences for this accident are:

- Primary confinement boundary
- Ventilation radiation monitors
- ~~Ventilation~~RVZ1e IU cell isolation mechanisms
- Holdup volume in the RVZ1e

13a2.2.4.4 Damage to Equipment

Chemical and radiological contamination may occur to systems within the IU cell. The contamination does not affect the safety function of the affected systems.

Following isolation of the primary confinement boundary, leakage between the IU cell and the IF is driven primarily by pressure-driven flow caused by N2PS. The IU cell sealing is a significant contributor to the function of the primary confinement boundary and will maintain its function under accident conditions.

The light water pool is required to act as a passive heat sink to remove decay heat from the irradiated target solution. The light water pool is constructed with a stainless steel liner surrounded by concrete and maintains the light water pool water inventory and will not be affected by the release of target solution.

13a2.2.4.5 Radiation Source Terms

The initial MAR for this scenario is the TSV target solution inventory at the end of approximately [ ]PROP/ECI of continuous 30-day irradiation cycles with a [ ]PROP/ECI downtime between cycles. The power level used for the analysis is 137.5 kW, which is 110 percent of design operating power. The entire radionuclide inventory in the TSV is instantaneously released to the light water pool and dispersed uniformly throughout the pool.

The accident source term development is discussed in Section 13a2.2. The ~~LPF~~RAF model values used in the source term development for the public and worker doses are provided in Table 13a2.2-1 and Table 13a2.2-2, respectively.

4. The radioactive material is then dispersed throughout the IF and exits to the environment through building penetrations.
5. Detection of high radiation in the RVZ1e ventilation from the IU cell via the RVZ1e IU cell radiation monitors actuates ventilation dampers and minimizes the transport of radioactive material to the environment. The assumed response time for RVZ1e ventilation is 20 seconds from detection of high airborne radiation. A sufficient time delay is provided by the holdup volume in RVZ1e to prevent radioactive gases from exiting through RVZ1e prior to isolation.
6. The TRPS initiates an IU Cell Safety Actuation signal which terminates irradiation operations and isolates the primary confinement boundary. The TRPS signal may be initiated by a TOGS failure or a RVZ1e high radiation signal. The N2PS actuates.
7. The main facility ventilation system (i.e., RVZ2) is isolated by the ESFAS within 30 seconds of detectable accident conditions. Leakage to the environment continues through unfiltered leakage pathways.
8. Personal dosimeters, local radiation alarms, and alarms in the facility control room notify facility personnel of radiation leakage.
9. Facility personnel evacuate the immediate area within 10 minutes upon actuation of the radiation area monitor alarms.

A portion of the gaseous iodine is adsorbed onto the cell walls, while the majority of the available MAR is transported to the IF through pressure-driven flow caused by the N2PS and leakage through the primary confinement boundary. Transport to the environment occurs through penetrations in the RCA boundary.

Safety Controls

The safety controls credited for mitigation of the dose consequences for this accident are:

- Primary confinement boundary
- ~~Ventilation~~RVZ1e IU cell radiation monitors
- Ventilation isolation mechanisms
- Holdup volume in the RVZ1e

It is assumed that the primary confinement boundary is intact and performs a mitigation function with respect to radionuclide transport from the TOGS cell to the IF. The primary confinement boundary components are designed to maintain their integrity under postulated accident conditions and are maintained in accordance with the facility configuration management and maintenance systems.

13a2.2.7.4 Damage to Equipment

The TOGS zeolite bed may continue to function following a failure of the TOGS but is not credited for source term reduction following the initiating event. Similarly, under normal operating conditions, the recirculating ventilation in the TOGS cell provides filtration which may reduce dose consequences but is not credited to remain functional under accident conditions. These assumed failures are conservative.

Leakage of the TOGS pressure boundary does not cause subsequent damage to equipment credited for safety.

3. The presence of [ ]PROP/ECI inhibits a potential deflagration.
4. Small amounts of hydrogen gas migrate into the PCLS and travel to the PCLS expansion tank, along with hydrogen normally generated in PCLS itself via radiolysis. The expansion tank is vented to RVZ1e to prevent hydrogen accumulation in that tank.
5. Small amounts of fission products from the multiplier migrate into the PCLS water. The presence of fission products in excess of normal operating levels is detected via ~~in-line~~the RVZ1e IU cell radiation monitor~~ing~~s installed in the exhaust of the PCLS expansion tank.

