ENCLOSURE 2
ATTACHMENT 1

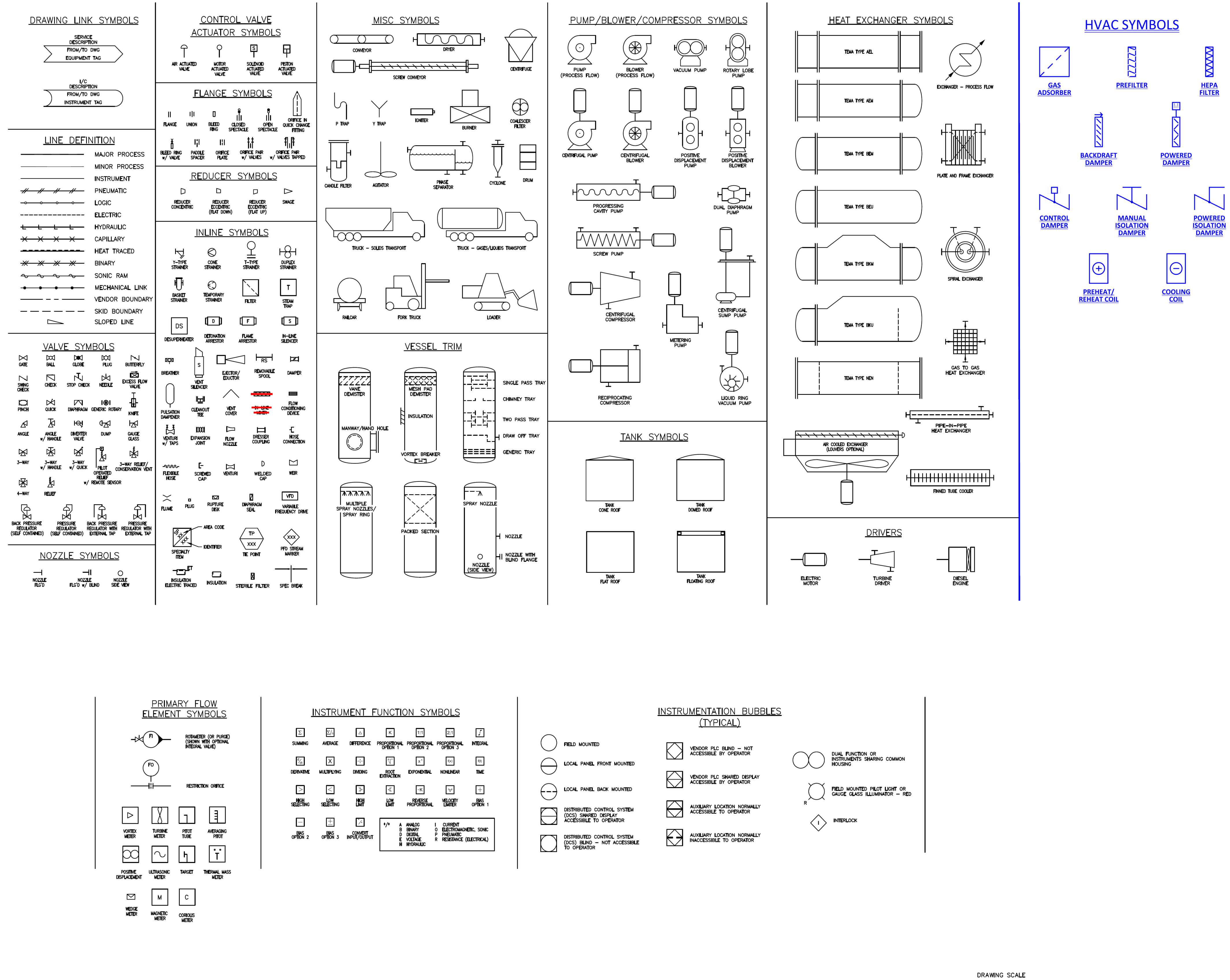
SHINE MEDICAL TECHNOLOGIES, INC.

SHINE MEDICAL TECHNOLOGIES, INC. APPLICATION FOR CONSTRUCTION PERMIT RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

PRELIMINARY SAFETY ANALYSIS REPORT CHANGES (MARK-UP)

24 pages follow

Figure 1.3-6 – Legend for Process Flow Diagrams
Sheet 1 of 2



4b.2 RADIOISOTOPE PRODUCTION FACILITY BIOLOGICAL SHIELD

4b.2.1 INTRODUCTION

The production facility biological shield (PFBS) provides a barrier to protect SHINE facility personnel, members of the public, and various components and equipment of the SHINE facility by reducing radiation exposure. The radioisotope production facility receives the irradiated target solution from the IU cell and distributes the target solution to various downstream processes. The target solution has a fission product activity that is defined in Chapter 11. The major areas outside of the IU cell that the target solution and by-product material occupies are:

- Supercell (for Mo extraction, purification, and packaging)
- Process tanks
- Pipe chases
- Waste processing cells
- UREX cell
- TDN ~~cell~~area
- Pump room hot cell
- PVVS cell
- NGRS shielded cell

A description of radiation source locations and source term characterizations can be found in Chapter 11.

The ventilation for these areas is described in Section 9a2.1.1.

4b.2.2 BIOLOGICAL SHIELD DESIGN BASIS

4b.2.2.1 Materials

The design bases for the materials included in the biological shield design are:

- The dose reduction by the biological shielding is sufficient to meet the radiation exposure goals defined in Chapter 11.

- All materials used for biological shielding meet or exceed the requirements of ANSI/ANS-6.4.2-2006, Specification for Radiation Shielding Materials (ANSI/ANS, 2006b).

- The design and construction of the concrete portions of the biological shield conforms to Regulatory Guide 1.69-2009.

4b.2.2.2 Geometry and Configuration

Bounding calculations for the biological shield in the RPF have been performed. Detailed calculations will be performed for locations throughout the RPF, and figures will be provided in the FSAR showing PFBS configurations.

Specified ~~CAMs/~~RAMs also trigger the ESFAS or RICS. The ESFAS or RICS incorporates safety relays whose function is to interrupt power to the active ESFs that have been identified in Chapter 13. The ESFAS or RICS can be tripped manually from the control room by an operator.

Refer to Subsection 7a2.2.4 for discussion of safety function performance analysis.

Potential variables, conditions, or other items that will be probable subjects of technical specifications associated with the radiation monitoring instrumentation are provided in Chapter 14.

7b RADIOISOTOPE PRODUCTION FACILITY INSTRUMENT & CONTROL SYSTEM

7b.1 SUMMARY DESCRIPTION

Within the SHINE facility, the RPF houses the extraction, purification, packaging, target solution preparation and cleanup, and waste treatment systems. The systems are enclosed predominately by hot cells and glove box designs. The RICS provides for monitoring and control of safety-related components (including ESFs) within the RPF. The RICS also provides process monitoring and control of the nonsafety-related systems within the RPF.

7b.1.1 RICS DESCRIPTION (SR/ESF)

The RICS is a DCS that monitors and controls SR components (including ESFs) within the RPF. When the monitored safety parameters exceed normal conditions, the RICS provides mitigative action by activating the ESF for the affected area. The ESFs in the RPF provide isolation functionality and alert operators of potential contamination events. The RICS can isolate one or any combination of the isolable hot cells in the RPF. The RICS also initiates the ESF isolation between ventilation zones in the RCA. This system is further described in Subsection 7b.2.3 and Section 7b.4.

7b.1.2 RICS DESCRIPTION (PROCESS CONTROL)

The RICS performs as the overall production process controller. It monitors and controls the required instrumented functions within the RPF. This includes monitoring of process fluid transfers and controlled inter-equipment pump transfers of process fluids. This system is further described in Section 7b.3.

