**ENCLOSURE 2**

**SHINE TECHNOLOGIES, LLC**

**SHINE TECHNOLOGIES, LLC APPLICATION FOR AN OPERATING LICENSE SUPPLEMENT NO. 27**

**FINAL SAFETY ANALYSIS REPORT CHANGE SUMMARY PUBLIC VERSION**

| Summary Description of Changes | FSAR Impacts |
|---|---|
| Update to the expected waste classification of spent neutron driver assembly system (NDAS) components. | Section 11.2, Table 11.2-1<br><br>Tables 11.2-1 and 11.2-2 of the Phased Startup Operations Application Supplement have been revised to incorporate conforming changes. |
| Update to clarify the nitrogen purge system (N2PS) flow path upon loss of power and the flow path upon receipt of an engineered safety features actuation system (ESFAS) actuation signal other than loss of power. | Section 6b.2, Section 7.3, Section 9b.6 |
| Update to clarify the location of the radioactive drain system (RDS) drip pans within the extraction and iodine and xenon purification and packaging (IXP) hot cells. | Section 9b.7 |
| Update to incorporate the encapsulation capabilities of the solid radioactive waste packaging system (SRWP). | Section 9b.7, Section 11.2, Table 11.2-1, Table 11.2-3<br><br>Chapter 9, Table 11.2-1, and Table 11.2-2 of the Phased Startup Operations Application Supplement have been revised to incorporate conforming changes. |
| Update to remove the shield plugs from the primary cooling rooms. | Section 4a2.5, Figure 4a2.5-1, Section 9b.7 |
| Update to remove the recirculation pump and associated piping from the target solution preparation system (TSPS) uranyl sulfate dissolution tanks. | Section 4b.4, Figure 4b.4-3, Section 6b.3 |

| Summary Description of Changes | FSAR Impacts |
|---|---|
| Update to replace carbon monoxide (CO) monitoring of the process vessel vent system (PVVS) carbon delay beds with temperature monitoring at the exhaust of the carbon delay beds as an indicator of fire in the beds.<br><br>Limiting Condition for Operation (LCO) 3.2.4, LCO 3.5.1, and LCO 3.8.10 of the technical specifications have been revised to incorporate conforming changes. | Section 6b.2, Section 7.3, Section 7.5, Table 7.5-1, Table 7.5-2, Figure 7.5-1, Section 9a2.3, Section 9b.6, Table 9b.6-1, Figure 9b.6-1, Section 11.1, Table 11.1-5, Table 11.1-6, Figure 11.1-1, Figure 11.1-2, Section 13b.1, Section 13b.2, Table 13b.2-1, Table 13b.2-2<br><br>Chapter 7 of the Phased Startup Operations Application Supplement has been revised to incorporate conforming changes. |
| Update to correct the maximum output pressure of components within the molybdenum extraction and purification system (MEPS). | Section 4b.3 |
| Update to correct inconsistencies in the location of components in the target solution vessel off-gas system (TOGS) recombiner loops. | Section 4a2.8 |
| Update to the ventilation provided to the uranium receipt and storage system (URSS) glovebox. | Figure 4b.4-2 |
| Update to the casting details of the neutron multiplier. | Section 4a2.2 |
| Update to the combustible loading classification of various areas within the facility. | Section 9a2.3 |
| Update to the expected dose rates above the drum storage bore holes. | Section 11.1, Table 11.1-4, Table 11.1-10, Figure 11.1-1 |

A markup of the Final Safety Analysis Report (FSAR) changes is provided as Attachment 1. Conforming Phased Startup Operations Application Supplement markups associated with the above FSAR Changes are provided as Attachment 2. Conforming technical specification markups associated with the above FSAR changes are provided as Attachment 3.

**ENCLOSURE 2**
**ATTACHMENT 1**

**SHINE TECHNOLOGIES, LLC**

**SHINE TECHNOLOGIES, LLC APPLICATION FOR AN OPERATING LICENSE SUPPLEMENT NO. 27**

**FINAL SAFETY ANALYSIS REPORT CHANGE SUMMARY**
**PUBLIC VERSION**

**FINAL SAFETY ANALYSIS REPORT MARKUP**

design life of the neutron multiplier is 30 years, but it is designed to allow remote replacement should physical damage occur to it, or a distortion that is outside of acceptable limits.

The multiplier is manufactured by casting natural uranium metal sections, machining the sections, and then placing the sections in a machined cladding. During the casting, the natural uranium is alloyed with a small weight fraction of silicon to assist in obtaining small, randomly-oriented grains to help reduced irradiation-induced growth. The uranium is cast in ~~two~~three axial pieces, with ~~one~~each piece supported on top of the ~~other~~prior piece when installed in the cladding. The cast uranium is machined to final dimensions, and then is inserted into the aluminum cladding. The aluminum cladding is type 6061 aluminum. The aluminum cladding is welded closed after the uranium core is inserted. [ ]PROP/ECI The cladding is leak-tested following fabrication.

The fast fusion neutrons that collide with the uranium metal can cause several high energy reactions to occur. The most common reactions in the multiplier include fission, and to a lesser extent (n,2n) and (n,3n) reactions with U-235 and U-238. The resulting spectrum of fast fission, fusion, epithermal, and thermal neutrons then enter the TSV.

The aluminum cladding contains fission products created within the uranium (the cladding thickness is much greater than the distance traveled by a fission fragment). In the event of a cladding failure, there are no consequences that would affect the safe operation and shutdown of the irradiation system. There is potential that the uranium metal could form surface oxidization, releasing hydrogen gas. [ ]PROP/ECI

A cladding failure could also result in fission products being released into the primary cooling water, leading to contamination in the PCLS. Sampling the PCLS detects such a breach via the increased radioactive contamination present in the water. Additionally, radiation monitors on the radiological ventilation zone 1 exhaust subsystem (RVZ1e) line ventilating the PCLS expansion tank can detect fission products leaving the PCLS cooling water. The TRPS initiates an IU Cell Safety Actuation if radiation levels exceed predetermined limits, resulting in the isolation of the PCLS supply and return lines and the RVZ1e IU cell line as described in Section 7.4.

Radiation damage and burnup are not expected to impact operation of the multiplier for the lifetime of the plant. The maximum fast neutron fluence (greater than approximately 100 thousand electron volts [keV]) of the multiplier over a 30 year period of continuous operation is calculated to be less than [ ]PROP/ECI. Nuclear parameters of the subcritical assembly at the end-of-life for the multiplier have been calculated and do not affect the safety of the subcritical assembly. Nuclear parameters are described in Section 4a2.6.

Bounding fission product gas generation for the lifetime of the multiplier has been incorporated into the design. [ ]PROP/ECI

Overall heat generation rate in the multiplier is approximately 15 kW (50,000 Btu/hr) during operation of the TSV at the licensed power limit. Heat generation in the multiplier is from fissions occurring within the multiplier and radiation absorbed from the fission process in the TSV. Most fission energy is short range (fission products, betas) and is deposited locally. Some energy from long range products (gammas and fast neutrons) is deposited in the multiplier, with the balance being deposited in structural materials, the TSV, and the cooling water. Heat deposited in the

The thickness of the walls of the IU cell shielding varies from approximately 4.0 feet (ft.) (1.2 meters [m]) to 5.8 ft. (1.8 m), the walls of the TOGS shielded cell shielding vary from approximately 4.0 ft. (1.2 m) to 6.0 ft. (1.8 m), and the walls of the primary cooling room shielding vary from approximately 0.7 ft. (0.2 m) to 1 ft. (0.3 m). The IU cell cover plug thickness is approximately 4.3 ft. (1.3 m), and the TOGS cover plug thickness is approximately 6.0 ft. (1.8 m), and the primary cooling room cover plug thickness is approximately 1.0 ft. (0.3 m).

Concrete shielding is of standard density (nominally 140 pounds per cubic foot [lb/ft$^3$]) (2.24 grams per cubic centimeter [g/cm$^3$]) concrete, and shield thicknesses result in general dose rates on the external surface of the shielding of less than 1.0 millirem per hour (mrem/hr). 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 (see Section 11.1). See Figure 4a2.5-1 for a general depiction of the ICBS.

The primary cooling room shield doors are carbon steel and have an approximate thickness of 3 inches (in.) (8 centimeters [cm]).

#### 4a2.5.2.3 Loss of Shield Integrity

The biological shield walls and supporting structures are designed and constructed to remain intact during normal operations as well as during and following design basis accidents. A loss of shield integrity is not credible given the seismic design and robust nature of the IU and TOGS cells.

#### 4a2.5.2.4 Unrestricted Environment

Based on the design and construction of the biological shield walls, the neutron flux to soils surrounding the biological shield walls, in the unrestricted environment, is estimated to be less than 100 n/cm$^2$-s. Thus, the neutron activation of groundwater and soils surrounding the biological shield is expected to be insignificant.

### 4a2.5.3 SHIELD MATERIALS

The ICBS concrete shielding uses two distinct materials in different configurations to assemble the biological shield and meet the radiation exposure goals defined in Chapter 11. The materials that make up the concrete shielding use an engineered concrete mix with carbon steel reinforcing bars. Standard concrete is used with no special additives for shielding purposes. In the shielding analyses, individual rebar is not modeled. Instead a homogenization of rebar and concrete is used when rebar is included in the modeling. Conservative assumptions are used to define the overall shielding properties of the concrete and rebar, and secondary radiation production is considered in the analysis.

#### 4a2.5.3.1 Shielding Calculations

Calculations are performed with the software package 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). 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 (LANL, 2011). The Monte Carlo method generates a statistical set of results for individual

**Figure 4a2.5-1 — Irradiation Facility Biological Shield (not to scale)
(Sheet 1 of 2)**

## 4a2.8 GAS MANAGEMENT SYSTEM

### 4a2.8.1 SYSTEM DESCRIPTION

The gas management system is the target solution vessel (TSV) off-gas system (TOGS). The TOGS removes radiolysis gases and a portion of the iodine in the gas space from the TSV during irradiation operation and from the TSV dump tank during target solution cooldown to maintain concentrations within safe limits.

The TOGS equipment is located in the TOGS cell and irradiation unit (IU) cell. A total of eight independent instances of TOGS are installed in the irradiation facility (IF), one for each IU. Each instance of TOGS consists of two separate recombiner loops, both of which must be operating during irradiation. One recombiner loop is equipped with hydrogen sensors~~,~~ and oxygen sensors, ~~and~~while the other recombiner loop is equipped with a zeolite bed for iodine capture. During a loss of off-site power (LOOP), at least one recombiner loop must continue to operate for a short period of time to assure safe shutdown.

### 4a2.8.2 SYSTEM PROCESS AND SAFETY FUNCTIONS

The process functions of the TOGS are listed below:

- TOGS sweeps the TSV headspace to dilute radiolytic hydrogen generated by the target solution in the TSV during irradiation, maintaining bulk hydrogen concentration within the primary system boundary (PSB) below the lower flammability limit (LFL) to prevent deflagration during normal operation.
- TOGS sweeps the TSV dump tank headspace to dilute radiolytic hydrogen generated by the target solution in the TSV dump tank during shutdown conditions, maintaining bulk hydrogen concentration within the PSB below the LFL to prevent deflagration during normal operation.
- TOGS absorbs iodine in the sweep gas to maintain iodine concentrations within the PSB gas space below the limits defined by the safety analysis.
- TOGS condenses water vapor generated by the target solution in the TSV and returns the condensate to the TSV to limit water holdup in TOGS to less than 3 liters.
- TOGS captures target solution droplets entrained in the sweep gas and returns them to the TSV to minimize buildup of fissile material in TOGS.
- The sections of the TOGS pressure boundary that form a portion of the PSB provide containment of fission product and decay product gases generated during target solution irradiation and cooldown.
- TOGS maintains the pressure within the PSB slightly sub-atmospheric with respect to the IU cell during normal conditions.

The safety functions of the TOGS are listed below:

- Provide confinement of target solution and fission products as part of the PSB to prevent release of radioactive material that could cause undue risk to health and safety of workers and the public.
- Maintain hydrogen concentrations below values which could result in a hydrogen explosion overpressure capable of rupturing the PSB, preventing release of radioactive material that could cause undue risk to health and safety of workers and the public.

The MEPS pipes and piping components that may contain uranyl sulfate or Mo eluate have a design pressure of 100 psi. The primary MEPS process equipment is described below.

a. Target solution heat exchanger
   - Description: cools target solution leaving MEPS and pre-heats target solution prior to extraction
   - Outlet temperature: nominally 68°F-158°F (20°C-70°C)
   - Design pressure: 100 pounds per square inch (psi)

b. Extraction column preheater
   - Description: pre-heats target solution prior to extraction
   - Exchange fluid: Hot water
   - Outlet temperature: nominally 158°F-203°F (70°C-95°C)
   - Design pressure: 100 psi

c. Mo-99 extraction column
   - Description: extracts Mo-99 from uranyl sulfate solution
   - Volume: [ ]PROP/ECI
   - Design pressure: 100 psi
   - Packing: [ ]PROP/ECI

d. [
   -

   ]PROP/ECI

e. Extraction column feed pump
   - Description: provides motive force to move solution through the Mo-99 extraction column
   - Design flow rate: [ ]PROP/ECI
   - Maximum output pressure (protected by internal or external overpressure protection): up to ~~5~~100 psig

f. [
   -

   ]PROP/ECI

g. Mo-99 eluate hold tank
   - Description: holds Mo-99 eluate and allows for re-acidification of solution [ ]PROP/ECI
   - Size: [ ]PROP/ECI
   - Design pressure: 15 psi (normally vented)

Chemical reagents are supplied to MEPS via the facility chemical reagent system (FCRS). FCRS reagents may be pre-heated prior to introduction into the extraction cell. See Subsection 9b.7.10 for the description of FCRS.

#### 4b.4.2.2.2 Dissolution of Uranium Oxide

Uranium oxide is converted to a uranyl sulfate solution within the uranyl sulfate dissolution tanks. Uranium oxide, within a uranium oxide storage canister, is transferred from the uranium oxide storage rack to the [ ]SRI. The uranium oxide storage canister is imported and opened within the TSPS glovebox. Only one uranium oxide storage canister is imported to the TSPS glovebox at any time. The TSPS glovebox is kept at negative pressure by RVZ1 and equipped with HEPA filters on the supply and exhaust connections. The volume of the filters is limited as a criticality safety control.

Measurement, by mass, of uranium oxide powder is performed in the TSPS glovebox, and the material is transferred to one of the two uranyl sulfate dissolution tanks via a normally closed port in the TSPS glovebox. Two ports are provided, one dedicated to each uranyl sulfate dissolution tank. The ports preclude backflow of liquid from a uranyl sulfate dissolution tank. Unused uranium oxide remains in the uranium oxide storage canister and is returned to the uranium oxide storage rack.

The uranyl sulfate dissolution tanks are designed with favorable dimensions for criticality safety and are spaced from one another to minimize reactivity by interaction. Sulfuric acid used to convert the uranium oxide to uranyl sulfate is added to the tank. Hydrogen peroxide may also be added as a catalyst, and uranyl peroxide is formed as an intermediate. Heat is applied to the uranyl sulfate dissolution tank to aid the conversion to uranyl sulfate. Heat also decomposes excess hydrogen peroxide if it is used as a catalyst. ~~Throughout the conversion process, the tank may be agitated.~~ A reflux condenser on the exhaust ventilation of the uranyl sulfate dissolution tank is used to condense and return evaporated water. Non-condensable gases are exhausted from the condenser to RVZ1 through a HEPA filter. The reflux condenser size is limited as a criticality safety control as described in Section 6b.3, but operation of the reflux condenser is not required to maintain a safe configuration.

On a leak of the reflux condenser into the dissolution tank, a high level in the tank results in an engineered safety features actuation system (ESFAS) Dissolution Tank Isolation, which closes the TSPS radioisotope process facility cooling system (RPCS) supply and return cooling valves, TSPS air inlet isolation valve, and TSPS RVZ1 exhaust isolation valve to prevent uranium bearing solution from exiting the tank.

Once operators verify the dissolution process is complete by sampling, the uranyl sulfate is pumped to the target solution preparation tank through a set of filters to remove any potentially undissolved solids. The filters are limited in size as a criticality safety control.