Safety Controls

- The design of the neutron multiplier to inhibit deflagration is a safety control (including [ ]PROP/ECI).

The sequences of events associated with unintended exothermic chemical reactions other than detonation are further discussed in Subsection 13a2.1.10.2.

13a2.2.10.4 Damage to Equipment

As discussed in Subsection 13a2.1.10, no damage beyond the initiating events is anticipated to occur as a result of unintended chemical reactions other than detonation.

13a2.2.10.5 Radiation Source Terms

Scenario 1 – Uranium Metal-Water Reaction in the Neutron Multiplier Assembly

Because a gross failure of the multiplier cladding is unlikely based on its design and a deflagration due to small leaks in the cladding is unlikely (as described in Subsection 13a2.1.10.2), a uranium metal-water reaction in the neutron multiplier assembly does not result in consequences to the worker or the public.

13a2.2.10.6 Radiological Consequences

Scenario 1 – Uranium metal-water reaction in the neutron multiplier assembly

Because a gross failure of the multiplier cladding is unlikely based on its design and a deflagration due to small leaks in the cladding is unlikely, there are no radiological consequences to the worker or the public from this event sequence.

13a2.2.11 SYSTEM INTERACTION EVENTS

As discussed in Subsection 13a2.1.11, no releases are expected to occur as a result of system interaction events. There are no consequences to the workers or the public from system interaction events, as discussed below. Accident consequences resulting from system interactions that are referenced to other subsections in Chapter 13 are evaluated in those subsections.

13a2.2.11.1 Initial Conditions

There are no unique initial conditions associated with system interaction events.

confinement boundary is described in detail in Section 6a2.2. Potential causes of the initiating event are discussed in Subsection 13a2.1.12.3.

13a2.2.12.2.3 Sequence of Events

It is assumed that the tritium confinement boundary is intact and performs a mitigation function with respect to radionuclide transport from the TPS to the IF. The tritium confinement boundary components are designed to maintain their integrity under postulated accident conditions and are maintained in accordance with the facility configuration management and maintenance programs.

1. The initiating event is a seismic event that causes a break in ~~the tritium piping and vessels which~~two TPS trains and instantaneously releases the ~~entire~~ tritium inventory ~~of the TPS system~~ into ~~a~~their respective TPS gloveboxes.
2. For the first 20 seconds, tritium escapes from each of the gloveboxes to the IF through the glovebox pressure control exhaust process vent to RVZ1.
3. The glovebox ventilation shuts down after 20 seconds due to ~~the glovebox~~high TPS confinement A/B/C tritium monitors.
4. During the 30 seconds after the initiating event, the TPS room vents to the IF at an elevated rate due to the facility RVZ2 ventilation system.
5. The RVZ2 ventilation damper from the TPS room isolates after 30 seconds due to ~~the glovebox~~high TPS confinement A/B/C tritium monitors.
6. The radioactive material is then dispersed throughout the IF and exits the facility to the environment through building penetrations.
7. Personal dosimeters, local radiation alarms, and alarms in the facility control room notify facility personnel of radiation leakage.
8. Facility personnel evacuate the immediate area within 10 minutes upon actuation of the radiation area monitor alarms.

Throughout the accident sequence, the leakage rate between ~~the~~each TPS glovebox and the TPS room is constant. After the TPS room ventilation is isolated, radiation transport is driven by air exchange between ~~the~~each TPS glovebox and the IF. Transport to the environment occurs through RCA boundary leak paths. The accident duration used in this analysis is 10 days, after which it is assumed that recovery actions will have occurred to stop further release and dispersion of radioactive material.