7b.1.3 RADIATION MONITORING

The RPF utilizes CAMS, RAMS, and the criticality accident alarm system (CAAS) for continuous monitoring of processes. The CAMS, RAMS, and CAAS are strategically placed throughout the RPF to alert personnel of any potential radiation hazards. The CAMS, RAMS, and CAAS monitor the RPF for radiation and perform alarming in the control room and locally at locations throughout the RPF. The CAAS is further described in Section 7b.6. The RAMS and CAMS are further described in 7a2.7.

Specific ~~CAMs/~~RAMs channels provide input to RICS for ESF functions.

7b.1.4 CONTROL ROOM AND INSTRUMENT DISPLAYS

The SHINE RPF is monitored and controlled from a centralized control room. The RICS has separate dedicated annunciation, alarming, and operator interface displays. The RICS operator panels and displays are electrically isolated and independent components. Within the control room, there are RICS consoles that are redundant in nature and can be operated simultaneously and independently. From these consoles, an operator can assess the state of a hot cell and other process enclosures within the RPF. The operator can view and trend essential measurement values from the operator interface display. From the RICS operator workstation, the operator controls many of the RPF processes that are not performed through manual means (such as radioisotope purification). The operator is provided real-time data from the essential measurements used to control and monitor the RPF process on the RICS displays. This system is further described in Section 7b.5.

The human-machine interface is addressed in Section 7b.5.

List of Figures

Acronyms and Abbreviations (cont'd)

Acronym/Abbreviation	Definition
RV	RCA ventilation System
RVZ1	radiological controlled area ventilation system zone 1
RVZ2	radiological controlled area ventilation system zone 2
~~RVZ2SA~~	~~RCA zone 2 supply air subsystem~~
RVZ3	radiological controlled area ventilation system zone 3
SCAS	subcritical assembly system
sccm	standard cubic centimeter per minute
SHINE	SHINE Medical Technologies, Inc.
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SNM	special nuclear material
SRWP	solid radioactive waste packaging
SSC	structures, systems and components
Tc	technetium
TCAP	thermal cycling absorption process
TDN	thermal denitration
TELCO	telephone company
TOGS	target solution vessel off gas system
TPCS	TSV process control system
TPS	tritium purification system
TRPS	target solution vessel reactivity protection system
TSPS	target solution preparation system

9a2 IRRADIATION FACILITY AUXILIARY SYSTEMS

9a2.1 HEATING, VENTILATION, AND AIR CONDITIONING SYSTEMS

9a2.1.1 RADIOLOGICALLY CONTROLLED AREA VENTILATION SYSTEM

The RCA ventilation system (RV) includes supply air and exhaust subsystems required to condition the air and maintain radiological confinement in the RCA. The supply and exhaust air systems perform safety functions to protect workers and the public from releases of radiological materials and hazardous chemicals.

A ~~V~~ventilation flow diagram~~s~~ ~~are~~is provided in Figure~~s~~ 9a2.1-1 ~~and 9a2.1-2~~ (the legend for process flow diagrams is provided on Figure 1.3-6).

RV consists of the following:

- ~~RVZ2SA—~~RCA ~~Zone 2 Supply Air~~Ventilation Zone 1 (RVZ1)

  ~~RVZ2SA provides conditioned air for workers and equipment in the RCA and maintains confinement in conjunction with the operation of the exhaust.~~

  ~~Outside air is drawn into the RCA through RVZ2SA air handling units (AHUs). The air-handling units supply 100 percent outside air to the RCA. Each AHU contains filters, pre-heat and cooling coils, and supply fans. The supply system includes three AHUs, each sized for 50 percent of total system capacity. If a single unit fails, the standby unit will start automatically. The units normally supply a constant volume of conditioned air to the RCA ventilation system Zone 2 (RVZ2) and Zone 3 (RVZ3).~~

  ~~RVZ3 air is cascaded into RVZ2 areas through engineered door leakage pathways by a negative pressure differential, maintaining the desired pressure drop between the zones. Terminal unit components in the supply duct system include air flow control valves and reheat coils. The terminal reheat coils provide final tempering of supply air to maintain the RVZ2 temperature set point. RVZ2 supply airflow control valves operate in conjunction with exhaust valves to control the negative pressure differential in each zone by maintaining a fixed offset between the total supply and exhaust air flows for each RVZ2 space. Since supply air to RVZ3 is cascaded into RVZ2 areas, there is no exhaust for RVZ3.~~

  ~~RVZ2SA controls operate through the facility integrated control system (FICS) and are nonsafety-related, except for the automatic isolation dampers (bubble-tight dampers) and backdraft dampers (bubble-tight dampers) in the supply duct system at the RCA boundary. These dampers perform a safety function and close when required to provide confinement at the RCA boundary. If a design basis event requires the activation of automatic isolation dampers, the radiological integrated control system (RICS) actuates the dampers.~~RVZ1, the primary confinement zone, includes those areas where high levels of airborne contamination are anticipated during normal operations. RVZ1 areas draw ambient supply air from adjacent RVZ2 spaces. RVZ1 areas are maintained at negative pressure with respect to their surrounding RVZ2 spaces. RVZ1 area air inlets are equipped with automatic isolation dampers (fail closed), manual isolation dampers, and non-credited high efficiency particulate air (HEPA) filters. These HEPA filters are not

assumed to be present in accident analyses, but are present to provide additional protection to workers and equipment.

The exhaust air from each RVZ1 area filters through local HEPA filters. In addition to the automatic isolation dampers on the air inlet, each RVZ1 area exhaust outlet includes automatic isolation dampers to enable confinement of the RVZ1 area. These automatic dampers are safety-related and isolate the RVZ1 areas upon a signal from the Engineered Safety Features Actuation System (ESFAS) or the Radiological Integrated Control System (RICS), and reduce the exhaust of released airborne material.

Negative space pressure in RVZ1 is controlled through modulation of local exhaust air flow control valves for each cell.

The RVZ1 exhaust system is equipped with redundant fans. During normal operation, one fan is operating while the other fan is on standby. If the operating fan fails, the standby fan will start automatically. The RVZ1 system exhaust fans draw air through the inlet filters, dampers, and piping, providing the pressure drop needed to maintain pressure negative within the RVZ1 area.

The speed of the RVZ1 exhaust fans is controlled to maintain a negative pressure set point in the RVZ1 exhaust duct header. RVZ1 exhaust also receives treated output from the Noble Gas Removal System (NGRS) through the Process Vessel Vent System (PVVS). The exhaust from RVZ1 areas collects in the RVZ1 system duct header and then draws through final, testable, HEPA filters and carbon adsorbers prior to discharge into the exhaust stack.

RVZ1 exhaust discharges to the nominally 56 inch diameter exhaust stack with a radiation monitoring system. The discharge point of the stack is approximately 10 feet above the roof line.

The RVZ1 exhaust heating, ventilation, and air conditioning (HVAC) control components operate through the Facility Integrated Control System (FICS) and are nonsafety-related, except for the isolation dampers noted above, and the automatic isolation dampers located in the RVZ1 exhaust ductwork downstream of the final filters. These isolation dampers are controlled by ESFAS and RICS, which are safety-related. The isolation dampers located in the RVZ1 exhaust ductwork downstream of the final filters perform a safety function and close when required to provide confinement at the RCA boundary.

- ~~RVZ1 Exhaust~~RCA Ventilation Zone 2 (RVZ2)

~~RVZ1 exhausts air from RVZ1 confinement zones and associated process systems.~~

~~The RVZ1 exhausts air from hot cells (controlled-environment work enclosures providing radioactive shielding and primary confinement of hazardous material), the noble gas storage cell, TSV off-gas system (TOGS) shielded cells, and irradiation unit cells in the RCA. The system also captures exhaust from the process vent vessel system (PVVS). The PVVS system includes a dedicated filtration and exhaust blower subsystem. The RVZ1 hot cell and irradiation unit cell enclosures draw ventilation air from the surrounding RVZ2 spaces through high efficiency particulate air (HEPA) filters. The exhaust air from each cell filters through local HEPA filters. The cells include automatic isolation dampers~~

on the air inlet and exhaust outlet to enable confinement at the irradiation unit, noble gas storage cell, TOGS shielded cell or hot cell boundaries. These automatic dampers are safety-related (SR) and isolate the cells upon a signal from the engineered safety features actuation system (ESFAS) or RICS and reduce the exhaust of released airborne material prior to decaying to safe levels.