#### 4b.4.2.2.3 Preparation of Target Solution

Both qualified target solution batches and uranyl sulfate makeup solutions are prepared for use in the target solution preparation tank. The target solution preparation tank has capacity for an entire batch of target solution and is a favorable geometry for criticality safety. Solutions are pumped into the target solution preparation tank from the uranyl sulfate dissolution tanks and blended to generate a target solution batch. If the solution is to be a qualified target solution batch, reagents, such as water, sulfuric acid, [ ]PROP/ECI are added to the tank to adjust solution properties within the constraints specified by the Target Solution Qualification Program, as described in Section 4a2.2. Makeup solution is adjusted by operators as needed to

**Figure 4b.4-2 – Uranium Receipt and Storage System Process Flow Diagram**

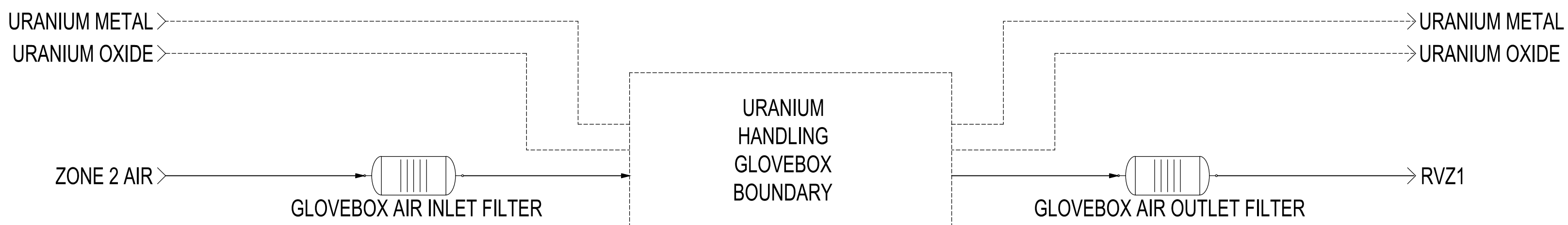
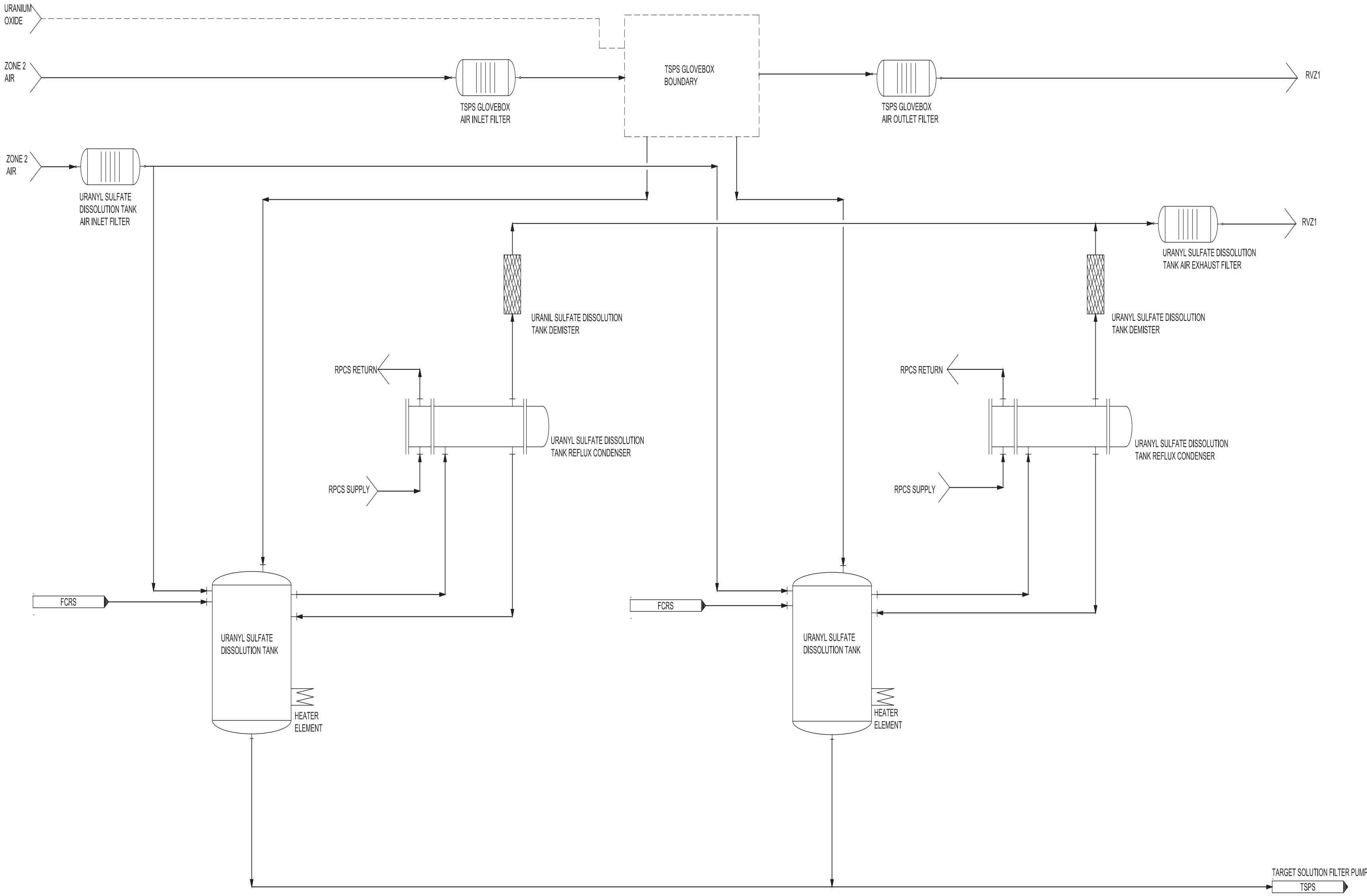


**Figure 4b.4-3 – Target Solution Preparation System Process Flow Diagram (Sheet 1 of 2)**



is a minor outflow of radioactive material from the confined area to the RPF and the environment under accident conditions. If sufficient radioactive material reaches the radiation monitors in the RVZ1 exhaust duct, ESFAS will isolate the RVZ building supply and exhaust. The evaluated accident sequence for which the process confinement boundary is necessary is listed in Table 6b.1-1 and discussed further in Section 13b.2.

The requirements needed for process confinement boundary system operability, periodic surveillance, setpoints, and other specific requirements needed to ensure the functionality of the process confinement boundary are located in technical specifications.

## 6b.2.2 PROCESS VESSEL VENT ISOLATION

The process vessel vent system (PVVS) captures or provides holdup for radioactive particulates, iodine, and noble gases generated within the RPF and primary system boundary. The system draws air from the process vessels through a series of processing components which remove the radioactive components by condensation, acid adsorption, mechanical filtration with high-efficiency particulate air (HEPA) filters, and adsorption in carbon beds. Two sets of carbon beds are used; the guard beds located in ~~the supercell~~a below-grade, shielded vault, and the delay beds located in the carbon delay bed vault.

Fires may occur in the carbon guard and delay beds which result in the release of radioactive material into the downstream PVVS system, which leads to the facility ventilation system and the environment. The PVVS guard and delay beds are equipped with isolation valves that isolate the affected guard bed or ~~group of~~ delay bed~~s~~ from the system and extinguish the fire. The isolation valves also serve to prevent the release of radioactive material to the environment. ~~The d~~Delay beds 1, 2, and 3 are equipped with sensors to detect fires which provide indication to ESFAS. The isolation valves on the affected delay bed close ~~within 30 seconds of the~~upon receipt of the actuation signal from ESFAS, preventing fire propagation to the downstream beds. The redundancy in the beds and the ability to isolate individual beds allows the PVVS to continue to operate following an isolation.

The evaluated accident sequence for which the PVVS isolation is necessary is listed in Table 6b.1-1 and discussed further in Section 13b.2.

The requirements to be specified in the technical specifications for system operability, periodic surveillance, setpoints, and other specific requirements needed to ensure the functionality of the PVVS isolations are located in Section 7.5 and Section 9.6, which describes the ESFAS and the PVVS, respectively.

## 6b.2.3 COMBUSTIBLE GAS MANAGEMENT

Hydrogen gas is produced by radiolysis in the target solution during and after irradiation. During normal operation, the PVVS removes radiolytic hydrogen and radioactive gases generated within the RPF and primary system boundary. The PVVS is described in detail in Section 9b.6. If PVVS becomes unavailable, the buildup of hydrogen gas is limited using the combustible gas management system, which uses the nitrogen purge system (N2PS), process system piping, and the PVVS to establish an inert gas flow through the process vessels.

The principle objective of the combustible gas management system is to prevent the conditions required for a hydrogen deflagration in the gas spaces in the RPF process tanks.

The N2PS provides a backup supply of sweep gas following a loss of electrical power or loss of sweep gas flow to the RPF tanks which are normally ventilated by PVVS. A functional block diagram of the combustible gas management system is shown in Figure 6b.2-3.

High pressure nitrogen gas is stored in pressurized vessels which are located in an above-grade reinforced concrete structure adjacent to the main production facility. On a loss of power or receipt of an ESFAS actuation signal, isolation valves on the radiological ventilation zone 2 (RVZ2) air supply to PVVS shut and isolation valves on the N2PS discharge manifold open, releasing nitrogen into the RPF N2PS distribution piping. The nitrogen gas flows through the RPF equipment and into the PVVS process piping. TOn loss of power, the discharged gases bypass the passive filtration skid equipment (i.e., the PVVS condenser, PVVS reheater, acid adsorber, HEPA filter, and guard bed) before being discharged to the alternate vent path in the PVVS and the stack. On receipt of an ESFAS actuation signal other than loss of power, the discharged gases flow through the PVVS passive filtration skid equipment and the passive filtration skid equipment bypass line before being discharged to the alternate vent path in the PVVS and the stack. The N2PS is described in detail in Section 9b.6.

The complete listing of variables within the ESFAS that can cause the initiation of an RPF Nitrogen Purge is provided in Subsection 7.5.3.1. These variables indicate a loss of flow. The active components required to function to initiate the RPF Nitrogen Purge are actuated by the ESFAS. A detailed description of the ESFAS is provided in Section 7.5.

The combustible gas management system prevents deflagrations and detonations in RPF process tanks which could lead to a tank or pipe failure and cause a target solution spill inside the process confinement boundary. The accident sequences for which the combustible gas management system is necessary are listed in Table 6b.1-1 and discussed in Chapter 13a2.

The requirements needed for PVVS system operability, periodic surveillance, setpoints, and other specific requirements needed to ensure the functionality of the combustible gas management system are located in technical specifications.

### 6b.2.4 CHEMICAL PROTECTION

The chemical dose analysis is provided in Section 13b.3 and has shown that no potential chemical release exceeds the established acceptance limits. As described in Section 13b.3, confinement barriers (i.e., supercell, gloveboxes, subgrade vaults) are credited for mitigation of chemical dose consequences. The URSS uranium storage racks are seismically qualified to maintain their structure and position during seismic events to limit the material at risk for uranium oxide accidents.

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 ~~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.

<u>Criticality Safety Basis</u>

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 or in downstream ventilation ductwork. Visual surveillance is performed to identify any spills of fissile material or introduction of moderators.

The TSPS room moderator exclusion features (e.g., non-hydrogenous fire protection, elevated floor) and glovebox itself are designed to preclude the intrusion of significant amounts of moderator. Therefore, the glovebox will remain safely subcritical under normal process conditions. The mass limit also protects the dissolution process in the dissolution tanks, though they are designed with favorable geometry even for the most reactive combination of uranium oxide and water.

Downstream of the dissolution tanks are pipes, transfer pumps, and filters, which are favorable geometry within the single parameter limit. The target solution preparation tank is favorable geometry including corrosion allowances and optimum concentration of solution. Interaction between components is controlled with minimum separation distances and a cage around the dissolution tanks.

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 that is generated via radiolysis. A portion of the PVVS equipment is located in a hot cell of the supercell (PVVS area), with other equipment located in the main production facility mezzanine or in below grade vaults. The PVVS is described in Subsection 9b.6.1.

Monitoring and Alarms

The PICS receives input from the ESFAS and provides alarms for PVVS flow (Subsection 7.5.4.1.15) and PVVS carbon delay bed exhaust ~~carbon monoxide~~temperature (Subsection 7.5.4.1.7).

The PICS directly monitors and provides alarms for nonsafety-related PVVS supply flow to individual tanks and vessels serviced by PVVS, PVVS reheater temperatures, PVVS condensate tank level, PVVS condenser cooling water temperature, PVVS carbon guard bed train exhaust temperature and differential pressure, PVVS carbon delay bed temperatures, and other system temperatures, pressures, and flows.

The PICS also provides alarms for automatic or manual Carbon Delay Bed ~~Group~~ 1/2/3 Isolations 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 ESFAS are controlled by PICS as described in Subsection 7.3.1.3.11.

The PICS provides automatic control of PVVS condensate transfer by stopping the condensate discharge pump on low PVVS condensate tank level after the operator has manually selected the destination tank and initiated the transfer.

The PICS provides automatic control of the PVVS makeup air supply valve by monitoring nonsafety-related PVVS return flow (from tanks and vessels serviced by PVVS), to maintain total flow to the PVVS blowers constant.

The PICS automatically controls temperature by energizing and deenergizing the PVVS reheaters based on the PVVS reheater downstream temperature.

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

Interlocks and Permissives

The PICS provides interlocks and permissives to:

- Close the PVVS inlet valve to a carbon guard bed train if differential pressure for the associated carbon guard bed train is above an allowable limit, and open the PVVS inlet and outlet valves and start the PVVS reheater for the redundant carbon guard bed train.
- Close the PVVS inlet and outlet valves for a carbon guard bed train if exhaust temperature for the associated carbon guard bed train is above an allowable limit, and 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.
- Deenergize PVVS reheater(s) if the associated outlet temperature exceeds an allowable limit.
- Open the corresponding delay bed outlet valves if the inlet three-way valve of delay bed 4, 5, 6, 7, or 8 is in the unpowered position.

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

The SGS generator controller automatically starts the generator in response to a loss of off-site power event. PICS automatically sequences the loads onto the generator.

Interlocks and Permissives

The generator automatic transfer switch design prevents paralleling the generator with either service entrance.

7.3.1.4.4 Nitrogen Purge System

The nitrogen purge system (N2PS) provides a backup supply of sweep gas to each 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 equipment prior to being discharged to the alternate vent path in the PVVS and the stack. The N2PS is described in Subsections 6b.2.3 and 9b.6.2.

Monitoring and Alarms

The PICS monitors and provides alarms for N2PS storage tube pressures, N2PS flows, and oxygen concentration in the N2PS structure general area.

The PICS also provides alarms for automatic or manual IU Cell Nitrogen Purge and RPF Nitrogen Purge described in Subsection 7.5.3.1.

Control Functions

The operator is able to use the PICS to manually open and close individual valves that are capable of being actuated by TRPS or ESFAS, as described in Subsection 7.3.1.3.11.

Interlocks and Permissives

None

7.3.1.4.5 Radiological Ventilation Systems

The RV systems are constant volume systems that include supply air, recirculating, and exhaust subsystems required to condition the air and provide the confinement and isolation needed to mitigate design basis accidents, as described in Section 9a2.1. The main production facility uses three ventilation zones and five subsystems in the radiologically controlled area (RCA) to maintain the temperature and humidity of the RCA and to maintain a pressure gradient from areas of least potential for contamination to areas with the most potential for contamination:

- RVZ1
- RVZ1 recirculating subsystem (RVZ1r)
- RVZ1e
- RVZ2
- RVZ2e
- RVZ2s

trip or bypass causes all channels associated with that SFM to be placed in trip or bypass, respectively.

The ESFAS bypass logic is implemented in all three divisions using scheduling, bypass, and voting modules (SBVMs) for divisions A and B, or scheduling and bypass modules (SBMs) for division C. The ESFAS voting and actuation logic is implemented in only divisions A and B. For divisions A and B, the three SBVMs, in each division, generate actuation signals when the SFMs in any two of three (or one of two) divisions determine that an actuation is required. Both ESFAS divisions A and B evaluate the input signals from the SFMs in each of three redundant SBVMs. Each SBVM compares the inputs received from the SFMs and generates an appropriate actuation signal if required by two or more of the three (or one or more of the two) divisions.

The output of the three redundant SBVMs in divisions A and B is communicated via three independent safety data buses to the associated equipment interface modules (EIMs). There are two independent EIMs for each actuation component, associated with each division A and B of ESFAS. The EIMs compare inputs from the three SBVMs and initiate an actuation if two out of three signals agree on the need to actuate. Both EIMs associated with a component are required to be deenergized for the actuation component(s) to fail to their actuated (deenergized) states~~, with the exception of the process vessel vent system (PVVS) carbon delay bed three-way and outlet isolation valves (Subsections 7.5.3.1.14, 7.5.3.1.15, and 7.5.3.1.16). These valves are energized to actuate~~.

## 7.5.2 DESIGN CRITERIA

The SHINE facility design criteria applicable to the ESFAS are stated in Table 3.1-1. The facility design criteria applicable to the ESFAS, and the ESFAS system design criteria, are addressed in this section.

The ESFAS utilizes a HIPS design. The HIPS design is applicable to both the target solution vessel (TSV) reactivity protection system (TRPS) and the ESFAS. The HIPS design is described in Subsection 7.4.5.

### 7.5.2.1 SHINE Facility Design Criteria

The generally-applicable SHINE facility design criteria 1 through 6 apply to the ESFAS. The ESFAS is designed, fabricated, and erected to quality standards commensurate to the safety functions to be performed; will perform these safety functions during external events; will perform these safety functions within the environmental conditions associated with normal operation, maintenance, and testing; does not share components between irradiation units unless that sharing will not significantly impair the ability to perform the required safety functions; and is able to be manually initiated from the facility control room. These elements of the ESFAS design contribute to satisfying SHINE facility design criteria 1 through 6.

SHINE facility Design Criteria 13 through 19 and 37 through 39 also apply to the ESFAS.

#### 7.5.2.1.1 Instrumentation and Controls

SHINE Design Criterion 13 – Instrumentation is provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated transients, and for postulated accidents as appropriate to ensure adequate safety, including those variables and

The ESFAS initiates a MEPS B Heating Loop Isolation based on the following variables or safety actuation:

- High MEPS heating loop radiation extraction area B
- RDS liquid detection
- Supercell Area 6 Isolation

7.5.3.1.13 MEPS C Heating Loop Isolation

MEPS C Heating Loop 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, Scenario 14).

A MEPS C Heating Loop Isolation initiates the following safety functions:

- Deenergize MEPS heating loop C inlet isolation valves
- Deenergize MEPS heating loop C discharge isolation valves
- Deenergize MEPS C extraction feed pump breakers

The ESFAS initiates a MEPS C Heating Loop Isolation based on the following variables or safety actuation:

- High MEPS heating loop radiation extraction area C
- RDS liquid detection
- Supercell Area 7 Isolation

7.5.3.1.14 Carbon Delay Bed Group 1 Isolation

Carbon Delay Bed Group 1 Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for RPF fire events (Subsection 13b.1.2.5, Scenario 1).