Safety Controls

The safety controls credited for mitigation of this accident are:

- TPS room ventilation isolations
- Glovebox pressure control and VAC/ITS ventilation isolations
- TPS ~~glovebox~~confinement A/B/C tritium ~~radiation~~ monitors
- Tritium confinement boundary, as described in Section 6a2.2

In addition, TPS glovebox deflagration is prevented by:

- TPS glovebox gas space inerted with helium
- TSP glovebox minimum volume prevents deflagration conditions

13b RADIOISOTOPE PRODUCTION FACILITY ACCIDENT ANALYSES

13b.1 RADIOISOTOPE PRODUCTION FACILITY ACCIDENT ANALYSIS METHODOLOGY

The accident analysis process for the radioisotope production facility (RPF) was conducted using the same methodology as the accident analysis in the irradiation facility (IF), described in Section 13a2.1. The radiological consequences were evaluated using the same methodology described in Section 13a2.2 for the IF.

13b.1.1 PROCESSES CONDUCTED OUTSIDE THE IRRADIATION FACILITY

The production of molybdenum-99 (Mo-99) and other fission products occurs in the IF. After the irradiation of the target solution is completed, the solution is transferred from the IF to the RPF and processed for radioisotope extraction and purification. Other processes occurring within the RPF include target solution processes for reuse, waste handling, and product packaging. These processes that occur within the RPF are evaluated via hazard identification and a process hazard analysis (PHA). The hazard identification process includes a review of potential radiological hazards, chemical hazards, and other facility hazards that might be present.

Process that are conducted in the RPF fall into the following categories:

- Operations with special nuclear material (SNM)
  - Irradiated target solution processed for radioisotope extraction
  - Irradiated target solution processed for reuse or for waste disposal
  - Operations with unirradiated SNM
- Radiochemical operations
- Operations with hazardous chemicals

The operations involving SNM include the uranium receipt and storage system (URSS), target solution preparation system (TSPS), the molybdenum extraction and purification system (MEPS), the iodine and xenon purification and packaging (IXP) system, the quality control and analytical testing laboratories (LABS), the target solution staging system (TSSS), the vacuum transfer system (VTS), the radioactive liquid waste storage (RLWS) system, the radioactive liquid waste immobilization (RLWI) system, and the radioactive drain system (RDS). The operations that do not involve SNM but pose a radiological or chemical hazard from radiochemical operations and operations with hazardous chemicals include the molybdenum isotope packaging system (MIPS), the process vessel vent system (PVVS), and the facility chemical reagent system (FCRS). Other systems in the RPF that do not have direct radiological or chemical hazards are evaluated ~~in the ISA~~ for impact on the systems listed above.

The URSS receives, thermally oxidizes (if needed), repackages, and stores low-enriched uranium prior to target solution preparation in the TSPS. The URSS is classified both as an operation with unirradiated SNM and as an operation with hazardous chemicals. Because of the presence of uranium, the URSS poses a criticality, radiological, and chemical hazard.

The TSPS prepares low-enriched uranyl sulfate solution, which, once qualified for use, is referred to as target solution. The TSPS is classified both as an operation with unirradiated SNM and as an operation with hazardous chemicals. Because of the presence of uranium, the TSPS poses a criticality, radiological, and chemical hazard.

Scenario 1 - Spill of Target Solution in the Supercell (MEPS Column Misalignment)

A spill of target solution in the supercell has the potential to release radioactive gases, aerosol, and particulates into the hot cell and ventilation system. Potential consequences of spilled target solution in the supercell include radiological dose. To mitigate the impact of spilled target solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (radiological ventilation zone 1 [RVZ1]) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to the engineered safety features actuation system (ESFAS) to isolate the affected cell and limit the amount of target solution introduced into the cell, hot cell outlet (RVZ1) ducts are equipped with carbon filters, hot cell inlet (radiological ventilation zone 2 [RVZ2]) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers, and ESFAS-controlled MEPS extraction pump breakers, VTS vacuum transfer pump breakers, and VTS vacuum break valves are provided to limit the amount of target solution introduced into the affected hot cell. This scenario is further described in Subsection 13b.2.4.1.