Negative space pressure in RVZ1 is controlled through modulation of local exhaust air flow control valves for each cell. The exhaust from the cells collects in an RVZ1 system duct header and then draws through final, testable, HEPA filters and carbon adsorbers prior to discharge into the exhaust stack. The speed of the RVZ1 exhaust fans is controlled to maintain a negative pressure set point in the RVZ1 exhaust duct header. The exhaust fans are fully redundant. If the operating fan fails, the standby fan will start automatically.

The RVZ1 exhaust HVAC control components operate through the FICS and are nonsafety-related, except for the cell isolation dampers noted above, and the automatic isolation dampers located in the RVZ1 exhaust ductwork downstream of the final filters. These dampers perform a safety function and close when required to provide confinement at the RCA boundary.

RVZ1 exhaust discharges to the nominally 56 inch (142 centimeter) diameter exhaust stack with a radiation monitoring system. The discharge point of the stack is nominally 7.6 feet (ft.) (2.3 meters [m]) above the nominal 58 ft. (17.1 m) roof line.RVZ2, the secondary confinement zone, includes those areas where airborne contamination could be (but is not routinely) generated during normal operations, or as a result of a breach of an RVZ1 confinement area. RVZ2 areas are transient spaces prone to fluctuations in pressure because of changing airflows based on door movements and fume hood activity.

RVZ2 areas are directly supplied air via the RCA supply air handling units (AHUs). The AHUs supply 100 percent outside air to the RVZ2 areas. Each AHU contains filters, pre-heat and cooling coils, and supply fans. The supply system includes three AHUs, each sized for 50 percent of total system capacity. If a single AHU fails, the standby AHU will start automatically. The AHUs normally supply a constant volume of conditioned air to RVZ2 and RVZ3 areas. In addition to the outside air supplied directly to RVZ2 areas, RVZ3 air is cascaded into RVZ2 areas through engineered airlock door leakage pathways by a negative pressure differential, maintaining the desired pressure drop between the zones. RVZ2 areas are maintained at negative pressure with respect to RVZ3 areas.

Terminal unit components in the supply duct system include air flow control valves and reheat coils. The terminal reheat coils provide final tempering of supply air to maintain the RVZ2 temperature set point. RVZ2 supply airflow control valves operate in conjunction with exhaust valves to control the negative pressure differential in each zone by maintaining a fixed offset between the total supply and exhaust air flows for each RVZ2 areas.

RCA supply air controls operate through the FICS and are nonsafety-related, except for the automatic isolation dampers (bubble-tight dampers) in the supply duct system at the

RCA boundary. These dampers are operated by the safety-related RICS, and perform a safety function, closing when required to provide confinement at the RCA boundary.

RVZ2 areas exhaust through general room exhausts and fume hood enclosures (where present). A portion of the air in RVZ2 areas is also transferred to RVZ1 areas through RVZ12 area air inlets, which contain automatic isolation dampers (fail closed), manual isolation dampers, and non-credited HEPA filters. As described above, the RVZ2 supply and exhaust systems will have airflow control valves, reacting to maintain the design differential pressure and ensuring the zone pressures are negative with respect to atmosphere and RVZ3. Flow control valves in fume hood exhaust ducts (where present) maintain a constant volume through each fume hood. The control valves automatically modulate to compensate for changes in pressure drop due to loading of local filters.

The RVZ2 exhaust system is equipped with redundant fans. During normal operation, one fan is operating while the other fan is on standby. If the operating fan fails, the standby fan will start automatically. Exhaust from RVZ2 areas collects in an RVZ2 exhaust header, and then draws through final, testable, HEPA filters and carbon adsorbers, prior to discharge into the exhaust stack. The RVZ2 exhaust fan speed is controlled to maintain the desired negative pressure in the RVZ2 exhaust header, and local automatic control valves adjust to maintain the negative pressure in the zone.

Along with RVZ1, RVZ2 exhaust discharges to the nominally 56 inch diameter exhaust stack, which contains a stack monitoring system. The discharge point of the stack is approximately 10 feet above the roof line.

The RVZ2 controls operate through the FICS and are nonsafety-related, except for the automatic isolation dampers in the supply duct at the RCA boundary and in the RVZ2 exhaust duct system located downstream of the final filters. These perform a safety function and close when required to provide confinement at the RCA boundary.

- ~~RVZ2 Exhaust~~

~~RVZ2 exhausts air from RVZ2 confinement zones and associated process systems.~~

~~The RVZ2 exhausts air from the operating areas, workrooms, and fume hoods to maintain confinement in radiologically controlled areas. This confinement protects workers in the facility from radiological and hazardous chemical releases in the RCA. The exhaust air from these spaces collects in an RVZ2 exhaust header and then draws through final, testable, HEPA filters and carbon adsorbers prior to discharge into the exhaust stack. The exhaust fan speed is controlled to maintain the desired negative pressure in the RVZ2 exhaust header. The exhaust fans are fully redundant. If the operating fan fails, the standby fan will start automatically.~~

~~Air flow control valves in the RVZ2 room exhaust duct system operate in conjunction with the zone supply valves to produce an offset between exhaust and supply flow rates. The flow offset enables a differential pressure.~~

~~Flow control valves in fume hood exhaust ducts maintain a constant volume through each fume hood. The control valves automatically modulate to compensate for changes in pressure drop due to loading of local filters.~~

The RVZ2 controls operate through the FICS and are nonsafety-related, except for the automatic isolation dampers in the RVZ2 exhaust duct system located downstream of the final filters. These perform a safety function and close when required to provide confinement at the RCA boundary.

RVZ2 exhaust system discharges to the nominally 56 inch (142 centimeter) diameter exhaust stack along with RVZ1. The discharge point of the stack is nominally 7.6 ft. (2.3 m) above the nominal 58 ft. (17.1 m) roof line.

- RCA Ventilation Zone 3 (RVZ3)

RVZ3, is the tertiary confinement zone, that includes process supportthose areas where airborne contamination is not expected to occur underduring normal operating conditionsfacility operations. RVZ3 areas are maintained at an elevated pressure relative to RVZ2 areas.

RVZ3 is supplied with air from the RVZ2SA, and air is exhausted to RVZ2. RVZ3 does not contain separate AHUs for exhaust or supply air.RVZ3 areas have airflow control valves on the supply side delivering air balanced to the design values. Forced air supplied to RVZ3 is then transferred to RVZ2 spaces through engineered airlock door leakage pathways. RVZ3 areas are maintained at an elevated pressure relative to RVZ2 areas, and a negative pressure relative to FVZ4 spaces. No RVZ3 exhaust system is anticipated, as the air from RVZ3 areas is transferred to RVZ2 areas.

9a2.1.1.1 Design Bases

The RV is designed to provide environmental conditions suitable for personnel and equipment. The functions of the system include conditioning the RCA environment for workers and equipment, and confinement of hazardous chemical fumes and airborne radiological materials. The ventilation system includes functions designated as nonsafety-related and safety-related. System safety functions are achieved through maintaining negative pressure gradients between confinement zones and to the outside atmosphere, air-exchange rates, exhaust stream air filtration, and isolation (closure) of ventilation duct systems at designated boundaries.

The RV is designed such that the FICS monitors and controls the RCA ventilation system equipment, flow rates, pressures, and temperatures. Instrumentation monitors the ventilation systems for off-normal conditions and signal alarms as required. The FICS starts, shuts down, and operates the RV in normal operating modes, which prevent positive pressurization of contaminated areas and creates flow patterns that direct air toward areas of increasing contamination potential.