A Carbon Delay Bed Group 1 Isolation initiates the following safety functions:

- EDeenergize PVVS carbon delay bed group 1 three-way valves
- EDeenergize PVVS carbon delay bed group 1 outlet isolation valves

The ESFAS initiates a Carbon Delay Bed Group 1 Isolation based on the following variable:

- High carbon delay bed group 1 exhaust carbon monoxidetemperature

7.5.3.1.15 Carbon Delay Bed Group 2 Isolation

Carbon Delay Bed Group 2 Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for RPF fire events (Subsection 13b.1.2.5, Scenario 1).

A Carbon Delay Bed Group 2 Isolation initiates the following safety functions:

- EDeenergize PVVS carbon delay bed group 2 three-way valves
- EDeenergize PVVS carbon delay bed group 2 outlet isolation valves

The ESFAS initiates a Carbon Delay Bed Group 2 Isolation based on the following variable:

- High carbon delay bed group 2 exhaust carbon monoxidetemperature

7.5.3.1.16 Carbon Delay Bed Group 3 Isolation

Carbon Delay Bed Group 3 Isolation is relied upon as a safety-related control in accordance with the SHINE safety analysis described in Chapter 13 for RPF fire events (Subsection 13b.1.2.5, Scenario 1).

A Carbon Delay Bed Group 3 Isolation initiates the following safety functions:

- EDeenergize PVVS carbon delay bed group 3 three-way valves
- EDeenergize PVVS carbon delay bed group 3 outlet isolation valves

The ESFAS initiates a Carbon Delay Bed Group 3 Isolation based on the following variable:

- High carbon delay bed group 3 exhaust carbon monoxidetemperature

7.5.3.1.17 VTS Safety Actuation

VTS Safety Actuation 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 8, 10, 11, 12, and 16), and for criticality safety requirements (Subsection 6b.3.2.5).

A VTS Safety Actuation Isolation initiates the following safety functions:

- Deenergize VTS vacuum transfer pump 1 breakers
- Deenergize VTS vacuum transfer pump 2 breakers
- Deenergize VTS vacuum break valves
- Deenergize MEPS A extraction column wash supply valve
- Deenergize MEPS A extraction column eluent valve
- Deenergize MEPS A [ ]PROP/ECI wash supply valve
- Deenergize MEPS A [ ]PROP/ECI eluent valve
- Deenergize MEPS B extraction column wash supply valve
- Deenergize MEPS B extraction column eluent valve
- Deenergize MEPS B [ ]PROP/ECI wash supply valve
- Deenergize MEPS B [ ]PROP/ECI eluent valve
- Deenergize MEPS C extraction column wash supply valve
- Deenergize MEPS C extraction column eluent valve
- Deenergize MEPS C [ ]PROP/ECI wash supply valve
- Deenergize MEPS C [ ]PROP/ECI eluent valve
- Deenergize IXP recovery column wash supply valve
- Deenergize IXP recovery column eluent valve

### 7.5.3.5 Seismic, Tornado, Flood

The ESFAS equipment is installed in the seismically qualified portion of the main production facility where it is protected from earthquakes, tornadoes, and floods. The ESFAS equipment is Seismic Category I, tested using biaxial excitation testing and triaxial excitation testing, in accordance with Section 8 of IEEE Standard 344-2013 (IEEE, 2013) (Subsection 7.5.3.12).

### 7.5.3.6 Human Factors

The ESFAS provides manual actuation capabilities for the safety functions identified in Subsection 7.5.3.1, except for the IU Cell Nitrogen Purge signal which originates in the TRPS, via the following manual push buttons located on the main control board:

- RCA Isolation
- Supercell Isolation (performs Supercell Areas 1 through 10 Isolations and MEPS A/B/C Heating Loop Isolations)
- VTS Actuation
- TPS Isolation (performs TPS Train A/B/C Isolation and TPS Process Vent ~~Isolation~~Actuation)
- Carbon Delay Bed ~~Group~~ 1 Isolation
- Carbon Delay Bed ~~Group~~ 2 Isolation
- Carbon Delay Bed ~~Group~~ 3 Isolation
- Extraction Column A Alignment Actuation
- Extraction Column B Alignment Actuation
- Extraction Column C Alignment Actuation
- IXP Alignment Actuation
- RPF Nitrogen Purge
- Dissolution Tank Isolation

To support the use of manual actuations, the ESFAS includes isolated outputs for each safety-related instrument channel to provide monitoring and indication information to the PICS. To facilitate operator indication of ESFAS actuation function status, manual initiation and reset of protective actions, the ESFAS, at the division level, includes isolated input/output for the following:

- Indication of ESFAS variable values
- Indication of ESFAS parameter values
- Indication of ESFAS logic status
- Indication of ESFAS equipment status
- Indication of ESFAS actuation device status

Operator display criteria and design are addressed in Section 7.6.

### 7.5.3.7 Loss of External Power

The ESFAS is powered from the UPSS, which provides a reliable source of power to maintain the ESFAS functional during normal operation and during and following a design basis event. The UPSS is designed to provide power to the ESFAS controls for six hours after a loss of off-site power. The UPSS is described in Section 8a2.2.

7.5.4.1.7 High PVVS Carbon Delay Bed Exhaust ~~Carbon Monoxide~~Temperature

The high PVVS carbon delay bed ~~group~~ 1/2/3 exhaust ~~carbon monoxide~~temperature signals protect against a fire in the PVVS delay beds (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 ~~group~~ 1/2/3 exhaust ~~carbon monoxide input~~temperature exceeds the high level setpoint. The PVVS carbon delay bed ~~group~~ 1/2/3 exhaust ~~carbon monoxide~~temperature 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 PVVS carbon delay bed ~~group~~ 1/2/3 exhaust ~~carbon monoxide~~temperature channels exceed their setpoint, then a Carbon Delay Bed Isolation for the affected ~~group~~bed is initiated.

7.5.4.1.8 VTS Vacuum Header Liquid Detection

The VTS vacuum header liquid detection 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 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 channels indicate liquid is detected, then a VTS Safety Actuation is initiated.

7.5.4.1.9 RDS Liquid Detection

The RDS liquid detection 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 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 channels indicate liquid is detected, 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~~and an RCA Isolation are 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~~and an RCA Isolation are initiated.

**Table 7.5-1 – ESFAS Monitored Variables**
**(Sheet 2 of 6)**

| Variable | Analytical Limit | Logic | Range | Accuracy | Response Time |
|---|---|---|---|---|---|
| RVZ1 supercell area 10 (IXP) exhaust ventilation radiation | 15x background radiation | 1/2↑ | $10^{-7}$ to $10^{-1}$ µCi/cc | 20 percent | 15 seconds |
| MEPS heating loop radiation extraction area A | 2500 mR/hr | 1/2↑ | 0.1 to 10,000 mR/hr | 20 percent | ~~5~~20 seconds |
| MEPS heating loop radiation extraction area B | 2500 mR/hr | 1/2↑ | 0.1 to 10,000 mR/hr | 20 percent | ~~5~~20 seconds |
| MEPS heating loop radiation extraction area C | 2500 mR/hr | 1/2↑ | 0.1 to 10,000 mR/hr | 20 percent | ~~5~~20 seconds |
| PVVS carbon delay bed ~~group~~ 1 exhaust ~~carbon monoxide~~temperature | ~~50 ppm~~121°C | 1/2↑ | ~~1 to 100 ppm~~15 to 300°C | 1~~0~~ percent | ~~15~~300 seconds |
| PVVS carbon delay bed ~~group~~ 2 exhaust ~~carbon monoxide~~temperature | ~~50 ppm~~121°C | 1/2↑ | ~~1 to 100 ppm~~15 to 300°C | 1~~0~~ percent | ~~15~~300 seconds |
| PVVS carbon delay bed ~~group~~ 3 exhaust ~~carbon monoxide~~temperature | ~~50 ppm~~121°C | 1/2↑ | ~~1 to 100 ppm~~15 to 300°C | 1~~0~~ percent | ~~15~~300 seconds |
| VTS vacuum header liquid detection | Liquid detected | 1/2↑ | Liquid detected/liquid not detected | Discrete input signal | 5.5 seconds |
| RDS liquid detection | Liquid detected | 1/2↑ | Liquid detected/liquid not detected | Discrete input signal | 5.5 seconds |
| TPS exhaust to facility stack tritium | 1 Ci/$m^3$ | 2/3↑ | 1 to 2,000,000 µCi/$m^3$ | 10 percent | 5 seconds |
| TPS IU cell 1 target chamber exhaust pressure | 8 psia | 1/2↑ | 0 to 19.5 psia | 1 percent | 10 seconds |

**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 supply isolation 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 supply isolation 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 supply isolation 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
PVVS carbon delay bed 1 outlet isolation valves
PVVS carbon delay bed 2 outlet isolation valves
PVVS carbon delay bed 3 outlet isolation valves

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

**Figure 7.5-1 – ESFAS Logic Diagrams**
**(Sheet 6 of 25)**

**Figure 7.5-1 – ESFAS Logic Diagrams**
**(Sheet 14 of 25)**

**Figure 7.5-1 – ESFAS Logic Diagrams**
**(Sheet 19 of 25)**

**Figure 7.5-1 – ESFAS Logic Diagrams**
**(Sheet 22 of 25)**

**~~Figure 7.5-1 – ESFAS Logic Diagrams~~**
**~~(Sheet 24 of 27)~~**

**Figure 7.5-1 – ESFAS Logic Diagrams**
**(Sheet 24 of 25)**

**~~Figure 7.5-1 – ESFAS Logic Diagrams~~**
**~~(Sheet 26 of 27)~~**

and impurities allowing for reuse of the solution in the irradiation process. These processes present a possibility of radiological release from processes, with fire presenting an energetic source that can drive release. Radiological release due to fire is typically associated with combustion of radiologically contaminated ordinary combustible materials or fire damage to confinement systems that could allow release of collocated radiological materials.

Uranium oxide and uranium metal are received and stored in the uranium receipt and storage system (URSS) room. Storage of the uranium metal and uranium oxide is in metal storage canisters. Canisters are stored on metal storage racks to ensure a safe configuration of the stored materials. Uranium metal is received in sufficiently massive configurations that it is not pyrophoric.

The TSPS and URSS rooms are protected with automatic fire detection and provided with appropriate portable fire extinguishers for incipient stage fire suppression. Combustible loading in these rooms is maintained lowat a moderate level to prevent fire. Fire response using water-based extinguishants is prohibited; elevated floors of the URSS and TSPS fire area are provided to prevent flooding of these rooms.

Irradiation is performed in the irradiation facility (IF). Chemical processing, to extract medical isotopes from the target solution, is performed in the RPF. The irradiation and chemical processing of radiological materials is discussed in detail in Chapter 4.

Once target solution is introduced to the irradiation process, it is contained in pipes and tanks. These pipes and tanks are located in the IU cells, hot cells, tank vaults, and pipe trenches throughout the IF and RPF. The IU cells, hot cells, tank vaults, and pipe trench structures are constructed of massive steel and concrete barriers to provide radiation shielding. The monolithic construction of these structures provides significant fire separation from the general areas of the IF and RPF. This construction provides protection to the pipes and tanks containing radiological materials. Combustible loading in the spaces within the IU cells, hot cells, tank vaults, and pipe trenches is maintained very low. Combustible materials in these spaces are limited to cable and equipment. Combustible loading in the IF and RPF general areas is maintained lowat a moderate level to present a minimal potential for fire. The IF and RPF general areas are equipped with automatic fire detection and provided with portable fire extinguishers to provide incipient fire suppression capability.

Filters contained in the facility ventilation systems that may contain fission products are replaced on a regular basis. Filters are contained in non-combustible ductwork. Areas of the radiologically controlled area (RCA) containing filters are protected with automatic fire detection and portable fire extinguishers. Combustible loading is maintained at a moderate or low level in these areas.

The carbon guard beds located in the process vessel vent system (PVVS) are equipped with temperature detection. The guard beds are isolated upon indication of an unacceptable increase in temperature. The carbon delay beds are monitored with in-bed and exhaust temperature detection and carbon monoxide detectors at the outlet of each carbon delay bed group. The cCarbon delay beds 1, 2, and 3 are equipped with a nitrogen purge line that may be used to extinguish hot spots if detected.

Three facility systems are provided to mitigate hydrogen generation due to radiolysis. These systems are the TSV off-gas system (TOGS), PVVS, and nitrogen purge system (N2PS).

the tank headspace, to the PVVS conditioning and filtration equipment. Gases pass through condensers, cooled with process chilled water, to remove excess heat and reduce absolute humidity of the off-gas.

Condensate is collected in the PVVS condensate tank within the PVVS hot cell, located within the supercell. Condensate may be returned to the target solution staging system (TSSS) tanks as makeup water or to the radioactive liquid waste storage (RLWS) system for waste processing. An in-line heater, the PVVS reheater, downstream of the condenser heats the off-gas back to ambient temperature to reduce the relative humidity. The off-gas then flows through acid adsorber beds and HEPA filters to neutralize entrained acid droplets or gases and filter particulates. The gas flows from the hot cell to below-grade, shielded vaults, passing through guard beds to capture iodine prior to passing through a series of delay beds packed with carbon to delay the release of fission product noble gases such as xenon and krypton. The eight delay beds are organized into three groups as shown in Figure 9b.6-1. Group 1 includes Delay Beds 1 and 2. Group 2 includes Delay Beds 3, 4, and 5. Group 3 includes Delay Beds 6, 7, and 8. Due to the large inventory of radionuclides nominally flowing through carbon delay beds 1, 2, and 3, safety-related isolation is provided to prevent the release of radioactive material in excess of acceptable levels in the event of ignition of carbon media in a delay bed. Carbon delay beds 4, 5, 6, 7, and 8 are provided with nonsafety-related isolation to limit the release of radioactive material in the event of ignition of carbon media in a delay bed. A final set of HEPA filters removes any entrained carbon fines upstream of the blowers, and the treated gases are discharged to the facility stack.

In the event PVVS flow drops below the minimum flow rate of 5.0 standard cubic feet per minute, the engineered safety features actuation system (ESFAS) automatically initiates an RPF Nitrogen Purge. This results in the nitrogen purge system (N2PS) providing nitrogen flow to the RPF tanks to mitigate hydrogen generation. Upon actuation of the N2PS, the RPF header valves actuate open, the isolation valves at the PVVS north and south header valves actuate closed, and the PVVS isolation valve at the radioactive liquid waste immobilization (RLWI) interface actuates closed to prevent nitrogen backflow. During the nitrogen purge, the PVVS equipment and piping continues to provide the flow path for the off-gas through the RPF. Safety-related bypasses are provided around filtration skid equipment in the hot cell (i.e., the PVVS condenser, PVVS reheater, acid adsorber, HEPA filter, and guard bed) that could contribute to a blocked pathway and an alternate, safety-related exhaust point to the roof is actuated open. The branch to the alternate release point is upstream of the PVVS blowers. On loss of power, the discharged gases bypass the filtration skid equipment before being discharged to the alternate vent path in the PVVS and the stack. For a receipt of an ESFAS actuation signal other than loss of power, the discharged gases flow through the PVVS passive filtration skid equipment and the filtration skid equipment bypass line before being discharged to the alternate vent path in the PVVS and the stack.

Fire protection is provided for the guard beds and delay beds. Temperature instrumentation and carbon monoxide detection areis used to monitor for oxidation. Thedetect potential fires. Delay beds may be1, 2, or 3 are isolated orupon high temperature and may be purged with nitrogen to smother the reaction. Additionally, operators can attempt to increase the system flow rate to increase convective cooling. The ESFAS automatically isolates the affected delay bed groups when carbon monoxide concentrations in the effluent gas exceed 50 ppm1, 2, or 3 prior to the exhaust temperature exceeding the analytical limit (Table 7.5-1). The process integrated control system (PICS) is used to isolate the affected delay bed 4, 5, 6, 7, or 8 if the exhaust temperature reaches a predetermined limit.

### 9b.6.1.4 Instrumentation and Control

Safety-related PVVS instrumentation has redundant channels and provides output to ESFAS. Nonsafety-related PVVS instrumentation provides output signals to the process integrated control system (PICS).

Temperature instrumentation is used to monitor the performance of the condensers, heaters, and acid adsorbers as well as the guard beds and delay beds. Temperature instrumentation is also used to monitor the exhaust temperature of the delay beds.

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 alternate vent path in the PVVS and 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.

### 9b.6.2.2 System Description

N2PS provides back-up sweep gas flow in the form of stored pressurized nitrogen gas. Downstream pressure is controlled with self-regulating pressure reducing valves with overpressure protection by pressure relief valves. On actuation of the N2PS, nitrogen flows through the irradiation facility (IF) and RPF equipment to ensure the hydrogen concentration is below the LFL. The nitrogen purge flows through the normal PVVS path and filtration equipment, including the delay beds, as described in Subsection 9b.6.1.2. After exiting the delay beds in PVVS, the nitrogen purge is diverted to a safety-related alternate vent path in case of a downstream blockage. Valves configured to fail open allow the diversion to the alternate vent path. After actuation of the N2PS, the pressurized storage tubes can be refilled by truck deliveries.

A process flow diagram of the N2PS is provided in Figure 9b.6-2.

Purge of an IU

Upon loss of normal power as determined by the engineered safety features actuation system (ESFAS) and after a delay or upon loss of normal sweep gas flow in the IU as determined by the TSV reactivity protection system (TRPS), solenoid valves on the nitrogen discharge manifold actuate open, releasing nitrogen into the IU cell supply header. Upon loss of sweep gas flow in any IU cell, nitrogen solenoid isolation valves for the given cell actuate open releasing nitrogen purge gas into the TSV dump tank, and valves in the TOGS actuate open to allow the nitrogen purge gas to flow to the PVVS. The nitrogen purge gas flows through the TSV dump tank, TSV, and TOGS equipment before discharging into PVVS. A flow switch provides indication that nitrogen is flowing to the IU cell. A detailed discussion of the IU Cell Nitrogen Purge is provided in Section 7.4.