Scenario 2 - Spill of Target Solution in the Supercell (MEPS Overpressurization)

A spill of target solution in the supercell caused by MEPS overpressurization has the potential to release radioactive gases, aerosol, and particulates into the hot cell and ventilation system. Potential consequences of spilled target solution in the supercell include radiological dose. To prevent deflagrations, which may cause overpressure events, the nitrogen purge system (N2PS) automatically actuates on a failure of PVVS and is relied on to dilute hydrogen concentrations in tanks and vessels in the RPF. Additionally, target solution extraction pumps are provided pressure relief mechanisms. To mitigate the impact of spilled target solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (RVZ1) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to ESFAS to isolate the affected cell and limit the amount of target solution introduced into the cell, hot cell outlet (RVZ1) ducts are equipped with carbon filters, hot cell inlet (RVZ2) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers, and ESFAS-controlled. MEPS extraction pump breakers, VTS vacuum transfer pump breakers, and VTS vacuum break valves are provided to limit the amount of target solution introduced into the affected hot cell. This scenario is further described in Subsection 13b.2.4.1.

Scenario 3 - Spill of Molybdenum Eluate Solution in the Supercell (Overfill or Drop of Rotovap Flask)

A spill of the molybdenum solution in the MEPS purification cell may result in the release of radioactive gases, aerosol, and particulates into the hot cell and ventilation system. Potential consequences of spilled eluate solution in a hot cell include radiological dose. To mitigate the impact of spilled eluate solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (RVZ1) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to ESFAS to isolate the affected cell, hot cell outlet (RVZ1) ducts are equipped with carbon filters, and hot cell inlet (RVZ2) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers. The resulting sequence of events for this scenario is analogous to the MEPS eluate spill described in Subsection 13b.2.4.2.

Scenario 4 - Spill of Target Solution in the Supercell (IXP Column Misalignment)

A spill of target solution in the IXP extraction cell caused by IXP column misalignment has the potential to release radioactive gases, aerosol, and particulates into the hot cell and ventilation system. Potential consequences of spilled target solution in supercell include radiological dose. To mitigate the impact of spilled target solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (RVZ1) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to ESFAS to isolate the affected cell and limit the amount of target solution introduced into the cell, hot cell outlet (RVZ1) ducts are equipped with carbon filters, hot cell inlet (RVZ2) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers, and ESFAS-controlled IXP extraction pump breakers, VTS vacuum transfer pump breakers, and VTS vacuum break valves are provided to limit the amount of target solution introduced into the affected hot cell. This scenario is further described in Subsection 13b.2.4.1.

Scenario 5 - Spill of Target Solution in the Supercell (IXP Overpressurization)

A spill of target solution in the IXP extraction cell caused by IXP column overpressurization has the potential to release radioactive gases, aerosol, and particulates into the hot cell and ventilation system. Potential consequences of spilled target solution in the supercell include radiological dose. To prevent hydrogen deflagrations, which may cause overpressure events, the N2PS automatically actuations on a failure of PVVS and is relied on to dilute hydrogen concentrations in tanks and vessels in the RPF. Additionally, target solution extraction pumps are provided pressure relief mechanisms. To mitigate the impact of spilled target solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (RVZ1) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to ESFAS to isolate the affected cell and limit the amount of target solution introduced into the cell, hot cell outlet (RVZ1) ducts are equipped with carbon filters, hot cell inlet (RVZ2) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers, and ESFAS-controlled IXP extraction pump breakers, VTS vacuum transfer pump breakers, and VTS vacuum break valves are provided to limit the amount of target solution introduced into the affected hot cell. This scenario is further described in Subsection 13b.2.4.1.

Scenario 6 - Spill of Target Solution in the Supercell (Liquid Nitrogen Leak in IXP Hot Cell)

A liquid nitrogen leak in the IXP hot cell may damage components in the supercell and result in a spill of target solution in the hot cell, with the potential to release radioactive gases, aerosol, and particulates into the supercell and ventilation system. Potential consequences of spilled target solution in the supercell include radiological dose. To mitigate the impact of spilled target solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (RVZ1) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to ESFAS to isolate the affected cell and limit the amount of target solution introduced into the cell, hot cell inlet (RVZ2) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers, hot cell outlet (RVZ1) ducts are equipped with carbon filters, and ESFAS-controlled IXP extraction pump breakers, VTS vacuum transfer pump breakers, and VTS vacuum break valves are provided to limit the amount of target solution introduced into the affected hot cell. This scenario is further described in Subsection 13b.2.4.1.