The primary operational design functions of the RCA ventilation system are summarized below:

- Provide ventilation air and condition the RCA environment for workers.
- Provide makeup air and condition the RCA environment for process equipment.
- Confine airborne radiological materials.
- Limit the spread of airborne contamination.
- Maintain dose uptake through ingestion to levels as low as reasonable achievable (ALARA) per 10 CFR 20 – Standards for Protection against Radiation.
- Confine hazardous chemical fumes.

The primary functions of the FVZ4 are summarized below:

- Provide conditioned air for workers and equipment.
- Provide outside makeup air for ventilation and pressurization.
- Remove hazardous chemical fumes.
- Maintain hydrogen concentration below 2 percent.

9a2.1.2.2 Safety Design Functions

FVZ4 has no safety functions.

9a2.1.3 FACILITY CHILLED WATER SUPPLY AND DISTRIBUTION SYSTEM

The facility chilled water supply and distribution system (FCHS) provides chilled water to the RCA and non-RCA of the SHINE facility.

The FCHS provides chilled water to the cooling coils of the ~~RVZ2SA~~RCA supply AHUs, and to the process cooling heat exchangers of the radioisotope production facility cooling system (RPCS). See Chapter 5 for more information on the RPCS. Also, FCHS provides chilled water to the cooling coils of the FVZ4 AHUs.

The primary components of the FCHS include:

- Air-cooled condensers.
- Chiller evaporators.
- Chilled water pumps, associated piping and valves, and makeup water and water treatment equipment.
- Expansion tank.

The FCHS is a closed loop system serving the RV and FVZ4 cooling coils that are located outside the RCA boundary. The FCHS also supplies water to the heat exchanger in the RPCS, located inside the RCA. The water-to-water heat exchanger provides separation between the RCA and non-RCA chilled water systems to limit the potential for cross-contamination.

Isolation valves on the chilled water supply and return lines to each cooling coil and heat exchanger allow isolation from the water loop for maintenance.

If supplemental ventilation system cooling is required in the RCA, the RPCS serves HVAC cooling coils within the RCA.

The FICS monitors and controls the FCHS equipment status, flow rates, pressures, and temperatures. Instrumentation monitors the system for off-normal conditions and signal alarms as required. The FICS starts, shuts down, and operates the FCHS. Chiller controls are nonsafety-related.

Temperature control valves in the chilled water coil piping for each ~~RVZ2SA~~RCA supply AHU are controlled by a supply air temperature controller with input from a temperature element (sensor) located in the discharge ductwork of each supply AHU. The control valve regulates the chilled water flow to the cooling coil to maintain the setpoint for the supply air discharge temperature.

9a2.1.3.1 Design Basis

The FCHS is designed such that the FICS can monitor and control the equipment, flow rates, pressures, and temperatures. Instrumentation monitors the ventilation systems for abnormal conditions and signal alarms as required.

The primary functions of the FCHS are as follows:

- Remove the heat and condition the air passing through the cooling coils of the ~~RVZ2SA~~RCA supply AHUs. Circulate chilled water through the cooling coils of ~~RVZ2SA~~RCA supply AHUs utilizing water as the working fluid.
- Remove heat from the RPCS. Circulate chilled water through the RPCS heat exchanger using water as the working fluid.
- Remove heat and condition the air passing through the cooling coils of the FVZ4 AHUs. Circulate chilled water through the cooling coils of the FVZ4 AHUs utilizing water as the working fluid.
- Maintain FCHS water quality.

9a2.1.3.2 Safety Design Functions

There are no safety functions identified for the FCHS.

9a2.1.4 FACILITY HEATING WATER SYSTEM

The facility heating water system (FHWS) provides heating water to the RCA and non-RCA of the SHINE facility.

The FHWS provides heating water to the preheat and reheat coils in the RVZ2 and FVZ4 supply systems.

The primary components of the FHWS include:

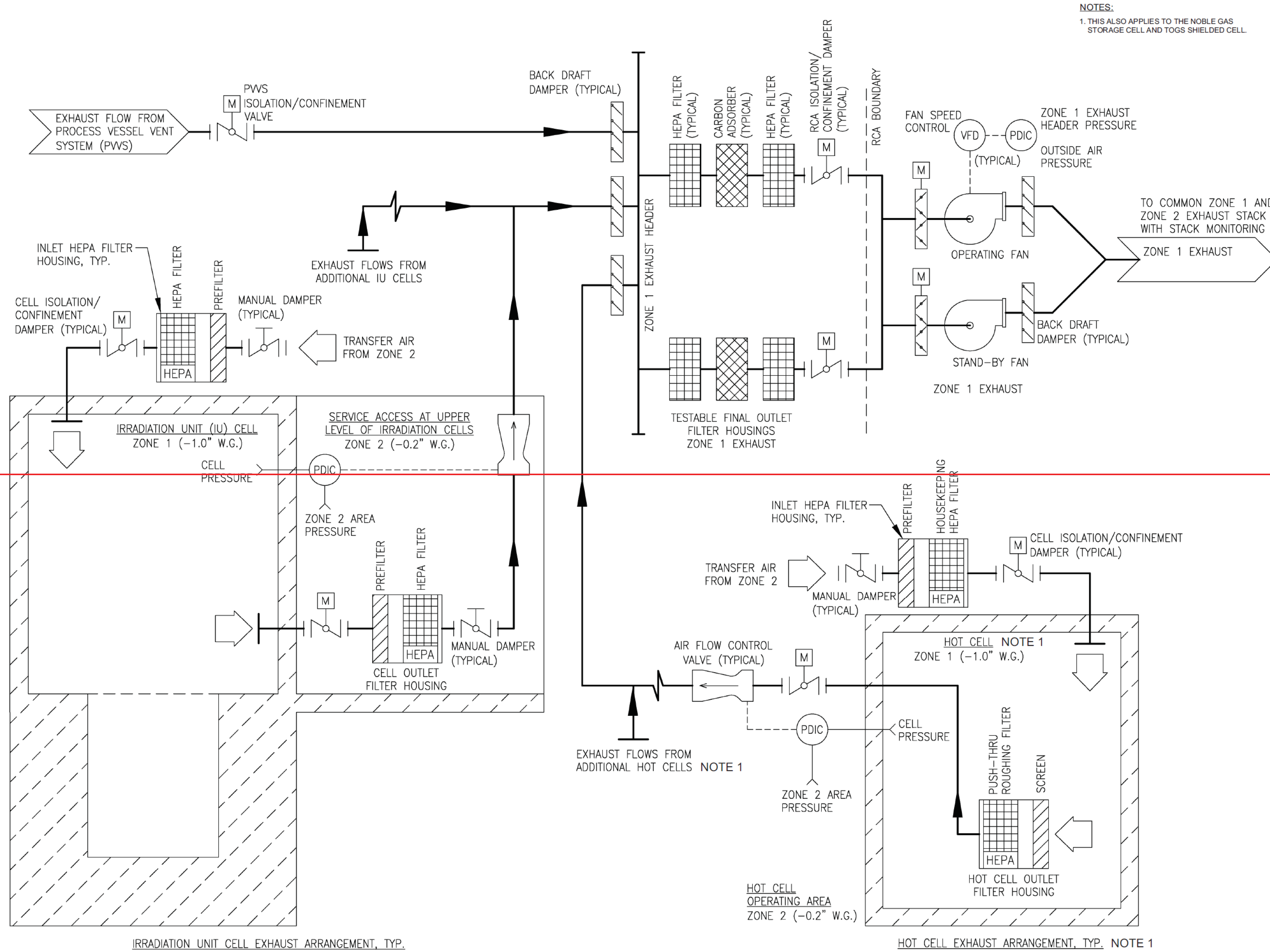
- Gas boiler.
- Pump, associated piping and valves, and makeup water and water treatment equipment.
- Expansion tank.