Purge of RPF Equipment

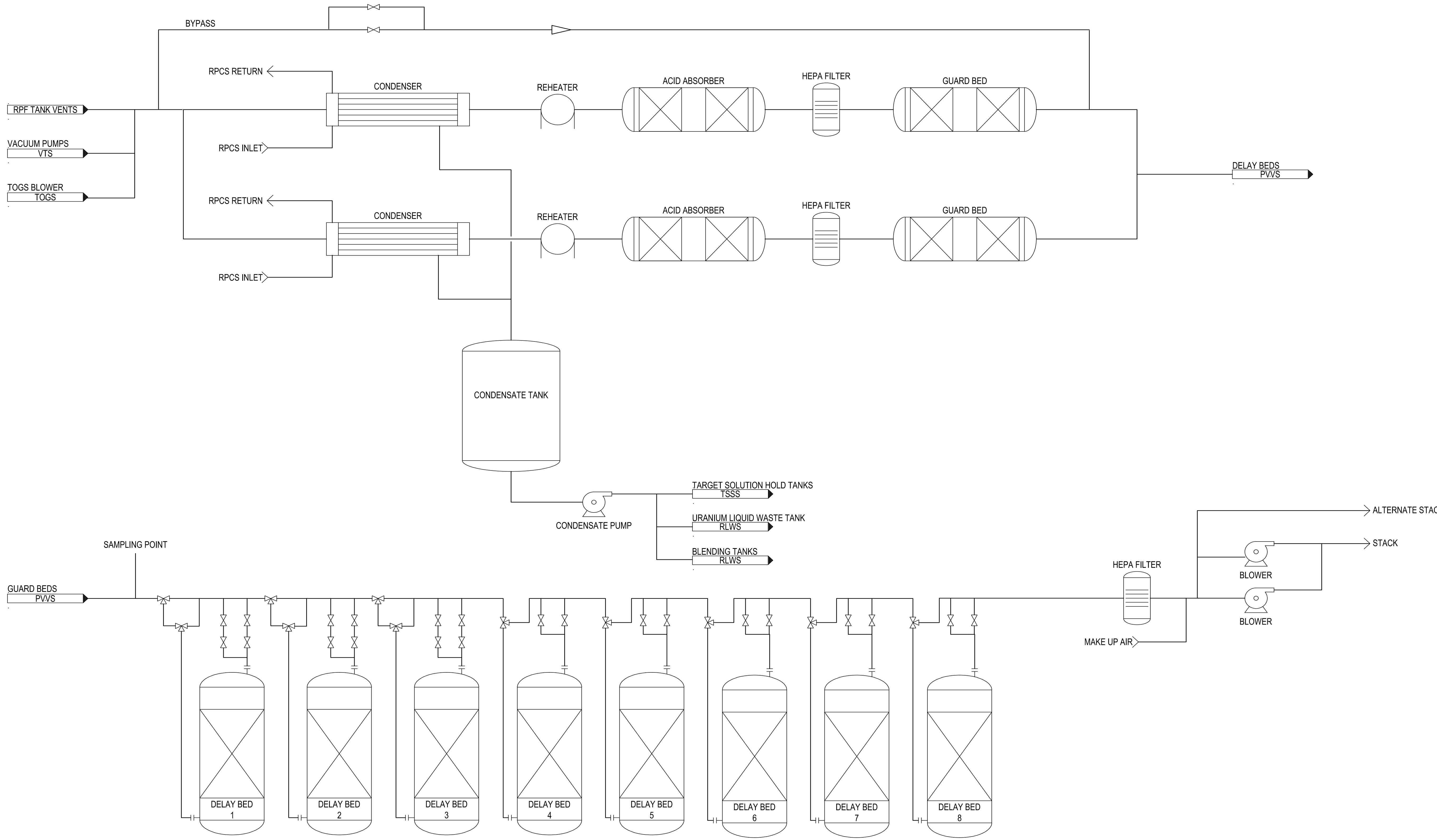
Upon loss of normal power or loss of normal sweep gas flow through PVVS, as determined by the ESFAS, solenoid valves on the ventilation zone 2 air supply to PVVS fail closed and isolate the sweep gas air flow to the RPF tanks. At the same time, solenoid valves on the nitrogen discharge manifold actuate open, releasing nitrogen into the RPF distribution piping. The nitrogen flows through the RPF equipment in parallel before discharging into PVVS. A flow switch provides indication that nitrogen is flowing to the RPF distribution piping.

Processes that receive ventilation air from the PVVS during normal conditions are also ventilated by N2PS during deviations from normal operation. In the RPF, the N2PS ventilates tanks in the TSSS, RLWS system, radioactive drain system (RDS), molybdenum extraction and

**Table 9b.6-1 – Process Vessel Vent System Interfaces (Sheet 1 of 2)**

| Interfacing System | Interface Description |
|---|---|
| Engineered safety features actuation system (ESFAS) | The ESFAS monitors the operation of the process vessel vent system (PVVS). ESFAS actuates the nitrogen purge system (N2PS) and opens the PVVS filtration bypass on low ventilation flow through PVVS, and isolates ~~the~~ delay beds 1, 2, or 3 on high ~~carbon monoxide concentration~~temperature detection in the affected bed. |
| Iodine and xenon purification and packaging (IXP) system | The PVVS ventilates tanks in the IXP. |
| Molybdenum extraction and purification system (MEPS) | The PVVS ventilates the molybdenum eluate hold tank and MEPS condensate tank. |
| Nitrogen purge system (N2PS) | The N2PS provides sweep gas flow through the PVVS piping and filtration equipment on loss of normal power or normal flow in PVVS. |
| Normal electrical power supply system (NPSS) | The NPSS is distributed to the PVVS blowers, the PVVS reheater, and ancillary equipment. |
| Process integrated control system (PICS) | The PICS controls the PVVS and monitors PVVS instrument signals. |
| Production facility biological shield (PFBS) | The PFBS provides shielding to workers from the PVVS. PVVS equipment is located in a hot cell and in a below-grade vault. |
| Radioactive drain system (RDS) | The PVVS ventilates the RDS tanks. |
| Radioactive liquid waste storage (RLWS) system | The PVVS ventilates the RLWS tanks. The PVVS drains condensate water to the RLWS for disposal. |
| Radioactive liquid waste immobilization (RLWI) system | The PVVS ventilates the immobilization feed tank. |
| Radioisotope process facility cooling system (RPCS) | The RPCS provides cooling capacity to the PVVS for the off-gas condensers. |
| Radiological ventilation zone 1 (RVZ1) | The PVVS blowers discharge into a header shared by RVZ1 to the facility stack. Some PVVS components are located in a hot cell, which is ventilated by RVZ1. |
| Radiological ventilation zone 2 (RVZ2) | The PVVS intake removes air from RVZ2 for use as sweep gas across the RPF tanks. |
| Stack release monitoring system (SRMS) | The SRMS monitors the discharge from the PVVS delay beds to the stack. |
| Standby generator system (SGS) | The SGS provides nonsafety-related backup power to PVVS components. |
| Target solution staging system (TSSS) | The PVVS ventilates the TSSS tanks to mitigate hydrogen generation. The PVVS may also transfer condensate water to the TSSS for reuse in the irradiation cycle. |

**Figure 9b.6-1 – PVVS Process Flow Diagram**



The IF overhead crane is designed and constructed such that it will remain in place and support the critical load during and after an aircraft impact but is not required to be operational after this event. Single failure-proof features are included such that any credible failure of a single component will not result in the loss of capability to stop and hold the critical load.

Radioisotope Production Facility Overhead Crane

The RPF overhead crane is a 15-ton, double girder, bridge style crane designed for the handling of shield cover plugs and equipment in the RPF. The RPF overhead crane is designed to span the width of the RPF and travel the length of the RPF.

The RPF overhead crane employs the use of mechanical stops, electrical-interlocks, and predetermined safe load paths to minimize the movement of loads in proximity to redundant or dual safe shutdown equipment. These safeguards ensures that off-normal load events from loads containing radioactive materials or safety-related SSCs that are beneath, or directly adjacent to a potential travel load path of the RPF overhead crane, could not result in the complete loss of a safe shutdown function or the release of radioactivity in excess of 10 CFR 20 limits.

The RPF overhead crane is designed and constructed following the seismic requirements for an ASME NOG-1, Type II crane so that it will remain in place with or without a load during a design basis earthquake. The crane is not required to support the critical load nor remain operational during and after such an event.

9b.7.2.3 Operational Analysis and Safety Function

The IF overhead crane removes irradiation unit (IU) cell plugs, the target solution vessel (TSV) off-gas system (TOGS) cell plugs, ~~primary cooling room plugs,~~ and neutron driver transport to and from IU cells and the neutron driver assembly system (NDAS) service cell. The IF overhead crane is used for lifting, repositioning, and landing operations associated with major components of the subcritical assembly system (SCAS), the primary closed loop cooling system (PCLS), the TOGS, and the tritium purification system (TPS) as well as various planned maintenance activities throughout the IF.

The RPF overhead crane is utilized for lifts including the removal of tank vault, valve pit, and pipe trench plugs, removal of carbon delay bed vault plugs, supercell manipulator replacements, and the removal of column waste drums and post cooldown shielding/packaging. The RPF overhead crane is used for various planned maintenance activities. In addition, the crane performs lifting of empty tanks in the RPF, immobilized waste drums and the associated shielding/packaging hardware, and other major components within the RPF.

The IF and RPF overhead cranes are inspected, tested, and maintained in accordance with ASME B30.2 (ASME, 2011a). The inspection requirements reduce the probability of a load drop that could result in a release of radioactive materials or damage to essential safe shutdown equipment that could cause unacceptable radiation exposures. Inspection and testing of special lifting devices are performed in accordance with American National Standards Institute (ANSI) N14.6, Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More (ANSI, 1993). Inspection and testing of lifting devices not specially designed are in accordance with ASME B30.9, Slings (ASME, 2018).

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 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, process (i.e., encapsulate), 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 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.

Used, activated NDAS units are disassembled prior to transport to the material staging building or storage in storage bore holes. Disassembly minimizes the waste volume shipped for ultimate disposal.

Separation columns used in the processes contained within the supercell are stored on supercell storage racks for a minimum of 14 days following their use. Following decay on storage racks, columns are transferred to column waste drums imported by the supercell. The column waste drums are exported and transferred to the drum storage bore holes. Following extended decay, column waste drums are removed from the bore holes by the supercell. Prior to disposal, the column waste drums may require encapsulation to meet the designated licensed disposal facility's waste acceptance criteria.

Depending on weight, solid waste may need to be transferred to the material staging building using forklifts or other lifting devices. Once in the material staging building, solid wastes may be held for decay. Waste is characterized and staged for shipment in the material staging building. Encapsulation of column waste drums takes place in the material staging building, as needed.

Waste is processed, handled, and shipped off site in accordance with the radioactive waste management program, described in Section 11.2.

SRWP system operations are performed in accordance with the requirements of the radiation protection program, described in Section 11.1.

No nuclear criticality safety requirements are identified for the SRWP system. Nuclear criticality safety is controlled in upstream interfacing systems, where appropriate.

The SRWP system is nonsafety-related.

#### 9b.7.5.4 Instrumentation and Control

No instrumentation or controls have been identified for the SRWP system.

#### 9b.7.5.5 Technical Specifications

There are no technical specification parameters associated with the SRWP system.

### 9b.7.6 RADIOACTIVE DRAIN SYSTEM

#### 9b.7.6.1 Design Bases

The design bases of the RDS include:

- Collect liquids leaked from tanks, piping, or other components which require favorable geometry for collection and storage.
- Collect liquids resulting from the overflow of the target solution storage tanks, target solution hold tanks, and uranium liquid waste tanks.
- Provide overpressure protection for the extraction cells and IXP cells of the supercell, as the RDS forms an open pathway through the RDS tanks to the PVVS.
- Allows a representative sample of the contents of the RDS sump tanks to be obtained.

9b.7.6.2 System Description

The RDS consists of drip pans with drain lines, tank overflow lines, collection tanks and instrumentation to alert operators of system status. The RDS includes drip pans located ~~beneath~~inside the extraction and IXP hot cells, favorable geometry tanks, and piping for systems that normally contain high concentration (> 25 gU/l) fissile solution. The RDS also collects overflow from target solution and uranium waste tanks. The RDS consists of two favorable geometry tanks (annular tanks) that collect leakage from postulated sources. The leakage and overflow are connected by piping that is substantially located within the basemat of the RPF as well as in the RPF pipe trench. Gravity provides the motive force between the various drip pans and the RDS tanks. No valves are installed between the potential collection source and the collection tanks.

Table 9b.7-4 identifies the systems which interface with the RDS.

Figure 9b.7-5 provides a process flow diagram for the RDS.

9b.7.6.3 Operational Analysis and Safety Function

The RDS includes two sump tanks, each sized to accept the largest volume of liquid containing SNM that is postulated to leak from a favorable geometry tank. The largest volume of liquid containing SNM postulated to leak into the RDS system is the volume of the largest favorable geometry tank, assuming the tank is filled to the overflow line. The inclusion of two RDS tanks provides operational margin.

The RDS sump tanks are connected to the target solution storage tanks, target solution hold tanks, and uranium liquid waste tanks. Additionally, the sump tanks are connected to drip pans in vaults containing annular tanks, drip pans in valve pits servicing annular tanks, drip pans in the main pipe trench, and drip pans in the extraction and IXP hot cells. Redundant overflows to a common RDS header are provided for each annular tank. The RDS is not used in any normal operating conditions. Instrumentation is provided to alert operators of the presence of liquid level in the RDS sump tanks. If liquid is detected in the sump tanks, contingency actions may be performed by using systems other than the RDS. Contents of the RDS tanks are sampled and transferred by the VTS to the appropriate location. Characterization of the sample is performed by the quality control and analytical testing laboratories (LABS).

The RDS needs to remain open for drainage of fissile-containing liquids (for criticality safety), while also not compromising the integrity of the confinement barrier. Fluids are contained within appropriate process piping and vessels, and the system is vented to the PVVS.

Piping that contains potentially-radiological material is routed through shielded pipe chases to limit the exposure of radiation to personnel. The RDS tanks are shielded by a tank vault, which is a part of the PFBS. The PFBS shielding requirements are described in Section 4b.2.

RDS operations are performed in accordance with the requirements of the radiation protection program, described in Section 11.1.

Table 11.1-3 lists the activity associated with the radionuclides listed in NUREG/CR-4467, Relative Importance of Individual Elements to Reactor Accident Consequences Assuming Equal Release Fractions (USNRC, 1986) for the nominal and safety basis radionuclide inventories after [ ]PROP/ECI of irradiation and the subsequent decay time in the TSV dump tank. At this time, it is ready to be pumped into the supercell to begin the molybdenum extraction and fission product removal processes. The cycle and decay times used for the radionuclide inventory generation are listed in Table 11.1-1.

SHINE uses the following radiation area designations, as defined in 10 CFR 20, including consideration for neutron and gamma dose rates:

- Unrestricted Area means an area to which access is neither limited nor controlled by SHINE. This would be the area beyond the site boundary.
- Radiation Areas (RAs) are those accessible areas in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 millirem (mrem) in 1 hour (hr) at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
- High Radiation Areas (HRAs) are those accessible areas in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 100 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
- Very High Radiation Areas (VHRAs) are those accessible areas in which radiation levels from radiation sources external to the body could result in an individual receiving an absorbed dose in excess of 500 rads in 1 hour at 1 meter from the radiation source or 1 meter from any surface that the radiation penetrates.

The SHINE facility is designed and constructed so that the measurable dose rate in the unrestricted area due to activities at the plant are less than the limits of 10 CFR 20.1301(a)(2).

The radiation shielding is designed to ensure that during normal operation internal facility radiation dose rates are consistent with as low as reasonably achievable (ALARA) radiological practices required by 10 CFR 20. The goal for the normal operations dose rate for normally occupied locations in the facility is 0.25 mrem/hr at 30 centimeters from the surface of the shielding. Radiation levels may rise above the 0.25 mrem/hr level during some operations such as tank transfers. At full-power operation of the eight units, portions of the normally occupied area in IF and RPF exceed the 0.25 mrem/hr goal but remain below 5 mrem/hr, except in a localized area above a portion of the drum storage bore hole trench near the most recently exported column waste drum and in small sections above the pipe trench during solution transfers. These dose rates were calculated using the maximum specified shield plug gap sizes, minimum density shielding materials, and the nominal inventories for full power operation.

A tabulation of normally and transient-occupied areas, dose rates, and designations is provided in Table 11.1-4. Figure 11.1-1 provides the probable radiation area designations, above grade, within the radiologically controlled area (RCA) at the main production facility.

Procedures for transient access to shielded vaults, cells, and rooms ensure doses are maintained ALARA by addressing the following:

- job planning,
- radiation protection coverage,

Nitrogen-16 is produced within the primary cooling loop and the light water pool. Dose rates from these sources are mitigated by delay tanks and biological shielding that limits radiation dose to occupied areas adjacent to the shielding.

The design of the main production facility maintains airborne radioactive material at very low concentrations in normally occupied areas. Confinement and ventilation systems are designed to protect workers from sources of airborne radioactivity during normal operation and minimize worker exposure during maintenance activities, keeping with the ALARA principles outlined in 10 CFR 20.

Although most process gas systems within the facility are maintained below atmospheric pressure, some leakage of process gases is expected due to the difference in partial pressure between the system and the surrounding environment. A conservative best estimate of airborne releases due to normal operation and maintenance was performed to estimate derived air concentrations (DACs) for the facility.