Scenario 7 - Spill of Iodine Solution in the Supercell (Overfill or Drop of Iodine Solution Bottle)

A spill of iodine eluate solution in the IXP cell results in the release of radioactive gases, aerosols, and particulates into the hot cell and ventilation system. Potential consequences of iodine solution spilling inside the IXP cell include radiological dose. To mitigate the impact of spilled iodine solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (RVZ1) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to ESFAS to isolate the affected cell, hot cell outlet (RVZ1) ducts are equipped with carbon filters, and hot cell inlet (RVZ2) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers. The resulting sequence of events for this scenario is analogous to the MEPS eluate spill described in Subsection 13b.2.4.2.

Scenario 8 - Spill of Target Solution in the Pipe Trench from a Single Pipe

A spill of target solution in the pipe trench results in the release of radioactive gases, aerosols, and particulates into the pipe trench. Potential consequences of spilled target solution inside the pipe trench include radiological dose. To mitigate the impact of spilled target solution, the following controls are applied: the pipe trench is designed as a confinement boundary, RDS drains prevent the accumulation of target solution in the pipe trench, the RDS sump tank liquid detection sensor detects fluid in-leakage and provides a signal to ESFAS to stop any in-process transfers of solution within the facility via opening ESFAS-controlled VTS vacuum transfer pump breakers and VTS vacuum break valves, and the RVZ1 and RVZ2 building exhausts are equipped with radiation monitors (i.e., the RVZ1 and RVZ2 RCA exhaust radiation monitors) that provide a signal to ESFAS to isolate the building ventilation supply and exhaust dampers on high radiation. This scenario is further described in Subsection 13b.2.4.3.

Scenario 9 - Spill of Target Solution in the Pipe Trench from Multiple Pipes

A spill of target solution in the pipe trench results in the release of radioactive gases, aerosols, and particulates into the hot cell and ventilation system. Potential consequences of spilled target solution in the pipe trench include radiological dose. To prevent the failure of multiple target solution-carrying pipes, the pipes are seismically qualified. This scenario is further described in Subsection 13b.2.4.3.

Scenario 10 - Spill of Target Solution in a Tank Vault (Hold Tank Leak or Rupture)

A spill of target solution in a tank vault results in a release of radioactive gases, aerosols, and particulates into the tank vault. Potential consequences of target solution spilling in the tank vault include radiological dose. To mitigate the impact of spilled target solution, the following controls are applied: the tank vault is designed as a confinement boundary, RDS drains prevent the accumulation of target solution in the tank vault, the RDS sump tank liquid detection sensor detects fluid in-leakage and provides a signal to ESFAS to stop any in-process transfers of solution within the facility via opening ESFAS-controlled VTS vacuum transfer pump breakers and VTS vacuum break valves, and the RVZ1 and RVZ2 building exhausts are equipped with radiation monitors (i.e., the RVZ1 and RVZ2 RCA exhaust radiation monitors) that provide a signal to ESFAS to isolate the building ventilation supply and exhaust dampers on high radiation. This scenario is further described in Subsection 13b.2.4.4.

Scenario 11 - Spill of Target Solution in a Tank Vault (Hold Tank Deflagration)

A spill of target solution in a tank vault caused by a hold tank deflagration results a release of radioactive gases, aerosols, and particulates into the tank vault. Potential consequences of target solution spilling in the tank vault include radiological dose. To prevent a deflagration in the hold tank, the N2PS automatically actuates on a failure of PVVS and is relied upon to dilute hydrogen concentrations. To mitigate the impact of spilled target solution, the following controls are applied: the tank vault is designed as a confinement boundary, RDS drains prevent the accumulation of target solution in the tank vault, the RDS sump tank liquid detection sensor detects fluid in-leakage and provides a signal to ESFAS to stop any in-process transfers of solution within the facility via opening ESFAS-controlled VTS vacuum transfer pump breakers and VTS vacuum break valves, and the RVZ1 and RVZ2 building exhausts are equipped with radiation monitors (i.e., the RVZ1 and RVZ2 RCA exhaust radiation monitors) that provide a signal to ESFAS to isolate the building ventilation supply and exhaust dampers on high radiation. This scenario is further described in Subsection 13b.2.4.4.