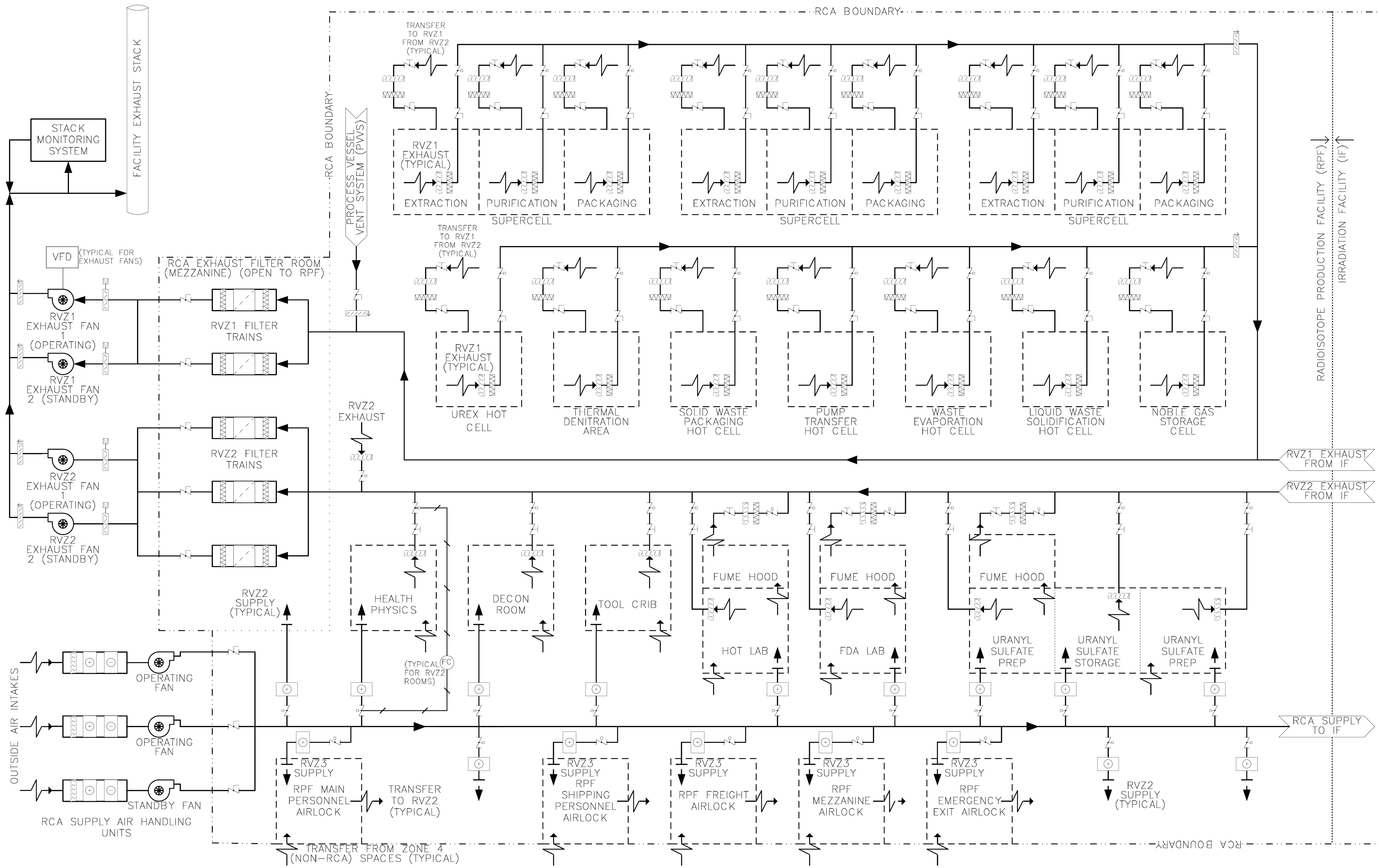
The FHWS is designed as a closed loop system where the water is heated by the gas boiler and circulated by the pump to the preheat and reheat coils of the RVZ2 and FVZ4 supply systems where it exchanges heat with the air before returning back to the boiler.

Isolation valves on the hot water supply and return lines to each heating coil and heat exchanger allow isolation from the water loop for maintenance.

The FICS monitors and controls the FHWS equipment status, flow rates, pressures, and temperatures. Instrumentation monitors the system for off-normal conditions and signal alarms as required. The FICS starts, shuts down, and operates the FHWS.

Figure 9a2.1-1 – ~~RVZ1~~RCA Ventilation System Flow Diagram (Sheet 1 of 2)





RCA BOUNDARY
FACILITY EXHAUST STACK
STACK MONITORING SYSTEM
VFD
(TYPICAL FOR EXHAUST FANS)
RVZ1 EXHAUST FAN 1 (OPERATING)
RVZ1 EXHAUST FAN 2 (STANDBY)
RVZ2 EXHAUST FAN 1 (OPERATING)
RVZ2 EXHAUST FAN 2 (STANDBY)
RCA EXHAUST FILTER ROOM (MEZZANINE) (OPEN TO RPF)
RVZ1 FILTER TRAINS
RVZ2 FILTER TRAINS
RVZ2 SUPPLY (TYPICAL)
PROCESS VESSEL VENT SYSTEM (PVVS)
TRANSFER TO RVZ1 FROM RVZ2 (TYPICAL)
RVZ1 EXHAUST (TYPICAL)
EXTRACTION
PURIFICATION
PACKAGING
SUPERCELL
UREX HOT CELL
THERMAL DENITRATION AREA
SOLID WASTE PACKAGING HOT CELL
PUMP TRANSFER HOT CELL
WASTE EVAPORATION HOT CELL
LIQUID WASTE SOLIDIFICATION HOT CELL
NOBLE GAS STORAGE CELL
RADIOISOTOPE PRODUCTION FACILITY (RPF)
IRRADIATION FACILITY (IF)
RVZ1 EXHAUST FROM IF
RVZ2 EXHAUST FROM IF
RVZ2 EXHAUST
HEALTH PHYSICS
DECON ROOM
TOOL CRIB
FUME HOOD
HOT LAB
FDA LAB
URANYL SULFATE PREP
URANYL SULFATE STORAGE
(TYPICAL FOR RVZ2 ROOMS)
FC
OUTSIDE AIR INTAKES
OPERATING FAN
STANDBY FAN
RCA SUPPLY AIR HANDLING UNITS
RCA SUPPLY TO IF
RVZ3 SUPPLY
RPF MAIN PERSONNEL AIRLOCK
TRANSFER TO RVZ2 (TYPICAL)
RPF SHIPPING PERSONNEL AIRLOCK
RPF FREIGHT AIRLOCK
RPF MEZZANINE AIRLOCK
RPF EMERGENCY EXIT AIRLOCK
RVZ2 SUPPLY (TYPICAL)
TRANSFER FROM ZONE 4 (NON-RCA) SPACES (TYPICAL)

Figure 9a2.1-1 – RCA Ventilation System Flow Diagram (Sheet 2 of 2)