Leakage from process systems was estimated based on the number of components and fittings, achievable leak tightness per fitting, permeation through equipment, and partial pressures of airborne radionuclides. For processes in hot cells that require routine disconnection of components (e.g., extraction columns) special fittings are used to minimize process leakage.

The effects of the confinement systems are incorporated into the analysis. The results of the evaluation, broken down into particulates, halogens, noble gases, and tritium, are provided in Table 11.1-6. These values provide a conservative best estimate of the facility DACs. Figure 11.1-2 provides the DAC zoning map for the facility, using the following definitions:

- Zone 1 (< 1.0 DAC);
- Zone 2 (1.0 – 10 DAC); and
- Zone 3 (> 10 DAC).

Gaseous activity from the TSV and process operations is routed through the PVVS which includes carbon delay beds to allow for airborne radionuclides to decay to low enough levels such that normal releases are below the 10 CFR 20 limits. ~~PVVS includes a sample line to the carbon monoxide (CO) detection cabinet that contains CO gas analyzers above grade. The CO cabinet does not have potential for excessive leakage.~~ Additional airborne release pathways are RVZ1 ventilation of the facility hot cells, flow out of the primary confinement boundary to RVZ1, and radiological ventilation zone 2 (RVZ2) ventilation of any leakage to the general area (material evaluated for the DAC). These additional pathways do not pass through the carbon delay beds but do contain filters as described in Subsection 9a2.1.1. Table 11.1-7 lists key parameters used in the normal release calculation. Tritium releases that are treated by TPS are negligible in comparison to tritium releases to the general area due to maintenance and leakage and are not included in Table 11.1-7 or Table 11.1-8.

Annual off-site doses due to the normal operation of the SHINE facility have been calculated using the computer code GENII2 (PNNL, 2012). The GENII2 computer code was developed for the Environmental Protection Agency (EPA) by Pacific Northwest National Laboratory (PNNL) and is distributed by the Radiation Safety Information Computational Center (RSICC). Annual average relative atmospheric concentration (χ/Q) values were determined using the methodology in Regulatory Guide 1.111, Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors (USNRC, 1977) with

**Table 11.1-4 – Radiation Areas at the Main Production Facility**

| Area | Dose Rate | Designation |
|---|---|---|
| Normally occupied areas within the RCA<br><br>TPS room<br><br>NDAS service cell without accelerator operation | ≤ 5 mrem/hr | Normally occupied area |
| IU cells, hot cells, and other shielded vaults; cells; and rooms – material not present or accelerator not in operation, after sufficient decay period<br><br>Above RPF trench during solution transfers<br><br>Primary cooling rooms during operation<br><br>IF general area during accelerator operation in NDAS service cell<br><br>Above drum storage bore hole near the most recently exported column waste drum | > 5 mrem/hr but ≤ 100 mrem/hr | Radiation Area (transient occupation) |
| IU cells, hot cells, and other shielded vaults; cells; and rooms – material present or accelerator in operation or shutdown without sufficient decay period<br><br>NDAS service cell with accelerator operation | > 100 mrem/hr (High Radiation Area) or > 500 rad/hr (Very High Radiation Area) | High Radiation Area or Very High Radiation Area (rarely occupied, per ALARA controls) |

**Table 11.1-5 – Airborne Radioactive Sources (Sheet 1 of 4)**

| System | Component | Location | Major Sources | Estimated Maximum Activity (Ci) | Exterior Dose Rate (mrem/hr)[a] |
|---|---|---|---|---|---|
| TPS | Tritium purification system | TPS gloveboxes | H-3 | 300,000[b] | < 0.25 |
| NDAS | Driver vacuum hardware | IU cell | H-3 | [ ][PROP/ECI(c)] | < 0.25 |
| TOGS | Off-gas piping, zeolite beds | TOGS shielded cell | I, Kr, Xe | 120,000[d] | < 0.25 |
| RVZ1 | IU cell atmosphere and PCLS | IU cell | Ar-41 and N-16 | Ar-41: 1E-05<br>N-16: 10[d] | N/A |
| RVZ1 | Supercell atmosphere | Supercell gloveboxes | I, Kr, Xe, and particulates | 3 | < 0.2 |
| PVVS and VTS | PVVS and VTS piping | Pipe trenches, valve pits, ~~PVVS CO cabinet,~~ and PVVS hot cell | I, Kr, Xe | 25,000[d] | < 1 |

a. Dose contribution from listed source in normally occupied area, includes direct dose at 30 cm from the exterior of the shielding surface and contributions from the derived air concentration.
b. Includes inventory in NDAS units.
c. H-3 activity is per NDAS unit.
d. Value is per irradiation unit (IU).

**Table 11.1-5 – Airborne Radioactive Sources (Sheet 4 of 4)**

PVVS and VTS, PVVS and VTS Piping, Pipe Trenches, Valve Pits, PVVS Hot Cell~~, PVVS CO Cabinet~~
(Conservative Best Estimate Activity)

| Isotope | Activity (Ci) |
|---|---|
| I-123 | [ ]PROP/ECI |
| I-124 | [ ]PROP/ECI |
| I-125 | [ ]PROP/ECI |
| I-126 | [ ]PROP/ECI |
| I-129 | [ ]PROP/ECI |
| I-130 | [ ]PROP/ECI |
| I-131 | [ ]PROP/ECI |
| I-132 | [ ]PROP/ECI |
| 1-132m | [ ]PROP/ECI |
| I-133 | [ ]PROP/ECI |
| I-133m | [ ]PROP/ECI |
| I-134 | [ ]PROP/ECI |
| I-135 | [ ]PROP/ECI |
| Kr-81 | [ ]PROP/ECI |
| Kr-83m | [ ]PROP/ECI |
| Kr-85 | [ ]PROP/ECI |
| Kr-85m | [ ]PROP/ECI |
| Kr-87 | [ ]PROP/ECI |
| Kr-88 | [ ]PROP/ECI |
| Xe-122 | [ ]PROP/ECI |
| Xe-123 | [ ]PROP/ECI |
| Xe-127 | [ ]PROP/ECI |
| Xe-131m | [ ]PROP/ECI |
| Xe-133 | [ ]PROP/ECI |
| Xe-133m | [ ]PROP/ECI |
| Xe-135 | [ ]PROP/ECI |
| Xe-135m | [ ]PROP/ECI |
| Xe-138 | [ ]PROP/ECI |

**Table 11.1-6 – Estimated Derived Air Concentrations**

| Source Description | Location | Particulate | Halogen | Noble Gas | Tritium | Total |
|---|---|---|---|---|---|---|
| Primary System Boundary | IF General Area | - | 0.1% | 0.0% | - | 0.1% |
| Tritium Systems | TPS Room | - | - | - | 1.4% | 1.4% |
| | IF General Area, Normal Operation | - | - | - | 0.8% | 0.8% |
| | IF General Area, Maintenance | - | - | - | 1.1% | 1.1% |
| Below-Grade Vaults~~, PVVS CO Cabinet~~ | RPF General Area | - | 0.8% | 0.0% | - | 0.8% |
| PVVS Hot Cell | PVVS Hot Cell | - | > 10 DAC | 271.6% | - | > 10 DAC |
| | RPF General Area | - | 0.1% | 0.0% | - | 0.1% |
| Extraction and IXP Hot Cells | Hot Cells | 18% | > 10 DAC | 76.3% | 0.0% | > 10 DAC |
| | RPF General Area | 0.0% | 1.5% | 0.0% | 0.0% | 1.5% |
| Purification Hot Cell | Purification Hot Cell | 38.7% | > 10 DAC | 222% | 0.0% | > 10 DAC |
| | RPF General Area | 0.0% | 2.2% | 0.0% | 0.0% | 2.2% |
| **IF General Area Total** | | - | 0.1% | 0.0% | 1.9% | 2.0% |
| **RPF General Area Total** | | 0.0% | 4.7% | 0.0% | - | 4.7% |

**Table 11.1-10 – Solid Radioactive Sources**
**(Sheet 1 of 5)**

| System[(a)] | Component[(a)] | Location | Major Sources | Estimated Maximum Activity (Ci) | Exterior Dose Rate (mrem/hr) |
|---|---|---|---|---|---|
| NDAS | Neutron Driver | IU Cell | Activation Products | 300[(b)] | N/A |
| TOGS | TOGS Components | IU Cell and TOGS Cell | Rb, Cs, Ba, Sr, Y, La, and Ce | 5.6E+04[(b)] | < 0.25 |
| SCAS | Neutron Multiplier, SASS | IU Cell | Activation and Fission Products | 1.5E+05[(b)] | N/A |
| MEPS | Spent Extraction [ ][PROP/ECI] | Supercell | [ ][PROP/ECI] | 2.6E+04[(c)] | < 5 |
| MEPS | Spent Extraction [ ][PROP/ECI] | Waste Drum Storage | [ ][PROP/ECI] | 1.4E+03[(c)] | < 50[(d)] |
| MEPS | Glassware | Supercell and Solid Waste Drum Storage | [ ][PROP/ECI] | 100[(c)] | N/A |
| TSPS and URSS | Fresh Uranium Metal and Uranium Oxide | Target Solution Preparation and Storage Areas | U-234, U-235, U-238 | 3 | N/A |
| RLWI | Solidified Waste Drum | Liquid Waste Solidification Cell | Activation and Fission Products | 125[(e)] | < 0.25 |
| Solid Radwaste | Spent Filters | Supercell | Iodine | 400 | < 1 |
| SCAS | Subcritical Multiplication Source | IU Cell | Alpha-neutron Source (PuBe or AmBe) | [ ][SRI] | N/A |

a. Descriptions of the systems and their physical characteristics can be found in Chapter 4.
b. Value is per irradiation unit (IU).
c. Value is per cycle.
d. Near most recently exported column waste drum.
e. Value is per drum.

**Figure 11.1-1 – Probable Radiation Area Designations Within the SHINE RCA, Ground Floor Level**

**Figure 11.1-2 – Estimated Derived Air Concentrations, Ground Floor Level**

#### 11.2.2.2.2 Target Solution Preparation System

The target solution preparation process may generate waste in the form of spent filters from the uranyl sulfate dissolution tanks, if not cleaned and reused, and spent HEPA filters from glovebox air supply and return lines. The spent filters are Class A waste.

#### 11.2.2.2.3 Irradiation Unit

An irradiation unit (IU) consists of a subcritical assembly system (SCAS) coupled with a neutron driver assembly system (NDAS). The IU components become activated during their service life. SCAS major components are designed for the life of the facility and are not anticipated waste streams. Spent NDAS components are Class A or B waste. Contaminated oil from the NDAS vacuum pumps is Class B waste.

#### 11.2.2.2.4 TSV Off-Gas System

The target solution vessel (TSV) off-gas system (TOGS) removes radiolysis and fission product gases from the TSV during irradiation operation and from the TSV dump tank during cool down operation. There are a total of eight independent TOGS, one for each IU.

The TOGS contains skid-mounted equipment that includes recombiner beds, demisters, and zeolite beds. Skid replacement occurs infrequently. Skids containing recombiner beds and demisters are treated with an acid flush and processed as Class A or B waste. Zeolite beds are designed for the life of the facility, however, if replaced more frequently and processed separately from the remainder of the skid components, the zeolite beds are expected to be Class B or Class C waste.

#### 11.2.2.2.5 Molybdenum Extraction and Purification System

The molybdenum extraction and purification system (MEPS) separates molybdenum from an irradiated uranyl sulfate target solution. The molybdenum is then concentrated and purified into a sodium molybdate solution. The MEPS is located within a series of hot cells. Waste generated from the MEPS includes spent molybdenum extraction columns, [ ][PROP/ECI], and purification glassware. MEPS liquid wastes are processed by the radioactive liquid waste immobilization (RLWI) system.

Spent extraction columns [ ][PROP/ECI] are stored in a hot cell, then transferred to the drum storage bore holes for decay~~, and ultimately disposed as Class B or C waste~~. After decay, the spent columns may be encapsulated via the solid radioactive waste packaging (SRWP) system prior to disposal.

Prior to encapsulation, the spent columns may exceed the Class C limits for alpha emitting transuranic nuclides with half-life greater than 5 years. The spent columns may be encapsulated to meet the designated licensed disposal facility's WAC, and ultimately disposed as Class B or C waste.

The glassware used in this process is not expected to contain significant quantities of long-lived radionuclides and is Class A waste.

10 CFR 20.2003 and 10 CFR 20.2007. There are no piped liquid effluent pathways from the RCA to the sanitary sewer. Liquids collected for discharge from the RCA are sampled and analyzed prior to discharge. Liquids that are not within limits for discharge are instead disposed of as low-level radioactive waste, while those that are acceptable are manually discharged to the sanitary sewer. Liquid discharge volumes are estimated to be less than 40 gallons weekly.

Table 11.2-1 shows the anticipated waste generation, classifications, shipment types, and expected disposal sites for the identified waste streams. Final determinations of waste classification and management will be made in accordance with the Radioactive Waste Management Program implementing procedures.

#### 11.2.3.1 Solid Wastes

The subsections below discuss the methodology for the eventual release of the major solid wastes generated by the SHINE facility. Processing requirements are in accordance with the receiving facility's WAC and will be modified as needed to reflect any change in the disposal site or WAC.

##### 11.2.3.1.1 Irradiation Units

Solid waste streams associated with the IUs are the NDAS activated components. The NDAS is comprised of an accelerator section, pumping section, roots stack, and target chamber assembly. The target chamber assembly is expected to be Class A or B waste and the WAC specified by Energy*Solutions* will apply. The accelerator stage, pumping stage and roots stack are considered "oversize" and must meet specific WAC applicable to oversize components. Table 11.2-2 displays the typical methodology associated with disassembly and processing of this waste stream.

##### 11.2.3.1.2 Spent Columns

Spent molybdenum extraction columns, [ ]$^{PROP/ECI}$, and IXP recovery, [ ]$^{PROP/ECI}$ will be held in hot cells for decay, then consolidated into supercell export waste drums prior to disposal.

The columns are removed from the process lines using quick-disconnect style inlet and outlet connectors specifically designed for use with remote manipulators in hot cell environments. Radiation and wear-resistant seals and automatically closing valves built into the connectors provide leak tightness to minimize or prevent leakage.

After removing a spent column from the originating process, it is stored in a hot cell for sufficient time to allow short-lived fission products to decay. After several columns have decayed, they are transported out of the cell in one transfer to reduce personnel exposure and the number of transfer operations. The number of columns transferred is limited based on export waste drum capacity. The export waste drum is shielded to ensure personnel doses are maintained ALARA and within procedure limits during the transfer. The estimated dose rate for an extraction column, at the time of process removal is approximately 9500 rem/hr at 3 feet unshielded. The peak dose rate drops to approximately 580 rem/hr at 3 feet unshielded after storage in the hot cell.

When a set of columns are to be transferred out of the hot cell, they are remotely loaded into an export waste drum within a shielded cask. Dose rates from the cask and contamination levels are

confirmed to be within limits, then the cask is remotely transported to a bore hole for interim below-grade storage. The shielded cask is surveyed and decontaminated, if needed, prior to reuse.

When a shipment of columns is to be prepared, the export waste drum is retracted using the remote-controlled grappler and placed into a shielded cask and t. The cask is transported to an areathe material staging building for processing (i.e., encapsulation) or loading into a Type B shipping container.

The as-generated waste classification of the spent columns is expected to be Class B, Class C, or GTCC and they are expected to be Typedisposed as Class B or C generated waste, following any necessary encapsulation. andSpent columns have no specified time requirement in storage. The spent columns are stored in order to consolidate shipments to minimize handling for ALARA and to consolidate the columns to reduce disposal volumes. Requirements for this waste stream are presented in Table 11.2-3.

Selective stripping columns are contained within the RLWI system. When a column is removed from service it is dewatered and processed for disposal as Type B or C waste.

11.2.3.1.3 Process Glassware

Spent molybdenum purification glassware is remotely handled to move the glassware from the hot cell to an export waste drum. The glassware may be crushed in the waste drum using a remotely controlled compactor and transported to the material staging building in a shielded transport cask. Requirements for this waste stream are presented in Table 11.2-4.

11.2.3.1.4 Zeolite Beds

The silver coated zeolite beds are a component of the TOGS and are provided to remove iodine from the sweep gas. Toxicity characteristic leaching procedure (TCLP) would result in the classification of this waste as Resource Conservation and Recovery Act (RCRA) waste; however, the waste is also radioactive and as such may be a mixed low level waste (MLLW). The waste classification for this material is a function of both the efficiency of the zeolite beds and the change out frequency of the beds. The design goal is for the beds to last the lifetime of the facility; however, this waste stream is assumed to be replaced every five years. The zeolite bed has the potential to be Class B or Class C waste.

11.2.3.1.5 Recombiner Beds, Demister and Component Replacement

This waste stream is associated with the TOGS. This waste stream is based on infrequent replacement of the TOGS skids. Acid flushing of the skid components (excluding the zeolite beds) will be performed prior to disposal. Cs-137 and Sr-90 are expected to dominate the waste classification. Remote handling and packaging may be required due to considerable dose rates expected should replacement be required. This waste stream is Class A or Class B waste.

11.2.3.1.6 PCLS and LWPS Deionizer Units

The PCLS and LWPS deionizer resins are contained in disposable deionizer units. The spent units are dewatered and disposed as Class A generated waste.