Scenario 12 - Spill of Target Solution in a Tank Vault (Seismic Event)

A spill of target solution in a tank vault caused by a seismic event results in a release of radioactive gases, aerosols, and particulates into the tank vault. Potential consequences of target solution spilling in the tank vault include radiological dose. To prevent seismically caused damage, the process tanks and piping are designed to withstand earthquakes. To mitigate the impact of spilled target solution, the following controls are applied: the tank vault is designed as a confinement boundary, RDS drains prevent the accumulation of target solution in the tank vault, the RDS sump tank liquid detection sensor detects fluid in-leakage and provides a signal to ESFAS to stop any in-process transfers of solution within the facility via opening ESFAS-controlled VTS vacuum transfer pump breakers and VTS vacuum break valves, and the RVZ1 and RVZ2 building exhausts are equipped with radiation monitors (i.e., the RVZ1 and RVZ2 RCA exhaust radiation monitors) that provide a signal to ESFAS to isolate the building ventilation supply and exhaust dampers on high radiation. This scenario is further described in Subsection 13b.2.4.4.

Scenario 13 - Spill of Molybdenum Eluate in the Supercell (Deflagration)

Loss of sweep gas flow from PVVS through the eluate tank in the supercell may result in a buildup of hydrogen in the eluate tank and a subsequent deflagration. A spill of molybdenum eluate caused by a deflagration in the eluate tank results in the release radioactive gases, aerosols, and particulates into the hot cell. Potential consequences of spilled eluate solution in a hot cell include radiological dose. To prevent deflagrations in tanks and vessels in the RPF, the N2PS automatically actuates upon a loss of PVVS and is relied upon to dilute hydrogen concentrations. To mitigate the impact of spilled eluate solution, the following controls are applied: the supercell is designed as a confinement boundary, hot cell exhaust ventilation (RVZ1) is equipped with radiation monitors (i.e., the RVZ1 supercell area 1-10 radiation monitors) that provide a signal to ESFAS to isolate the affected cell, hot cell outlet (RVZ1) ducts are equipped with carbon filters, and hot cell inlet (RVZ2) and outlet (RVZ1) ventilation ducts are equipped with ESFAS-controlled redundant isolation dampers. This scenario is further described in Subsection 13b.2.4.2.

Scenario 14 - Target Solution Leaking out of the Supercell (MEPS Preheater Tube Leak)

A leak in the MEPS extraction column preheater allows target solution to enter the hot water loop. Potential consequences of target solution leaking into the hot water loop, which is partially located outside of the supercell, include radiological dose. To prevent the target solution from circulating through the water loop, conductivity instrumentation in the hot water loop detects target solution in-leakage and provides a signal to ESFAS to close the isolation valves on the supply and return of the hot water loop at the supercell boundary. This scenario was evaluated qualitatively and is not described in Section 13b.2 because the accident sequence is prevented.

Scenario 15 - Extraction Column Three-Way Valve Misalignment

A controller or operator error resulting in a misaligned three-way valve causes target solution to flow towards the chemical skid, which is located outside of the supercell. Potential consequences of this event include radiological dose. To prevent target solution from entering the chemical skid, a check valve in the chemical wash line prevents target solution backflow, and ESFAS monitoring of extraction three-way valve position causes the valves to de-energize and reposition whenever they are incorrectly aligned. This scenario was evaluated qualitatively and is not described in Section 13b.2 because the accident sequence is prevented.

Scenario 16 - Spill of Target Solution in a Valve Pit (Pipe Rupture or Leak)

A spill of target solution in a valve pit caused by a pipe rupture or leak results in a release of radioactive gases, aerosols, and particulates into the valve pit. Potential consequences of spilled target solution in the valve pit include radiological dose. To mitigate the consequences of spilled target solution, the following controls are applied: the valve pit is designed as a confinement boundary, RDS drains prevent the accumulation of target solution in the valve pit, the RDS sump tank liquid detection sensor detects fluid in-leakage and provides a signal to ESFAS to stop any in-process transfers of solution within the facility via the opening ESFAS-controlled VTS vacuum transfer pump breakers and VTS vacuum break valves, and the RVZ1 and RVZ2 building exhausts are equipped with radiation monitors (i.e., the RVZ1 and RVZ2 RCA exhaust radiation monitors) that provide a signal to ESFAS to isolate the building ventilation supply and exhaust dampers on high radiation. The resulting sequence of events for this scenario is analogous to the target solution leak in a pipe trench, which is further described in Subsection 13b.2.4.3.