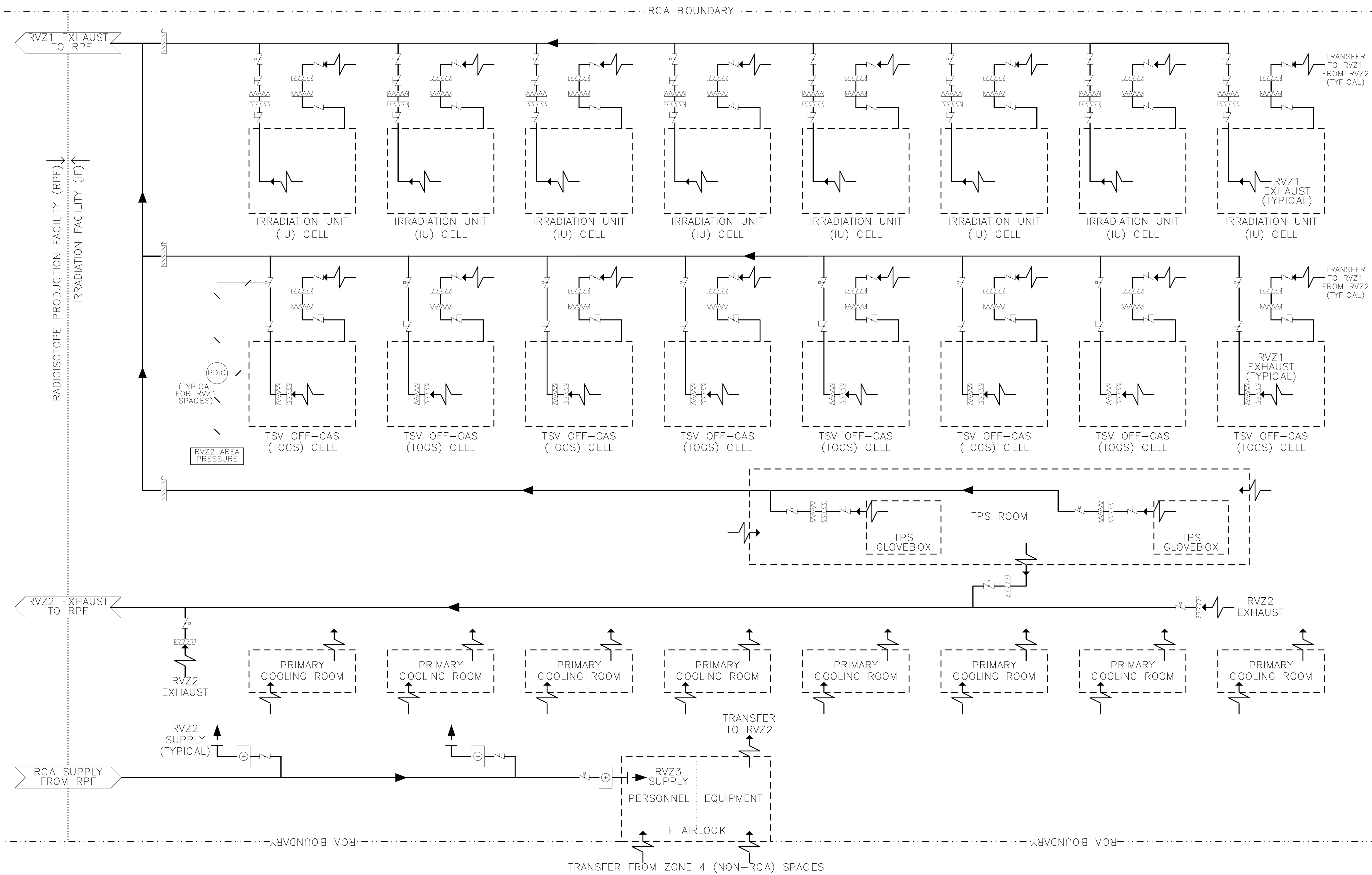


Figure 9a2.1-2 – ~~RVZ2SA and RVZ2 Ventilation Flow Diagram~~This figure number not used

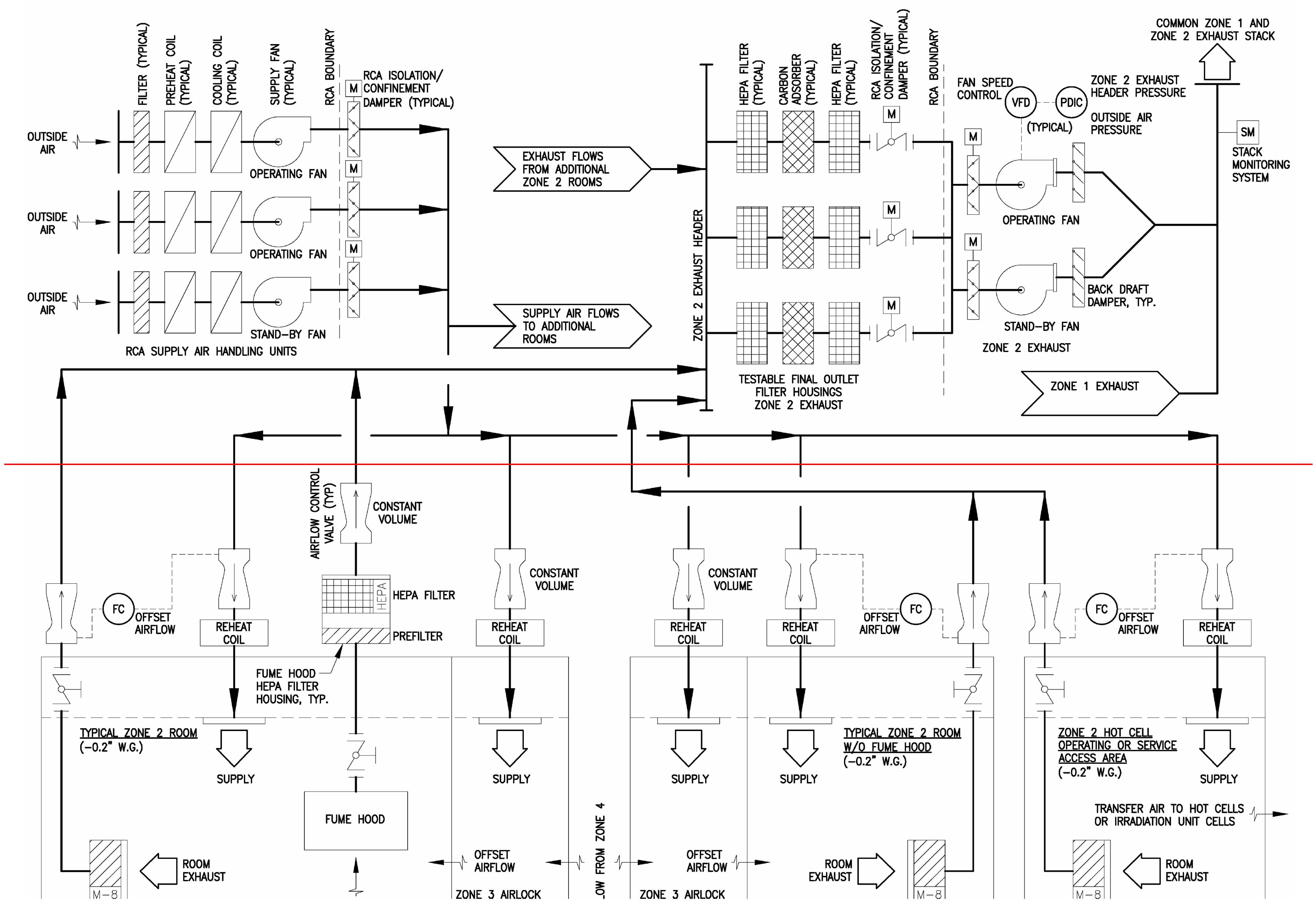


Table 11.1-3 lists the activity associated with the radionuclides listed in NUREG/CR-4467 contained in one TSV batch of target solution that has been through [Proprietary Information] 5.5-day irradiation cycles and after it has decayed for [Proprietary Information] in the TSV dump tank. At this time it is ready to be pumped into the supercell to begin the molybdenum extraction and fission product removal processes. The activities in Table 11.1-3 are the bounding values case at [Proprietary Information].