**Table 11.2-1 – Estimated Annual Waste Stream Summary (Sheet 1 of 2)**

| Description | Matrix | Class as Generated | As Generated Amount | As Generated Units | As Disposed ($ft^3$) | Shipment Type | Destination[(a)] |
|---|---|---|---|---|---|---|---|
| MEPS Extraction Columns [ ]PROP/ECI | [ ]PROP/ECI | B ~~or~~, C, or GTCC | [ ]PROP/ECI | $ft^3$/yr | 2~~70~~95 | Type B | WCS |
| Selective Ion Stripping Columns | [ ]PROP/ECI | B or C | 72 | $ft^3$/yr | 72 | Type B | WCS |
| IXP Separation Columns | [ ]PROP/ECI | B or C | [ ]PROP/ECI | $ft^3$/yr | 47 | Type B | WCS |
| LWPS Deionizer Units | Resin | A | 48 | $ft^3$/yr | 80 | Type A or LSA | Energy*Solutions* |
| PCLS Deionizer Units | Resin | A | 48 | $ft^3$/yr | 80 | Type A or LSA | Energy*Solutions* |
| Uranium Canisters | Solid | A | 2.0[(b)] | $ft^3$/yr | 3.3 | Type A or LSA | Energy*Solutions* |
| NDAS Accelerator Subassembly | Solid | A | [ ]PROP/ECI | $ft^3$/yr | 3,321 | Type A or LSA | Energy*Solutions* |
| NDAS Target Chamber Subassembly | Solid | ~~A~~B | [ ]PROP/ECI | $ft^3$/yr | 586 | Type A, B, or LSA | Energy*Solutions* |
| TOGS Skids | Solid | A or B | 846 | $ft^3$/yr | 1,411 | Type A, B, or LSA | Energy*Solutions* or WCS |
| TOGS Zeolite Beds | Solid | B or C | 0.64 | $ft^3$/yr | 1.1 | Type B | WCS |
| LWPS Filters | Solid | A | 1.6 | $ft^3$/yr | 2.7 | Type A or LSA | Energy*Solutions* |
| PCLS Filters | Solid | A | 1.6 | $ft^3$/yr | 2.7 | Type A or LSA | Energy*Solutions* |
| TSPS, URSS, PVVS, Hot Cell, RVZ1, RVZ2, RLWI HEPA Filters | Solid | A | 182 | $ft^3$/yr | 142 | Type A or LSA | Energy*Solutions* |
| Hot Cell, RVZ1, RVZ2 Charcoal Filters | Solid | A | 32 | $ft^3$/yr | 54 | Type A or LSA | Energy*Solutions* |
| TSPS Uranyl Sulfate Solution Filters | Solid | A | 0.35[(c)] | $ft^3$/yr | 0.58 | Type A or LSA | Energy*Solutions* |

**Table 11.2-3 – Waste Methodology for Spent Columns[a]**

| Requirement | Basis |
|---|---|
| Hold spent columns in hot cell for a period of decay sufficient to allow short-lived fission products to decay. | Spent columns are highly radioactive when removed from active service. Hold time is for decay and consolidated processing. |
| Remote transfer from hot cell to export waste drum. | Maintain worker dose ALARA. |
| Provide safe, shielded storage outside of hot cell. | Protected on-site storage until a full shipment of spent columns is prepared for disposal. |
| Provide management controls to ensure proper hold time is applied to spent columns. | Since multiple columns can be held in each hot cell post service, it is necessary to ensure each column has been held for a sufficient time to meet radiological dose requirements during handling prior to being transferred. |
| Determine if free liquid is present and absorb liquids, if present. | Required to meet WAC maximum free liquids requirement of 1 percent. |
| Fill void space (if required) in accordance with the WAC. | Required to meet WAC requirement to minimize void space. |
| Encapsulate the spent column drums (if required) in accordance with the WAC. | May be required to meet WAC requirements which prohibit disposal of GTCC waste. |

a. Applicable to spent molybdenum extraction columns [ ]PROP/ECI and IXP recovery, [ ]PROP/ECI.

consequences of a heavy load drop include radiological dose. To prevent damage to a cover block, the cover blocks have been designed to withstand a heavy load drop. This scenario was evaluated qualitatively and is not described in Section 13b.2 because the accident sequence is prevented.

13b.1.2.4 RPF Inadvertent Nuclear Criticality

Nuclear criticality safety (NCS) in the RPF is accomplished through the use of criticality safety controls to prevent criticality during normal and abnormal conditions. Each process that involves the use, handling, or storage of SNM is evaluated by the SHINE nuclear criticality safety staff under the requirements of the NCS program. Radiological consequences of criticality accidents are not included in the accident analysis because preventative controls are used to ensure criticality events are highly unlikely. Further discussion of the criticality safety bases for RPF processes is included in Section 6b.3.

13b.1.2.5 RPF Fire

The RPF was evaluated for internal fire risks based on the fire hazards analysis (FHA). The FHA documents the facility fire areas and each area was individually evaluated for fire risks. Internal facility fires are generally evaluated as an initiating event for the release of radioactive material and are included in the scenarios evaluated in Section 13a2.1 and this section. Two unique scenarios are described below and evaluated in detail in Section 13b.2.

The main production facility maintains a facility fire protection plan to reduce the risks of fires, as described in Section 9a2.3.

Scenario 1 - PVVS Carbon Delay Bed Fire (Beds 1, 2, or 3)

An upset or malfunction in the PVVS (high moisture or high temperature) results in ignition of the carbon media in a delay bed. A fire in ~~the~~ carbon delay beds 1, 2, or 3 results in a release of the captured radioactive material into the PVVS downstream of the delay bed and to the environment via the facility exhaust stack. A release to the environment results in radiological exposure to the public. Release of radioactive material in excess of acceptable levels is prevented by the carbon delay bed ~~carbon monoxide (CO) detectors~~exhaust temperature sensors~~, which~~. The temperature sensors provide a signal to ESFAS to close the PVVS carbon delay bed isolation valves for the affected carbon delay bed ~~group~~ and bypass the affected ~~group~~bed in the event of high ~~CO concentration~~exhaust temperature indicative of a fire in a bed. ~~Releases to the RPF are further mitigated by the process confinement boundary (~~The isolation valves for carbon delay beds 1, 2, and 3 function to prevent fire propagation to downstream carbon delay bed~~ vault~~s~~)~~. This scenario is further described in Subsection 13b.2.6.1.

Scenario 2 - PVVS Carbon Delay Bed Fire (Beds 4, 5, 6, 7, or 8)

An upset or malfunction in the PVVS (high moisture or high temperature) results in ignition of the carbon media in a delay bed. A fire in carbon delay beds 4, 5, 6, 7, or 8 results in a release of the captured radioactive material into the PVVS downstream of the delay bed and to the environment via the facility exhaust stack. A release to the environment results in radiological exposure to the public. In the event that delay bed 4, 5, 6, 7, or 8 ignites, there is no automatic isolation in place to prevent propagation to downstream beds. It is assumed that carbon delay bed 4 ignites and the fire propagates to the remaining carbon delay beds, releasing the radionuclide inventory of

the five beds. The resulting release of radioactive material is below acceptable levels. This scenario is further described in Subsection 13b.2.6.2.

Scenario 23 - PVVS Carbon Guard Bed Fire

An upset or malfunction in the PVVS (high moisture or high temperature) results in ignition of the carbon media in a guard bed. A fire in the guard bed results in a release of the captured radioactive material into the PVVS downstream of the guard bed, into the delay beds, and to the environment via the facility exhaust stack. A release to the environment results in radiological exposure to the public. Release of radioactive material in excess of acceptable levels is prevented by the downstream carbon delay beds, which reduce or delay radioisotope release. Releases to the RPF are further mitigated by the supercell confinement boundary. This scenario is further described in Subsection 13b.2.6.2Subsection 13b.2.6.3.

13b.1.2.6 RPF Chemical Accidents

Potential chemical exposures in the RPF were evaluated to identify chemical hazards and necessary controls. The bounding inventories of chemicals used in the main production facility were identified and evaluated for exposure to workers and the public. Only exposure to uranium oxide presents a risk that exceeds the applicable evaluation criteria. This scenario is discussed further in Section 13b.3.

### 13b.2.5 RPF INADVERTENT NUCLEAR CRITICALITY

Inadvertent nuclear criticality events were evaluated in the accident analysis using the same methodology as non-criticality accidents. Nuclear criticality safety is achieved through the use of preventative controls throughout the RPF, which reduces the likelihood of a criticality accident to highly unlikely (or better). Preventative controls were selected based on nuclear criticality safety evaluations conducted under the facility nuclear criticality safety program. The nuclear criticality safety program and the criticality safety basis for RPF processes is described in Section 6b.3.

### 13b.2.6 RPF FIRE

Facility fires were evaluated in the accident analysis. Facility fire scenarios and their effects are discussed in Subsection 13b.1.2.5. Two facility fire scenarios were evaluated for radiological consequences.

#### 13b.2.6.1 PVVS Carbon Delay Bed Fire (Beds 1, 2, or 3)

*Initial Conditions*

The PVVS is operating normally, with nominal flow through a carbon delay bed.

The affected carbon delay bed contains noble gases from RPF process streams. The MAR in this scenario is a combination of gases from eight IUs with various modifiers applied to account for decay and processing capacity of target solution batches in the supercell. The purge volumes and decay times used provide a maximum radiological inventory that could be present on an individual bed.

*Initiating Event*

An upset or malfunction in the PVVS results in high moisture or high temperature flow through the carbon delay bed. The high moisture or high temperature results in ignition of the carbon delay bed absorber media. Potential initiating events are discussed further in Subsection 13b.1.2.5, Scenario 1.

*Sequence of Events*

1. Ignition of the carbon delay bed occurs, resulting in an exothermic release of stored radioactive material to the PVVS downstream of the delay bed.
2. ~~R~~After a period of time, the entire radioactive material inventory of the affected carbon delay bed is released to the downstream delay beds and to the environment through the PVVS and facility stack.
3. ~~Incipient f~~Fire conditions are detected by the ~~in-line carbon monoxide detectors~~exhaust temperature sensors, which send a~~n actuation~~ signal to the ESFAS.
4. ESFAS ~~isolates~~initiates a Carbon Delay Bed Isolation for the affected carbon delay bed ~~group using installed actuation valves. Valve closure is assumed to occur within 30 seconds of detection for bounding consequence determination~~to prevent fire propagation to downstream beds.
5. ~~Following valve closure, the gross release of radioactive material is stopped and the fire is extinguished. Leakage through the valve occurs at a diminished rate.~~

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

- PVVS carbon delay bed ~~carbon monoxide detectors~~1, 2, and 3 temperature sensors
- PVVS carbon delay bed 1, 2, and 3 isolation valves
- ESFAS carbon delay bed 1, 2, and 3 isolation function

*Damage to Equipment*

The occurrence of fire damages the affected carbon delay bed and eliminates its ability to function. No other damage to the PVVS system or its components occurs.

*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. ~~For this accident, the release of material for the first 30 seconds is assumed to be instantaneous and is transported to the environment at an increased rate. Following isolation valve actuation, the transport occurs at a reduced rate.~~The release rate of material from the bed is based on a conservative calculation of the effects of a fire in the delay bed. It is assumed that radionuclide inventories are released from the bed prior to isolation. Material released from the delay bed passes through the remaining delay beds, with a reduced holdup efficiency, prior to being released to the environment.

*Radiation Source Terms*

The initial MAR for this scenario is a portion of the noble gas inventory evolved from target solution during normal operations. Development of the accident source term for this scenario is discussed further in Section 13a2.2.

The noble gas inventory is produced by decay of fission products and continuously evolved from the target solution and through the TOGS during operations. The MAR uses selected time intervals for the most recent purges (i.e., [ ]$^{\text{PROP/ECI}}$) to account for the processing capacity of target solution batches in the supercell for the combined eight IUs. The gases accumulate in the carbon delay bed and decay. The MAR assumes the combined noble gas inventory produced by eight IUs over approximately [ ]$^{\text{PROP/ECI}}$ of irradiation with the most recent purges of [ ]$^{\text{PROP/ECI}}$. Partitioning fractions for noble gases are used to describe the quantities of noble gases in solution that move to the RPF to account for removal during movement of solution. Additional decay time is applied based on which of the carbon delay beds is assumed to be impacted by the fire event.

*Radiological Consequences*

The radioactive material is contained in the PVVS system and does not result in ~~worker exposure~~material being released into the RPF. The radiological consequences of this accident scenario are determined as described in Section 13a2.2. The results of the determination are provided in Table 13b.2-2.

### 13b.2.6.2 PVVS Carbon Delay Bed Fire (Beds 4, 5, 6, 7, or 8)

*Initial Conditions*

The PVVS is operating normally, with nominal flow through a carbon delay bed.

The affected carbon delay beds contain noble gases from RPF process streams. The MAR in this scenario is a combination of gases from eight IUs with various modifiers applied to account for decay and processing capacity of target solution batches in the supercell. The purge volumes and decay times used provide a maximum radiological inventory that could be present on an individual bed.

*Initiating Event*

An upset or malfunction in the PVVS results in high moisture or high temperature flow through the carbon delay bed. The high moisture or high temperature results in ignition of the carbon delay bed absorber media. Potential initiating events are discussed further in Subsection 13b.1.2.5, Scenario 2.

*Sequence of Events*

1. Ignition of the carbon delay bed 4, 5, 6, 7, or 8 occurs, resulting in an exothermic release of stored radioactive material.
2. The fire propagates to carbon delay beds that are downstream of the bed where the fire originated.
3. After a period of time, the entire radioactive material inventory of affected beds is released to the environment through the PVVS and facility stack.

No components are credited for mitigation of the dose consequences for this accident. The consequences of unmitigated release of delay beds 4, 5, 6, 7, and 8 inventories are below the SHINE Safety Criteria.

*Damage to Equipment*

The occurrence of fire damages the affected carbon delay beds and eliminates their ability to function. No other damage to the PVVS system or its components occurs.

*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 a portion of the noble gas inventory evolved from target solution during normal operations. Development of the accident source term for this scenario is discussed further in Section 13a2.2.

The noble gas inventory is produced by decay of fission products and continuously evolved from the target solution and through the TOGS during operations. The MAR uses selected time

intervals for the most recent purges (i.e., [ ]PROP/ECI) to account for the processing capacity of target solution batches in the supercell for the combined eight IUs. The gases accumulate in the carbon delay bed and decay. The MAR assumes the combined noble gas inventory produced by eight IUs over approximately [ ]PROP/ECI of irradiation with the most recent purges of [ ]PROP/ECI. Partitioning fractions for noble gases are used to describe the quantities of noble gases in solution that move to the RPF to account for removal during movement of solution. Additional decay time is applied based on which delay bed is assumed to be impacted by the fire event.

*Radiological Consequences*

The radioactive material is contained in the PVVS system and does not result in material being released to the RPF. The radiological consequences of this accident scenario are determined as described in Section 13a2.2. The results of the determination are provided in Table 13b.2-2.

### 13b.2.6.3 PVVS Carbon Guard Bed Fire

*Initial Conditions*

The PVVS is operating normally, with nominal flow through a carbon guard bed.

The affected carbon guard bed contains iodine from RPF process streams. The MAR in this scenario is a combination of iodine from eight IUs with various modifiers applied to account for decay and processing capacity of target solution batches in the supercell.

*Initiating Event*

An upset or malfunction in the PVVS results in high moisture or high temperature flow through the carbon guard bed. The high moisture or high temperature results in ignition of the carbon guard bed adsorber material. Potential initiating events are discussed further in Section 13b.1.2.5, Scenario ~~2~~3.

*Sequence of Events*

1. Ignition of the carbon guard bed occurs, resulting in an exothermic release of stored radioactive material to the PVVS downstream of the guard bed.
2. Radioactive material is captured by the downstream carbon delay bed and filtered. One percent of the released radioactive material is released through PVVS and the facility stack to the environment.

The component credited for mitigation of the dose consequences for this accident is:

- PVVS delay bed filtration

*Damage to Equipment*

The occurrence of fire damages the affected carbon guard bed and eliminates its ability to function. No other damage to the PVVS system or its components occurs.

*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. For this accident, the guard bed inventory is assumed to be instantly transported to the delay bed. The delay bed is credited to reduce the release of material by 99 percent with no credit taken for carbon guard bed isolation functions.

*Radiation Source Terms*

The initial MAR for this scenario is a portion of the iodine gas inventory evolved from target solution during normal operations. Development of the accident source term for this scenario is discussed further in Section 13a2.2.

The iodine gas inventory is produced by fission and decay of fission products and continuously evolved from the target solution and through the TOGS during operations. Partitioning fractions for iodine gas are used to describe the quantities of iodine in solution that move to the RPF. Removal of iodine by the TOGS zeolite beds are credited for all gases that are transported to the RPF. The MAR uses selected time intervals for the most recent purges (i.e., [ ]PROP/ECI) to account for the operational sequencing of the combined eight IUs. The MAR assumes the combined iodine gas inventory produced by eight IUs over approximately [ ]PROP/ECI of irradiation with the most recent purges of [ ]PROP/ECI. The iodine accumulates in the carbon guard bed and decays.

*Radiological Consequences*

The radioactive material is contained in the PVVS system and does not result in ~~worker exposure~~material being released into the RPF.