Scenario 17 - Spill of Radioactive Liquid Waste in the RLWI Shielded Enclosure

A pipe leak or rupture in the RLWI shielded enclosure results in a release of radioactive gases, aerosols, and particulates into the enclosure. Potential consequences of a pipe leak or rupture in the RLWI shielded enclosure include radiological dose. To prevent unacceptable doses to workers, RLWS operating procedures provide limitations on concentration of waste solutions and require a minimum holdup time in the blending tank prior to transfer to the RLWI enclosure. This scenario is further described in Subsection 13b.2.4.5.

Scenario 18 - Heavy Load Drop onto RLWI Shielded Enclosure or Supercell

A crane failure or operator error resulting in a heavy load drop on the RLWI shielded enclosure or the supercell causes damage to the affected structure and internal equipment. Potential consequences of a heavy load drop on the RLWI shielded enclosure or supercell include radiological dose. To prevent a heavy load drop on the enclosure or the supercell, crane operation procedures include safe load paths to avoid the RLWI enclosure and supercell, and require suspension of supercell and RLWI activities during a heavy lift. The supercell damage

[ ]PROP/ECI in the TSV dump tank prior to beginning the extraction process. The target solution irradiation assumptions are described in Section 13a2.2.

Initiating Event

An event causes a break in the MEPS piping between the extraction pump discharge and the extraction column. The break downstream of the pump discharge causes spray and aerosolization of the target solution without any extraction of isotopes by the extraction column. Potential initiating events for this scenario and analogous scenarios for the iodine and xenon purification (IXP) system cell are discussed further in Subsection 13b.1.2.3; Scenarios 1, 2, 4, 5, and 6.

Sequence of Events

1. A break in the MEPS piping between the extraction pump discharge and the extraction column occurs.
2. Aerosolized target solution sprays from the break into the hot cell, releasing radioactive material into the hot cell and causing the cell to become pressurized to the nominal pressure of the cell drain loop seal.
3. RVZ1 supercell area 2/6/7 radiation ~~detectors~~monitors in the hot cell exhaust ventilation detect high airborne radiation and cause the engineered safety features actuation system (ESFAS) to shut down the vacuum transfer system (VTS), shut down the extraction pump, and isolate the hot cell ventilation.
4. Leakage of radioactive material from the hot cell to the RPF and the environment through the ventilation dampers occurs, resulting in radiological consequences to workers and the public.

The maximum volume of spilled target solution in this accident scenario is limited by the volume of the vacuum lift tanks and installed piping of the MEPS. The ESFAS shutdown of the VTS prevents additional target solution from entering the hot cell after high radiation has been detected. The analyzed volume of target solution for this scenario is 30 liters, which is conservatively based on the volume of two vacuum lift tanks plus additional pipe volume.

The controls credited for mitigation of the dose consequences for this accident are:

- Supercell confinement boundary
- ~~Hot cell r~~Radiological ventilation zone 1 (RVZ1) supercell area 2/6/7 radiation monitors
- Hot cell RVZ1 outlet carbon filters (radioiodine)
- Inlet (radiological ventilation zone 2 [RVZ2]) and outlet (RVZ1) ventilation isolation dampers
- MEPS or IXP extraction pump breakers
- VTS vacuum transfer pump breakers
- VTS vacuum break valves
- ESFAS Supercell Isolation function
- ESFAS VTS Safety Actuation function

Damage to Equipment

The leak of target solution in the supercell does not cause subsequent damage to equipment.

Transport of Radioactive Material

The methods used to calculate radioactive material transport are described in Section 13a2.2. The LPF model terms used in this accident are provided in Table 13b.2-1.

Radiation Source Terms

The initial MAR for this scenario is 30 liters of target solution from the IU at [ ]PROP/ECI post-shutdown. The action of the TOGS during this [ ]PROP/ECI period removes more than 67 percent of the iodine present in the solution at shutdown. It is conservatively assumed that 35 percent of the post-shutdown iodine inventory is released to the supercell during the accident. Additionally, partitioning fractions are applied to the noble gases present in target solution. Development of the accident source term for this scenario is discussed further in Section 13a2.2.