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 Title 10 of the Code of Federal Regulations (10 CFR) 20 and 71, and with Department of Transportation regulations for shipment of product and waste (49 CFR). The goal for the normal operations dose rate for normally occupied locations in the facility is 0.25 millirem per hour (mrem/hr) at 12 in. (30.48 cm) from the surface of the shielding. Radiation levels may rise above the 0.25 mrem/hr level during some operations such as tank transfers. Facility shielding is designed to meet this goal.

Major radiation sources in the balance of the facility originate in the target solution and in the TOGS. At the end of each TSV irradiation cycle, irradiated target solution is piped to one of the three supercells for processing. After [Proprietary Information] irradiation cycles the target solution is also processed through the UREX process where fission products and uranium are separated. After each irradiation cycle off-gas is purged to one of the noble gas storage tanks to allow for decay of short-lived noble gas nuclides before being released through the facility exhaust stack. Airborne, liquid, and solid radioactive materials are contained in piping systems and tanks. Radiation levels for major system components and locations are provided below. RPF and process special nuclear material inventories are tabulated in Tables 4b.4-1 and 4b.4-13, respectively.

The three sections below describe the major radiation sources in the facility. Other radiological sources in the facility are bounded by the fission product source coming from the TSV described in Subsection 11.1.1.2.

11.1.1.1 Airborne Radioactive Sources

Radioactive sources that could become airborne at the SHINE facility are primarily in the form of radioactive gases produced as a byproduct of the Mo-99 production process. The systems handling gaseous radioactive materials include the tritium purification system (TPS) and the TSV off-gas system (TOGS), both located in the irradiation facility (IF) area; and the noble gas removal system (NGRS) and the process vessel vent system (PVVS), both located in the RPF. These airborne radioactive materials are contained within closed systems consisting of piping components and tanks. Table 11.1-4 provides information on the various locations, types, and expected dose rates from gaseous radioactive sources.

Argon-41 is produced in the IU cells during operations. Argon-41 levels in the IU cell are diluted and diffused by RVZ1. Approximately 15.2 curies per year (Ci/yr) of argon-41 are released to the environment through the facility stack.

Nitrogen-16 is produced within the primary cooling loops. Dose rates from this source are mitigated by biological shielding that limits radiation dose to occupied areas adjacent to the shielding.

Gaseous activity released from the target solution during the production process is collected and sent to the NGRS. This includes activity that may be released into the hot cells. No activity is released to the general access area of the facility, so no worker exposure to airborne activity is expected during process operations. Activity may be released during maintenance operations that require the opening of process systems. Radiation protection procedures are used to ensure that worker exposure to airborne activity is minimized during maintenance operations. Predicted personnel dose rates (including maintenance activity dose rates) and the associated methodology will be provided in the FSAR.

Gaseous activity from the TSV and process operations is held in noble gas storage tanks until radiodecay has reduced the activity such that releases are below the 10 CFR 20 limits. 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 (NRC, 1977) with the meteorological data in Section 2.3. The χ/Q values for the maximally exposed individual (MEI), which is the nearest point on the site boundary, and the nearest full-time resident are 7.1E-5 sec/m^3 and 5.3E-6 sec/m^3, respectively.

Table 11.1-9 contains the estimated gaseous activity production rates for a single TSV. Noble gases are the primary gaseous radionuclides produced in the TSV. Iodine is also volatile and is assumed to become airborne. Iodine is removed in the TOGS and a small fraction is transferred to the NGRS. The minimum holdup time in the NGRS is 960 hours (40 days). As shown in Table 11.1-9, many noble gas and iodine nuclides are short-lived and decay away during this holdup. The resulting annual release, with eight TSVs operating, is limited to a few nuclides as shown in the table.

The dose analysis considered the release of airborne radionuclides and exposure to off-site individuals through direct exposure and potential environmental pathways, such as leafy vegetable ingestion, meat ingestion, and milk ingestion. The analysis considered variations in consumption and other parameters by age group. The estimated annual doses (excluding tritium) at the MEI and the nearest resident are 9.0 mrem and 0.6 mrem, respectively, which is a small fraction of the 10 CFR 20.1301 limit of 100 mrem. ~~The tritium purification system and neutron driver~~Activities in the IF and RPF are designed such that the estimated annual doses to the MEI and the nearest resident are below the dose constraint specified in 10 CFR 20.1101(d).

Calculational methodologies related to accidental releases of airborne radioactive sources are discussed in Chapter 13.

11.1.1.2 Liquid Radioactive Sources

There are numerous locations within the SHINE facility where the presence of radioactive liquids results in a source of radiation. These sources (except for two) are derived from the irradiated uranyl sulfate target solution as it is being processed through the facility. The first exception is the primary coolant, which carries activation product nitrogen-16 (N-16) along as it is pumped through the primary cooling heat exchangers. The second exception is the production of

associated with implementation of a radiation protection program. Other members of the Radiation Protection Program staff are trained and qualified consistent with the guidance provided in Regulatory Guide 1.8.

Sufficient resources in terms of staffing and equipment are provided to implement an effective radiation protection program.

11.1.2.1.3 Independence of the Radiation Protection Program

The Radiation Protection Program is independent of facility operations. This independence ensures that the Radiation Protection Program maintains its objectivity and is focused only on implementing sound radiation protection principles necessary to achieve occupational doses and doses to members of the public that are ALARA.

11.1.2.1.4 Radiation Safety Committee

A radiation safety committee (RSC) is established and meets periodically (at least annually) to review the status of projects, measure performance, look for trends and to review radiation safety aspects of facility operations, in accordance with 10 CFR 20.1101(c). The radiation protection manager chairs the RSC. The other RSC members come from quality assurance, operations, maintenance, and technical support.

The objectives of the RSC are to maintain a high standard of radiation protection in facility operations. The RSC reviews the content and implementation of the radiation protection program at a working level and strives to improve the program by reviewing exposure trends, the results of audits, regulatory inspections, worker suggestions, survey results, reportable occurrences, and exposure incidents.

A written report of each RSC meeting is forwarded to all managers.

An official RSC charter will be prepared defining the purposes, functions, authority, responsibility, composition, quorum, meeting frequency, and reporting requirements of the RSC.

11.1.2.1.5 Commitment to Written Radiation Protection Procedures

Radiation protection procedures are to be prepared, reviewed and approved to carry out activities related to the Radiation Protection Program. Procedures are used to control radiation protection activities in order to ensure that the activities are carried out in a safe, effective and consistent manner. Radiation protection procedures are reviewed and revised as necessary by the radiation protection manager to incorporate any facility or operational changes.

Work performed in radiologically ~~restricted~~controlled areas is performed in accordance with a radiation work permit (RWP). The procedures controlling RWPs are consistent with the guidance provided in Regulatory Guide 8.10. A RWP is required whenever the radiation protection manager determines one is necessary. ~~Activities involving licensed materials not covered by operating procedures and where radioactivity levels are likely to exceed airborne radioactivity limits require the issuance of a RWP. Both routine and non-routine activities are performed under a RWP.~~ The RWP provides a description of the work to be performed. The RWP summarizes the results of recent dose rate surveys, contamination surveys, and airborne radioactivity measurements. The RWP specifies the precautions to be taken by those performing

- A "contaminated area" is an area which SHINE defines as an area where removable contamination levels are above 0.33 Becquerel per 100 square centimeters (Bq/100 cm^2) (20 disintegrations per minute per 100 square centimeters [dpm/100 cm^2]) of alpha activity or 16.7 Bq/100 cm^2 (1,000 dpm/100 cm^2 beta/gamma activity).

- Areas of “caution” exist within the restricted area. For instance, the NRC limits the soluble uranium intake of an individual to 10 milligrams in a week in consideration of chemical toxicity.

11.1.5.2 Access and Egress Control

SHINE establishes and implements an access control program that ensures that (a) signs, labels, and other access controls are properly posted and operative, (b) restricted areas are established to prevent the spread of contamination and are identified with appropriate signs, and (c) step-off pads, change facilities, protective clothing facilities, and personnel monitoring instruments are provided in sufficient quantities and locations.