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

**Table 13b.2-1 – Radiation Transport Factors**
**(Sheet 2 of 2)**

| Accident Scenario | Radionuclide Group | Receptor Activity Fraction (RAF) |
|---|---|---|
| PVVS Carbon Delay Bed Fire (Beds 1/2/3) | Nobles | 5.66E-03 Public<br>6.70E+00 Worker |
| PVVS Carbon Delay Bed Fire (Beds 4/5/6/7/8) | Nobles | 5.66E-03 Public<br>6.70E+00 Worker |
| PVVS Carbon Guard Bed Fire | Iodine | 5.66E-03 Public<br>6.70E+00 Worker |
| PVVS Carbon Delay Bed Fire | Nobles | 1.50E-04 Public<br>1.63E-01 Worker |

**Table 13b.2-2 – Radioisotope Production Facility Accident Dose Consequences**

| Accident Scenario | Public Dose TEDE (mrem) | Worker Dose TEDE (mrem) |
|---|---|---|
| Spill of Target Solution in the Supercell | 42 | 76 |
| Spill of Eluate Solution in the Supercell | 88 | 122 |
| Spill of Target Solution in the RPF Pipe Trench | 22 | 40 |
| Spill of Target Solution from a Tank | 24 | 42 |
| Spill of Waste Solution in RLWI | 557 | 1880 |
| PVVS Carbon Delay Bed Fire (Beds 1/2/3) | ~~532~~117 | ~~40~~8 |
| PVVS Carbon Delay Bed Fire (Beds 4/5/6/7/8) | 686 | 48 |
| PVVS Carbon Guard Bed Fire | 546 | 1390 |

**ENCLOSURE 2**
**ATTACHMENT 2**

**SHINE TECHNOLOGIES, LLC**

**SHINE TECHNOLOGIES, LLC APPLICATION FOR AN OPERATING LICENSE SUPPLEMENT NO. 27**

**FINAL SAFETY ANALYSIS REPORT CHANGE SUMMARY**
**PUBLIC VERSION**

**PHASED STARTUP OPERATIONS APPLICATION SUPPLEMENT MARKUP**

## 7.5.2 DESIGN CRITERIA

The description of the SHINE facility design criteria and ESFAS system design criteria provided in Subsection 7.5.2 of the FSAR are not affected by phased startup operations. ESFAS functions are operable as required for equipment that is in operation for a given phase and meet the design criteria. ESFAS inputs that are disabled as described in Section 7.5.1 do not impact the ability of the system to meet the design criteria.

Since disabled inputs are not processed as an actuation request as described in Section 7.4.5, they do not function in a manner analogous to the maintenance bypass feature described in Section 7.5 of the FSAR. The maintenance bypass feature is utilized in conjunction with taking an SFM out of service, where the feature to disable inputs will be part of the normal operation of the ESFAS during the phased approach. The ESFAS will continue to satisfy SHINE facility design criteria and ESFAS system design criteria as provided in Subsection 7.5.2 of the FSAR, since the disabled inputs do not impact the trip determination logic or the ability to perform maintenance on the system. Disabled inputs will be restored and verified to be operable prior to entering the specified conditions in the applicability of the technical specifications.

## 7.5.3 DESIGN BASIS

The descriptions of the safety functions associated with Supercell Area 1 (PVVS Area) Isolation, Supercell Area 2 (Extraction Area A) Isolation, Supercell Area 3 (Purification Area A) Isolation, Supercell Area 4 (Packaging Area 1) Isolation, Supercell Area 5 (Purification Area B) Isolation, Supercell Area 6 (Extraction Area B) Isolation, Supercell Area 7 (Extraction Area C) Isolation, Supercell Area 8 (Purification Area C) Isolation, Supercell Area 9 (Packaging Area 2) Isolation, MEPS A Heating Loop Isolation, MEPS B Heating Isolation, MEPS C Heating Loop Isolation, Carbon Delay Bed ~~Group~~ 1 Isolation, Carbon Delay Bed ~~Group~~ 2 Isolation, Carbon Delay Bed ~~Group~~ 3 Isolation, TPS Train A Isolation, RPF Nitrogen Purge, Extraction Column A Alignment Actuation, Extraction Column B Alignment Actuation, Extraction Column C Alignment Actuation, and Dissolution Tank Isolation provided in Subsection 7.5.3.1 of the FSAR are not affected by phased startup operations.

The safety functions associated with Supercell Area 10 (IXP Area) Isolation, VTS Safety Actuation, TPS Train B Isolation, TPS Train C Isolation, TPS Process Vent Actuation, IU Cell Nitrogen Purge, RCA Isolation, and IXP Alignment Actuation, as described in Subsection 7.5.3.1 of the FSAR, have inputs disabled and safety functions not utilized during the phased startup operations, as described in Table 7.5-1 and Table 7.5-2.

The descriptions of the completion of protective actions; single failure; operating conditions; and seismic, tornado, flood provided in Subsections 7.5.3.2 through 7.5.3.5 of the FSAR are not affected by phased startup operations.

The manual push buttons identified in Subsection 7.5.3.6 of the FSAR will only actuate safety functions utilized in a given phase of operation. A list of safety functions not utilized during specific phases of the phased startup operations is provided in Table 7.5-2.

The descriptions of loss of external power, fire protection, classification and identification, setpoints, prioritization of functions, and design codes and standards provided in Subsections 7.5.3.7 through 7.5.3.12 of the FSAR are not affected by phased startup operations. The information in Table 7.5-2 of the FSAR for fail safe component positions on ESFAS loss of power is not affected by phased startup operations.

## 7.5.4 OPERATION AND PERFORMANCE

The descriptions of high radiological ventilation zone 1 (RVZ1)/ radiological ventilation zone 2 (RVZ2) RCA Exhaust Radiation, High RVZ1 Supercell Exhaust Ventilation Radiation (PVVS Hot Cell), High RVZ1 Supercell Exhaust Ventilation Radiation (MEPS Hot Extraction Cells), High RVZ1 Supercell Exhaust Ventilation Radiation (Purification and Packaging Hot Cells), High MEPS Heating Loop Radiation, High PVVS Carbon Delay Bed Exhaust ~~Carbon Monoxide~~Temperature, VTS Vacuum Header Liquid Detection, RDS Liquid Detection, High TPS Exhaust to Facility Stack Tritium, Low PVVS Flow, MEPS Area A/B/C Three-Way Valve Position Indication, TSPS Dissolution Tank 1/2 Level, and UPSS Loss of External Power provided in Subsection 7.5.4.1 of the FSAR are not affected by phased startup operations.

The monitored variables and response associated with High RVZ1 Supercell Exhaust Ventilation Radiation (IXP Hot Cell), High TPS IU Cell 1/2/3/4/5/6/7/8 Target Chamber Exhaust Pressure, High TPS IU Cell 1/2/3/4/5/6/7/8 Target Chamber Supply Pressure, High TPS Confinement Tritium, TRPS IU Cell 1/2/3/4/5/6/7/8 Nitrogen Purge, and IXP Three-Way Valve Position Indication provided in Subsection 7.5.4.1 of the FSAR have inputs disabled as described in Table 7.5-1. The system response for these monitored variables remains as described in Subsection 7.5.4.1 of the FSAR for inputs that are not disabled, to include the actuation of safety functions that are utilized in a given phase of operation. A list of safety functions not utilized during specific phases of the phased startup operations is provided in Table 7.5-2.

The description of operational bypass, permissives, and interlocks provided in Subsection 7.5.4.2 of the FSAR is not affected by phased startup operations.

The facility master operating permissive provided in Subsection 7.5.4.3 of the FSAR will only actuate safety functions utilized in a given phase of operation. A list of safety functions not utilized during specific phases of the phased startup operations is provided in Table 7.5-2.

The description of maintenance bypass, testing capability, and technical specification and surveillance provided in Subsections 7.5.4.4 through 7.5.4.6 of the FSAR are not affected by phased startup operations.

## 7.5.5 HIGHLY INTEGRATED PROTECTION SYSTEM (HIPS) DESIGN

The phased startup approach in association with the HIPS platform is described in Subsection 7.4.5. This subsection addresses the HIPS design attributes, access control and cyber security, software development requirements, and HIPS performance analysis for phased startup operations.

## 7.5.6 CONCLUSION

The conclusions described in Subsection 7.5.6 of the FSAR is not affected by phased startup operations.

# 7.6 CONTROL CONSOLE AND DISPLAY INSTRUMENTS

Control console and display instruments in the FCR described in Section 7.6 of the FSAR will be installed prior to Phase 1 operation.

Waste solidified during Phase 1 and Phase 2 may have higher dose rates and higher waste classifications than wastes solidified during Phase 3 and Phase 4. During Phase 1 and Phase 2, liquid waste is stored in the subgrade RLWS tanks prior to transfer to RLWI in order to maximize the decay time and limit the volume of solidified waste requiring disposal. Estimated waste streams during phased startup operations are described in Section 11.2.

## 9b.7.4 RADIOACTIVE LIQUID WASTE STORAGE SYSTEM

The RLWS description provided in Subsection 9b.7.4 of the FSAR is not affected by phased startup operations, except that IXP is not available during Phase 1 through Phase 3. During Phase 1 through Phase 3 operations, interfacing RLWS connections to the IXP system are isolated as described in Section 4b.3; RLWS does not receive or process wastes from IXP during Phase 1 through Phase 3.

## 9b.7.5 SOLID RADIOACTIVE WASTE PACKAGING SYSTEM

The SRWP description provided in Subsection 9b.7.5 of the FSAR is not affected by phased startup operations, except that the MATB is not available during Phase 1 and Phase 2. Solidified waste generated during Phase 1 and Phase 2 are stored in the RCA within the main production facility prior to shipment off site to a designated disposal site. During Phase 1 and Phase 2, solid wastes are characterized and staged for shipment in the main production facility in accordance with the radioactive waste management program. There is adequate bore hole storage space for waste streams that may require encapsulation processing until the MATB is available during Phase 3.

## 9b.7.6 RADIOACTIVE DRAIN SYSTEM

The radioactive drain system (RDS) description provided in Subsection 9b.7.6 of the FSAR is not affected by phased startup operations, except that IXP is not available during Phase 1 through Phase 3. During Phase 1 through Phase 3, the IXP hot cell drain to RDS is plugged as described in Section 4b.1; RDS does not provide collection of IXP process liquids or overpressure protection for IXP during Phase 1 through Phase 3.

## 9b.7.7 FACILITY POTABLE WATER SYSTEM

The facility potable water system (FPWS) description provided in Subsection 9b.7.7 of the FSAR is not affected by phased startup operations.

## 9b.7.8 FACILITY NITROGEN HANDLING SYSTEM

The facility nitrogen handling system (FNHS) description provided in Subsection 9b.7.8 of the FSAR is not affected by phased startup operations, FNHS is available for operation in Phase 1. During Phase 1 and Phase 2, interfacing FNHS connections to IU specific instances of IU systems (i.e., TOGS) are isolated outside the IU cell as described in Section 4a2.1 (i.e., interfaces with IUs 3 through 8 are isolated during Phase 1, interfaces with IUs 6 through 8 are isolated during Phase 2). During Phase 1 and Phase 2, interfacing FNHS connections to tritium purification system (TPS) trains are isolated as described in Section 9a2.7 (i.e., interfaces with TPS Train B and Train C are isolated during Phase 1, interfaces with TPS Train C are isolated during Phase 2). During Phase 1 through Phase 3, interfacing FNHS connections to the IXP system are isolated as described in Section 4b.3. Isolating the interfaces to individual IU

## Table 11.2-1 – Estimated As-Generated Annual Waste Stream Summary During Phased Startup Operations (Sheet 1 of 2)

| Description | Matrix | Class as Generated | Phase 1 | Phase 2 | Phase 3 | Units |
|---|---|---|---|---|---|---|
| MEPS Extraction Columns [ ][PROP/ECI] | [ ][PROP/ECI] | B, C, or GTCC | [ ][PROP/ECI] | [ ][PROP/ECI] | [ ][PROP/ECI] | ft$^3$/yr |
| Selective Ion Stripping Columns | [ ][PROP/ECI] | B or C | N/A | N/A | 72 | ft$^3$/yr |
| IXP Separation Columns | [ ][PROP/ECI] | B or C | N/A | N/A | N/A | ft$^3$/yr |
| LWPS Deionizer Units | Resin | A | 12 | 30 | 48 | ft$^3$/yr |
| PCLS Deionizer Units | Resin | A | 12 | 30 | 48 | ft$^3$/yr |
| Uranium Canisters | Solid | A | 0.49[a] | 1.2[a] | 2.0[a] | ft$^3$/yr |
| NDAS Accelerator Subassembly[b] | Solid | A | N/A | N/A | [ ][PROP/ECI] | ft$^3$/yr |
| NDAS Target Chamber Subassembly[b] | Solid | ~~A~~B | N/A | N/A | [ ][PROP/ECI] | ft$^3$/yr |
| TOGS Skids[b] | Solid | A or B | N/A | N/A | 846 | ft$^3$/yr |
| TOGS Zeolite Beds[b] | Solid | B or C | N/A | N/A | 0.64 | ft$^3$/yr |
| LWPS Filters | Solid | A | 0.41 | 1.0 | 1.6 | ft$^3$/yr |
| PCLS Filters | Solid | A | 0.41 | 1.0 | 1.6 | ft$^3$/yr |
| TSPS, URSS, PVVS, Hot Cell, RVZ1, RVZ2, RLWI HEPA Filters | Solid | A | 182 | 182 | 182 | ft$^3$/yr |
| Hot Cell, RVZ1, RVZ2 Charcoal Filters | Solid | A | 32 | 32 | 32 | ft$^3$/yr |
| TSPS Uranyl Sulfate Solution Filters | Solid | A | 0.35[c] | 0.35[c] | 0.35[c] | ft$^3$/yr |

**Table 11.2-2 - Estimated As-Disposed Annual Waste Stream Summary During Phased Startup Operations (Sheet 1 of 2)**

| Description | Matrix | Class as Disposed | Phase 1 ($ft^3/yr$) | Phase 2 ($ft^3/yr$) | Phase 3 ($ft^3/yr$) | Shipment Type | Destination[a] |
|---|---|---|---|---|---|---|---|
| MEPS Extraction Columns [ ]PROP/ECI | [ ]PROP/ECI | B or C | ~~68~~74 | ~~169~~184 | ~~270~~295 | Type B | WCS |
| Selective Ion Stripping Columns | [ ]PROP/ECI | B or C | N/A | N/A | 72 | Type B | WCS |
| IXP Separation Columns | [ ]PROP/ECI | B or C | N/A | N/A | N/A | Type B | WCS |
| LWPS Deionizer Units | Resin | A | 20 | 50 | 80 | Type A or LSA | Energy*Solutions* |
| PCLS Deionizer Units | Resin | A | 20 | 50 | 80 | Type A or LSA | Energy*Solutions* |
| Uranium Canisters[b] | Solid | A | 0.82 | 2.1 | 3.3 | Type A or LSA | Energy*Solutions* |
| NDAS Accelerator Subassembly[c] | Solid | A | N/A | N/A | 3,321 | Type A or LSA | Energy*Solutions* |
| NDAS Target Chamber Subassembly[c] | Solid | ~~A~~B | N/A | N/A | 586 | Type A, B, or LSA | Energy*Solutions* |
| TOGS Skids[c] | Solid | A or B | N/A | N/A | 1,411 | Type A, B, or LSA | Energy*Solutions* or WCS |
| TOGS Zeolite Beds[c] | Solid | B or C | N/A | N/A | 1.1 | Type B | WCS |
| LWPS Filters | Solid | A | 0.68 | 1.7 | 2.7 | Type A or LSA | Energy*Solutions* |
| PCLS Filters | Solid | A | 0.68 | 1.7 | 2.7 | Type A or LSA | Energy*Solutions* |
| TSPS, URSS, PVVS, Hot Cell, RVZ1, RVZ2, RLWI HEPA Filters | Solid | A | 142 | 142 | 142 | Type A or LSA | Energy*Solutions* |
| Hot Cell, RVZ1, RVZ2 Charcoal Filters | Solid | A | 54 | 54 | 54 | Type A or LSA | Energy*Solutions* |
| TSPS Uranyl Sulfate Solution Filters[d] | Solid | A | 0.58 | 0.58 | 0.58 | Type A or LSA | Energy*Solutions* |

**ENCLOSURE 2**
**ATTACHMENT 3**

**SHINE TECHNOLOGIES, LLC**

**SHINE TECHNOLOGIES, LLC APPLICATION FOR AN OPERATING LICENSE SUPPLEMENT NO. 27**

**FINAL SAFETY ANALYSIS REPORT CHANGE SUMMARY PUBLIC VERSION**

**TECHNICAL SPECIFICATIONS MARKUP**

Table 3.2.4 ESFAS Process Instrumentation Actions

| | Action | Completion Time |
|---|---|---|
| 1. | If one channel of PVVS flow is inoperable,<br>Place the SFM for the associated channel in trip<br>AND<br>Restore the channel to Operable. | <br>2 hours<br><br>30 days |
| 2. | If two or more channels of PVVS flow are inoperable,<br>OR<br>Action and associated completion time of Condition 1 not met,<br>Actuate the RPF Nitrogen Purge. | <br><br><br>1 hour |
| 3. | If one channel is inoperable,<br>Open the VTS vacuum pump breakers<br>AND<br>Open the VTS vacuum break valves. | <br>12 hours<br><br>12 hours |
| 4. | If both channels are inoperable,<br>Open the VTS vacuum pump breakers<br>AND<br>Open the VTS vacuum break valves. | <br>1 hour<br><br>1 hour |
| 5. | If one channel for a single carbon delay bed ~~group~~ is inoperable,<br>Close the associated carbon delay bed ~~group~~ isolation valves<br>AND<br>Verify at least 5 carbon delay beds are operating. | <br>12 hours<br><br>12 hours |
| 6. | If both channels for a single carbon delay bed ~~group~~ are inoperable,<br>Close the associated carbon delay bed ~~group~~ isolation valves<br>AND<br>Verify at least 5 carbon delay beds are operating. | <br>1 hour<br><br>1 hour |
| 7. | If one channel of dissolution tank level is inoperable,<br>Place the dissolution tank isolation actuation components in their actuated states. | <br>12 hours |
| 8. | If both channels of dissolution tank level are inoperable,<br>Place the dissolution tank isolation actuation components in their actuated states. | <br>1 hour |

Table 3.2.4-a ESFAS Process Instrumentation

| | Variable | Setpoint | Required Channels | Applicability | Action | SR |
|---|---|---|---|---|---|---|
| a. | PVVS carbon delay bed exhaust carbon monoxide temperature | ≤ 42 ppm219°F | 2 (per delay bed group) | Associated carbon delay bed group Operating | 5, 6 | 1, 2 |
| b. | VTS vacuum header liquid detection | Liquid detected | 2 | Solution transfers using VTS in-progress | 3, 4 | 3 |
| c. | RDS liquid detection | Liquid detected | 2 | Solution transfers using VTS in-progress | 3, 4 | 3 |
| d. | PVVS flow | ≥ 7.1 SCFM | 3 | Facility not Secured | 1, 2 | 1, 2 |
| e. | TSPS dissolution tank level | High level | 2 | Dissolution tank or TSPS glovebox contains uranium | 7, 8 | 3 |
| f. | Uninterruptible electrical power supply system (UPSS) loss of external power | Loss of Power; actuation delayed by ≤ 180 seconds | 2 | Any IU in Mode 1 or 2 | 9, 10 | 3 |
| g. | MEPS three-way valve position indication | Supplying | 2 (per valve) | Target solution present in the associated hot cell | 11, 12 | 3 |
| h. | IXP three-way valve position indication | Supplying | 2 (per valve) | Target solution present in the IXP hot cell | 11, 12 | 3 |
| i. | TPS target chamber supply pressure | ≤ 7.7 psia | 2 (per IU) | Tritium present in associated TPS process equipment and not in storage | 13, 14 | 1, 2 |
| j | TPS target chamber exhaust pressure | ≤ 7.7 psia | 2 (per IU) | Tritium present in associated TPS process equipment and not in storage | 13, 14 | 1, 2 |

LCO 3.2.4 addresses the input devices and the trip determination portions of ESFAS. The scope of this LCO (i.e., each channel) begins at the input devices, includes the safety function modules (SFMs) and extends to the inputs to the SBVMs or SBMs. Radiation monitors that provide inputs to ESFAS are addressed in LCO 3.7.1.