Radiological Consequences

The radiological consequences of this accident scenario are determined as described in Section 13a2.2. The results of the determination are shown in Table 13b.2-2.

13b.2.4.2 Spill of Eluate Solution in the Supercell

Initial Conditions

At the time of the initiating event, eluate solution in the MEPS eluate tank is spilled onto the floor of the hot cell, releasing radioactive material into the hot cell atmosphere.

Initiating Event

An event causes the failure of the MEPS eluate tank, which results in a spill of eluate solution. Potential initiating events for this scenario and analogous scenarios for the purification and IXP cells are discussed further in Subsection 13b.1.2.3; Scenarios 3, 7, and 13.

Sequence of Events

1. A break in the MEPS eluate tank occurs.
2. Eluate solution spills from the tank into the hot cell, releasing radioactive material into the hot cell and causing the cell to become pressurized to the nominal pressure of the cell drain loop seal.
3. RVZ1 supercell area 3/5/8/10 radiation ~~detectors~~monitors in the hot cell exhaust ventilation detect high airborne radiation and cause ESFAS to isolate hot cell ventilation.
4. Leakage of radioactive material from the hot cell to the RPF and the environment through the ventilation dampers occurs, resulting in radiological consequences to workers and the public.

The controls credited for mitigation of the dose consequences for this accident are:

- Supercell confinement boundary
- ~~Hot cell~~ RVZ1 supercell area 3/5/8/10 radiation monitors
- Hot cell RVZ1 outlet carbon filters (radioiodine)

15.3 FINANCIAL ABILITY TO DECOMMISSION THE SHINE FACILITY

15.3.1 DECOMMISSIONING REPORT

The decommissioning report contains information, in accordance with 10 CFR 50.33(k), describing how SHINE will provide reasonable assurance that funds will be available for the decommissioning process. The decommissioning report includes:

- a cost estimate for decommissioning the facility;
- the method or methods described in 10 CFR 50.75(e), as applicable, that will be used to provide funds for decommissioning; and
- a description of the means of adjusting the cost estimate and associated funding level periodically over the life of the facility.

15.3.1.1 Decommissioning Cost Estimate

The decommissioning cost estimate (DCE) for the SHINE facility is $5~~1~~0,0~~00~~58,000. The estimate considers costs for decommissioning activities as described in NUREG-1757, Volume 3, Section 4.1 and Appendix A.3 (USNRC, 2012), including planning and preparation, decontamination and dismantling of facility components, costs of equipment and supplies, radioactive waste characterization, waste packaging and shipment, waste disposal, contingency costs, contractor costs, and radiation surveys. The DCE assumes that decommissioning activities begin immediately after radioisotope production activities and operations involving radioactive materials cease. The DCE encompasses the costs necessary to decommission and release the site for unrestricted use in accordance with 10 CFR 20.1402.

15.3.1.2 Method to Provide Funds for Decommissioning

In accordance with 10 CFR 50.75(e), SHINE will maintain an external escrow account in which deposits will be made periodically, coupled with a surety method, insurance, or some other form of guarantee. This escrow account, coupled with a surety method, insurance, or some other form of guarantee, is intended to provide reasonable assurance that funds will be available to decommission the facility.

15.3.1.3 Means of Adjusting Decommissioning Cost Estimate and Funding Level

The decommissioning funding level will be adjusted every three years, or when the amounts or types of materials at the facility change, to demonstrate that a reasonable level of assurance will be provided that funds will be available when needed to cover the cost of decommissioning. The triennial adjustments account for inflation, for other changes in the prices of goods and services (e.g., disposal cost increases), for changes in facility conditions or operations, and for changes in expected decommissioning procedures, as applicable. The triennial adjustments account for changes such as:

- leaks and spills of radioactive material producing additional facility contamination or residual radioactivity in on-site subsurface material;
- newly detected facility, soil, or groundwater contamination;
- waste inventory increasing above the amount estimated;
- waste disposal costs increasing above the amount previously estimated, including any additional costs associated with the availability of disposal facilities;