More than one input device provides a signal to each SFM. The following table describes the allocation of inputs to the ESFAS modules:

Table B-3.2.4 ESFAS Input Variable Allocation

| | Variable | Division A | Division B | Division C |
|---|---|---|---|---|
| a. | PVVS carbon delay bed ~~group~~ 1 exhaust ~~carbon monoxide~~temperature | [ | | |
| | PVVS carbon delay bed ~~group~~ 2 exhaust ~~carbon monoxide~~temperature | | | |
| | PVVS carbon delay bed ~~group~~ 3 exhaust ~~carbon monoxide~~temperature | | | |
| b. | VTS vacuum header liquid detection | | | |
| c. | RDS liquid detection | | | |
| d. | PVVS flow | | | |
| e. | TSPS dissolution tank level | | | |
| f. | UPSS loss of external power | | | |
| g. | MEPS area A three-way valve position indication | | | |
| | MEPS area B three-way valve position indication | | | |
| | MEPS area C three-way valve position indication | | | |
| h. | IXP three-way valve position indication | | | |
| i. | TPS IU Cell 1 target chamber supply pressure | | | ]PROP/ECI |

trip/bypass switch located below the SFM, as described in FSAR Subsection 7.5.4.4. Placing an SFM in trip or bypass causes all channels associated with that SFM to be placed in trip or bypass, respectively.

For variables provided with two channels, actuation of the safety function occurs on 1-out-of-2 voting logic. For the low PVVS flow signal (item e.), when all three channels are Operable, actuation of the safety function occurs on 2-out-of-3 voting logic. When any single channel is inoperable, the inoperable channel is required to be placed in trip within 2 hours, effectively changing the voting logic to 1-out-of-2, preserving the single failure protection. A completion time of 2 hours allows for the action to be accomplished in an orderly manner.

Performance of a Channel Test or Channel Calibration may cause a channel to be unable to perform its safety function during the SR. To allow the performance of these SRs during operation of equipment protected by ESFAS, any single channel for any of the ESFAS process instrumentation variables may be placed in bypass for up to 2 hours during performance of a required SR on a channel associated with that SFM, effectively changing the voting logic to 2-out-of-2 (with two other channels Operable) or 1-out-of-1 (with one other channel Operable). A time limit of 2 hours is acceptable based on the small amount of time the channel could be in bypass, the continual attendance by operations or maintenance personnel during the test, the continued operability of the redundant channel(s), and the low likelihood that an accident would occur during the 2 hour time period.

When a channel is declared inoperable due to an inoperable input device or other issue associated with only one input on an SFM, only the applicable action(s) listed in Table 3.2.4-a for the affected channel are required to be completed within the specified completion time, or the condition of applicability exited.

When a channel is declared inoperable due to an inoperable module (SFM), all variables (i.e., channels) associated with that module as listed in Tables B-3.2.4 and B-3.7.1 are inoperable. Applicable action(s) listed in Tables 3.2.4-a and 3.7.1-a for all affected channels are required to be completed within the specified completion time, or the condition(s) of applicability exited.

Any inoperable SFM that has been placed in trip in accordance with this LCO is required to be restored to Operable within 30 days. A completion time of 30 days allows for replacement of failed components, while limiting the amount of time equipment protected by the ESFAS is allowed to operate with reduced ESFAS reliability. The 30 day duration is acceptable because placing the SFM in trip preserves the single failure criterion for the remaining Operable modules.

Additional discussion for each variable listed in Table 3.2.4-a is provided below:

a. The ESFAS monitors the ~~carbon monoxide concentration~~temperature of the gases leaving the first three PVVS carbon delay beds to protect against a fire in the carbon delay beds, as described in FSAR Subsections 6b.2.2 and 7.5.4.1.7. The setpoint of ≤ ~~42 ppm~~219°F provides indication of combustion occurring inside of a carbon delay bed ~~within the delay bed group~~ and provides margin to an analytical limit of ~~50 ppm~~250°F. Two channels of ~~carbon monoxide~~temperature instrumentation are provided for each of the first three carbon delay beds~~ group~~. Only the first three carbon delay beds require safety-related temperature monitoring and isolation, as a fire in beds

four through eight has been analyzed and shown to meet the SHINE Safety Criteria without the need for safety-related controls, as described in FSAR Subsection 13b.2.6.2. Exceeding the ~~carbon monoxide~~temperature setpoint results in a Carbon Delay Bed Isolation for the affected carbon delay bed ~~group~~.

With one channel for a single carbon delay bed ~~group~~ inoperable, the associated ~~group~~ bed is required to be isolated within 12 hours to fulfill the Carbon Delay Bed Isolation function. Five carbon delay beds must also be verified to be Operating within 12 hours. A completion time of 12 hours allows for the performance of minor repairs and is acceptable based on the continued availability of the redundant channel. With both channels for a single carbon delay bed inoperable, the ~~group~~ bed is required to be isolated within 1 hour to fulfill the Carbon Delay Bed Isolation function. Five carbon delay beds must also be verified to be Operating within 1 hour. A completion time of 1 hour recognizes the importance of promptly isolating the equipment to prevent the potential for an event when the safety function has been lost. The completion time is acceptable based on the low likelihood of an event during the limited time. When a carbon delay bed ~~group~~ is isolated in accordance with this LCO, the applicable actions from LCO 3.5.1 are also required to be entered to manage the length of time the carbon delay beds are inoperable. Verification of the number of Operating carbon delay beds additionally allows the prompt entry into LCO 3.5.1 if necessary.

Additional individual isolation valves are provided on the inlet and outlet of each carbon delay bed to isolate an individual bed as required for maintenance. At least seven of the eight carbon delay beds are required to be Operating to provide the design noble gas residence time. If only five or six carbon delay beds are Operating, the noble gas residence time is reduced, affecting the total curies released from the facility. The total curies released from the facility are managed in accordance with LCO 3.7.2.

b. The ESFAS monitors for the presence of liquid in the VTS vacuum header to protect against an overflow of liquid out of the VTS lift tanks, as described in FSAR Subsections 6b.3.1.5, 7.5.4.1.8, and 9b.2.5.3. The liquid detection instrumentation provides a discrete signal indicating the presence or absence of liquid. Two Divisions of liquid detection are located in the VTS vacuum header serving all lift tanks that may contain target solution. The detection of liquid results in a VTS Safety Actuation to stop any in-progress transfers of fluid. The function is required to prevent degrading one of the controls to prevent a criticality, by preventing target solution entering non-favorable geometry locations in the VTS system, as described in FSAR Subsection 6b.3.2.5.

   With one channel inoperable, the VTS vacuum pump breakers and VTS vacuum break valves are required to be opened within 12 hours to stop the transfer of solution within the facility. A completion time of 12 hours allows for the performance of minor repairs and is acceptable based on the continued availability of the redundant channel. With both channels inoperable, the VTS vacuum pump breakers and VTS vacuum break valves are required to be opened within 1 hour to stop the transfer of solution within the facility. A completion time of 1 hour recognizes the importance of taking prompt action when equipment credited for the prevention of an unintended criticality is

Basis 3.5.1 LCO

The PVVS ensures there is sufficient flow through process vessels to provide hydrogen mitigation and contamination control, as described in FSAR Subsection 9b.6.1. A minimum total PVVS flowrate of 7.1 SCFM, measured at the exhaust of PVVS, is based on an analytical limit of 5.0 SCFM and is calculated to maintain hydrogen concentration ≤ 3% by volume in tanks served by PVVS. The PVVS design flowrate is 16 SCFM at 70°F and 40% relative humidity entering the eight delay beds, which achieves a xenon residence time of 40 days, and provides margin to prevent effluents from the facility from exceeding 10 CFR 20 limits. For PVVS to be considered Operable:

1. At least two PVVS blowers must be running providing flow above the minimum total exhaust flowrate. A loss of minimum PVVS flow results in an automatic RPF Nitrogen Purge.
2. Either the north or south inlet header flow path must be open. The N2PS RVZ2 north and south header valves provide the normal inlet flow path to PVVS. Inadvertent isolation of both flow paths valves renders the PVVS inoperable.
3. Seven (of eight) carbon delay beds are required to be Operating to capture iodine and provide sufficient noble gas residence time to prevent the facility from exceeding 10 CFR 20 limits. A carbon delay bed is considered Operating when it contains carbon material and is not isolated.
4. PVVS flow from individual tanks ventilated by the PVVS are within required specification to maintain hydrogen concentration ≤ 3% by volume. PVVS flow is only required for tanks containing target solution or radioactive liquids.

The carbon guard bed(s) function to protect the long-term capacity and efficiency of the carbon delay beds but are not required to be Operating to consider the PVVS Operable.

With PVVS inoperable due to fewer than the minimum number of PVVS blowers operating, PVVS total flow below the required minimum flowrate, or an insufficient PVVS inlet flow path, an RPF Nitrogen Purge is required to be actuated within 1 hour to provide the hydrogen mitigation function. This completion time recognizes the importance of ensuring that the hydrogen mitigation function for the RPF is maintained.

To isolate any individual bed as required for maintenance, safety-related isolation valves are provided for inlet and outlet isolation of carbon delay beds 1, 2, and 3, and ~~Nonsafety~~nonsafety-related isolation valves are provided ~~on the~~for inlet and outlet ~~of each~~isolation of carbon delay beds 4 through 8 ~~to isolate an individual bed as required for maintenance~~. At least seven of the eight carbon delay beds are required to be Operating to prevent facility effluents from exceeding 10 CFR 20 limits over the course of a year. If only five or six carbon delay beds are Operating, the noble gas residence time is reduced. With PVVS inoperable due to fewer than seven PVVS carbon delay beds Operating, at least seven carbon delay beds are required to be restored to Operating within 60 days. This condition is only allowed for up to 60 days, after which actions are taken to minimize the radionuclide inventory in the PVVS in accordance with action 3. The

Table 3.8.10 Safety-Related Valves Actions

| | Action | Completion Time |
|---|---|---|
| 1. | If one Division is inoperable,<br>Restore the Division to Operable | <br>72 hours |
| 2. | If two Divisions are inoperable,<br>OR<br>Action and associated completion time of Condition 1 not met,<br>Open the VTS vacuum pump breakers<br>AND<br>Open at least one VTS vacuum break valve. | <br><br><br>12 hours<br><br>12 hours |
| 3. | If two Divisions are inoperable,<br>OR<br>Action and associated completion time of Condition 1 not met,<br>Open at least one PVVS blower bypass valve<br>AND<br>Close the PVVS blower makeup air supply valve. | <br><br><br>12 hours<br><br>12 hours |
| 4. | If two Divisions are inoperable,<br>OR<br>Action and associated completion time of Condition 1 not met,<br>Open at least one carbon guard bed bypass valve. | <br><br><br>12 hours |
| 5. | If two Divisions for a single carbon delay bed ~~group~~ are inoperable,<br>OR<br>Action and associated completion time of Condition 1 not met,<br>Close the associated carbon delay bed ~~group~~ isolation valves<br>AND<br>Verify at least 5 carbon delay beds are Operating. | <br><br><br>12 hours<br><br>12 hours |
| 6. | If the required Division is inoperable,<br>Suspend RLWI immobilization feed operations<br>AND<br>Close at least one RLWI PVVS valve. | <br>1 hour<br><br>12 hours |

Table 3.8.10-a Automatically-Actuated Safety-Related Valves

| | Component | Number Provided per Flow Path | Applicability | Action |
|---|---|---|---|---|
| a. | VTS vacuum break valves | 2 | VTS Operating | 1, 2 |
| b. | PVVS blower bypass valves | 2 | Facility not Secured | 1, 3 |
| c. | PVVS carbon guard bed bypass valves | 2 | Facility not Secured | 1, 4 |
| d. | PVVS carbon delay bed ~~group~~ three-way valves | 2<br>(per delay bed ~~group~~) | Associated carbon delay bed ~~group~~ Operating | 1, 5 |
| e. | PVVS carbon delay bed ~~group~~ outlet isolation valves | 2<br>(per delay bed ~~group~~) | Associated carbon delay bed ~~group~~ Operating | 1, 5 |
| f. | RLWI PVVS isolation valve | 1 | PVVS ventilation to RLWI Operating | 6 |
| g. | N2PS IU cell header valves | 2 | Facility not Secured | 1, 7 |
| h. | N2PS RPF header valves | 2 | Facility not Secured | 1, 8 |
| i. | N2PS RVZ2 header valves<br>1. North<br>2. South | 2<br>(per location) | Facility not Secured | 1, 9 |
| j. | TSPS RPCS supply cooling valves | 2 | Dissolution tank or TSPS glovebox contains uranium | 10 |
| k | TSPS RPCS return cooling valve | 1 | Dissolution tank or TSPS glovebox contains uranium | 10 |
| l. | TSPS ventilation isolation valves<br>1. Air Inlet<br>2. RVZ1 Exhaust | 1<br>(per location) | Dissolution tank or TSPS glovebox contains uranium | 10 |
| m. | MEPS extraction column three-way valves<br>1. Upper<br>2. Lower | 1<br>(per location, per hot cell) | Target solution or radioactive process fluids present in the associated extraction hot cell | 11 |
| n. | IXP extraction column three-way valves<br>1. Upper<br>2. Lower | 1<br>(per location) | Target solution or radioactive process fluids present in the IXP hot cell | 11 |

completion time is acceptable based on the continued availability of the redundant isolation valve. With both Divisions inoperable, the VTS vacuum pump breakers are opened to shut down the VTS, and at least one VTS vacuum break valve is opened to break vacuum in the system within 12 hours. The completion time allows for investigation and correction of minor problems, and is acceptable based on the low likelihood of an event during the allotted time.

b. PVVS blower bypass valves are used to bypass the PVVS blowers during operation of the N2PS to ensure a flow path for N2PS to the safety-related release point is available. The valves are opened on an RPF Nitrogen Purge signal. With one Division inoperable, the valve is required to be restored to Operable within 72 hours. This completion time is acceptable based on the continued availability of the redundant isolation valve. With both Divisions inoperable, at least one PVVS blower bypass valve is opened within 12 hours to ensure the availability of the flow path. With the PVVS blowers Operating, opening these valves could reduce the flowrate of sweep gas to the RPF tanks by providing another source of makeup air. Therefore, the normal PVVS blower makeup air supply is required to be closed within 12 hours when the PVVS blower bypass valves are open to ensure the blowers are capable providing adequate sweep gas flow for RPF tanks. The completion time allows for investigation and correction of minor problems and is acceptable based on the low likelihood of an event during the allotted time.

c. PVVS carbon guard bed bypass valves are used to ensure a flow path exists around the PVVS carbon guard beds to ensure the hydrogen mitigation function of N2PS is maintained. The valves are opened on an RPF Nitrogen Purge actuation signal to ensure a flow path exists for N2PS. With one Division inoperable, the valve is required to be restored to Operable within 72 hours. This completion time is acceptable based on the continued availability of the redundant isolation valve. With both Divisions inoperable, at least one PVVS carbon guard bed bypass valve is opened within 12 hours to ensure the N2PS flow path is maintained. The completion time allows for investigation and correction of minor problems and is acceptable based on the low likelihood of an event during the allotted time.

d. - e. PVVS carbon delay bed three-way and outlet isolation valves are used to isolate a PVVS carbon delay bed ~~group~~ in the event of a fire in a bed within that ~~group~~bed. The valves are deenergized to isolate the affected ~~group~~bed on a Carbon Delay Bed Isolation signal. With one Division inoperable, the valve is required to be restored to Operable within 72 hours. This completion time is acceptable based on the continued availability of the redundant isolation valve. With both Divisions inoperable, the associated carbon delay bed ~~group~~ is required to be isolated, and the remaining carbon delay beds are verified to be Operating within 12 hours. The completion time allows for investigation and correction of minor problems and is acceptable based on the low likelihood of an event during the allotted time.

f. The RLWI PVVS isolation valve is used to isolate the RLWI immobilization feed tank from the PVVS in the event of an RPF Nitrogen Purge actuation to prevent backflow of nitrogen into the RLWI skid. PVVS normally provides ventilation for the RLWI, but this function is not required to prevent unacceptable levels of hydrogen accumulation in the RLWI system and is not