Because there are high radiation areas in the facility, access to those areas is physically prevented due to radiation level. Access control is by a combination of administrative methods and active as well as passive engineered safeguards.

SHINE will provide active and passive safety features to control access to high radiation areas in accordance with 10 CFR 20.1601. These safety features include:

- Neutron driver personnel access door interlocks de--energize the accelerator to reduce the level of radiation upon personnel entry, and accelerator key switches prevent the activation of the accelerator while personnel are present.
- Based on the hazards analysis during final design, hot cells requiring periodic/routine entry where there is potential for excessive personnel exposures are equipped with door interlocks to prevent the hot cell door from being opened when the evaluated hazard exists (e.g., excessive radiation field, target solution transfer occurring in cell).
- The neutron driver and hot cells are equipped with audible and visual warnings so that an individual attempting to enter the high radiation area and the supervisor of the activity are made aware of the entry, consistent with 10 CFR 20.1601(a)(2).
- High radiation areas are radiologically shielded and isolated from access to individuals by the use of engineered physical barriers, as described in Subsection 11.1.5.1.1. These include structural shield blocks and/or locked shield doors, consistent with 10 CFR 20.1601(a)(3).

Personnel who have not been trained in radiation protection procedures are not allowed access to the restricted area without escort by other trained personnel.

Access to and egress from the restricted area is through one of the monitor stations at the restricted area boundary. Access to and egress from each radiation area, high radiation area, contaminated area or airborne radioactivity area within the restricted area may also be individually controlled. A monitor (frisker), step-off pad and container for any discarded protective clothing may be provided at the egress point from certain of these areas to prevent the spread of contamination.

- Mishandling or malfunction of equipment affecting PSB (Subsection 13a2.2.7).
- Tritium purification system design basis accident (Subsection 13a2.2.12.3).

Further analysis of the above DBAs involved: (1) Identification of the limiting IE and bounding conditions, (2) Reviewing the sequence of events for functions and actions that change the course of the accident or mitigate the consequences, (3) Identifying damage to equipment or the facility that affects the consequences of the accident, (4) Review of the potential radiation source term and radiological consequences, and (5) Identification of facility-wide safety controls to prevent or mitigate the consequences of the accident.

Results of these analyses in Subsection 13a2.2, taking credit for safety-related SSCs and engineered safety features (ESFs) for each DBA, demonstrate that the mitigated consequences do not exceed the dose limits in 10 CFR 20.

13a2.1.1 MAXIMUM HYPOTHETICAL ACCIDENT

In accordance with the guidance in the Final ISG Augmenting NUREG-1537, an MHA that bounds the potential radiological consequences of any accident considered to be credible is analyzed. The basis for selecting an MHA includes assumptions described below.

The SHINE facility is divided into two major process areas, the IF and the RPF areas. The IF includes eight IUs each containing, among other components, an SCAS (including the TSV and TSV dump tank), light water pool system (LWPS), and the TSV off-gas system (TOGS). The TSV, TOGS, TSV dump tank, and associated components make up the PSB. The RPF consists of several process areas that extract and purify the molybdenum-99 (Mo-99) product, recycle uranium, and extract other fission products. These include the molybdenum extraction cells, the purification cells, the uranium extraction (UREX) process cells, thermal denitration (TDN) ~~cells~~area, and waste processing areas. A supercell is comprised of a molybdenum extraction area, a purification area, and a packaging area that form one hot cell structure. The RPF contains three supercells.

The MHA is used to demonstrate that the maximum consequences in operating the facility at a specific site are within acceptable regulatory limits of 10 CFR 20.1201 and 10 CFR 20.1301. The MHA is a non-credible accident scenario that results in a release with radiological consequences that bound the DBAs. The Final ISG Augmenting NUREG-1537 specifies several possible MHAs that could be considered.

13a2.1.1.1 Initial Conditions and Assumptions

Potential MHA scenarios suggested by the Final ISG Augmenting NUREG-1537 include:

- Energetic dispersal of contents of the PSB with bypass of scrubbing capacity.
- Detonation of hydrogen in the recombiner resulting in waste gas tank failure and release of some or all of the target solution and fission-product contents in aerosolized form.
- Complete loss of target solution inventory (e.g., TSV break).
- Man-made external event that breaches the PSB of more than one IU.
- Facility-wide external event that breaches various systems containing radioactive fluids.

13b.2 ANALYSES OF ACCIDENTS WITH RADIOLOGICAL CONSEQUENCES

This section analyzes the RPF accidents with radiological consequences. Each defined accident does not necessarily lead to a release of radioactivity; therefore, consequences for those events are not applicable. For the accidents analyzed, further detail (e.g., uncertainties, margins of safety, detailed discussions of the computer codes used, code validating for the applications, etc.) will be provided in the FSAR.

13b.2.1 MAXIMUM HYPOTHETICAL ACCIDENT IN THE RPF

Section 13a2.1.1 identifies a release of inventory stored in the NGRS storage tanks as the postulated MHA scenario for the RPF resulting in a maximum release of radiological material to the workers and individual members of the public. The event occurs within the confinement of the noble gas storage area, located in the RPF. This subsection discusses the detailed evaluation of the effects of the MHA event in the RPF including safety design features to mitigate the consequences of the MHA. A discussion of the effects of an MHA considered in the IF is presented in Subsection 13a2.2.1.

The RPF includes the MEPS, UNCS (including uranium extraction [UREX] and thermal denitration), and waste processing systems. These include the molybdenum extraction cells, the purification cells, UREX process cell, thermal denitration ~~cell~~area, and waste processing areas. A supercell is comprised of a molybdenum extraction cell, purification cell, and packaging cell that form one structure. The RPF contains three supercells.

The MHA postulated for the RPF is a release of the inventory stored in the NGRS storage tanks. This event occurs within the confinement of the noble gas storage cell. The radionuclide inventory released from the NGRS storage tanks represents the bounding source term for any other postulated accident in the RPF.

13b.2.1.1 Initial Conditions and Assumptions

The purpose of the NGRS is to collect and store the radioactive gases from the TOGS and monitor the gases until the short-lived radioisotopes decay, prior to release. The NGRS consists of two gas compressors, five noble gas storage tanks, a condensate knock-out tank, and radiation monitoring instrumentation. Hydrogen is also present, and the TOGS catalytic recombiner ensures the hydrogen concentration is below the LFL prior to gas transfer to NGRS (see Section 9b.6.2). The noble gas storage cell is located in the RPF.

The initial conditions and assumptions of the SSCs at the time of the accident or that may be affected by the release of the inventory stored in the NGRS storage tanks into the noble gas storage cell are as follows:

- The largest source term inventory for a radioactive release in the RPF is the contents of the five noble gas storage tanks.
- Penetrations for piping, ducts and electrical cables, and access doors are sealed to limit the release of radioactive materials from noble gas storage cell into the RPF.
- Piping that penetrates the NGRS storage cell boundary and the RPF is isolable by means of redundant, automatic isolation valves or by dual, normally-closed manual valves.
- The RVZ1 is equipped with multi-filter housing units containing 2-stage HEPA filtration and single stage carbon adsorbers (see Subsection 9a.2.1).

Some of these materials are stored for specific minimum periods of time to allow for decay of short-lived isotopes, either in one of the hot cells or in the waste storage area.

- The RVZ1, RVZ2, and RVZ3 systems are normally operated in an automatic mode to maintain a negative pressure in the RPF with respect to the environment outside of the SHINE facility. Automatic isolation of the system occurs on either a loss of off-site power or on indication of a high radiation condition.
- Noble gases are received from the TOGS and stored in a bank of five noble gas storage tanks that are filled on a staggered basis. The noble gas storage tanks have enough capacity to store the generated noble gases for at least 40 days.
- NGRS noble gas storage tanks and associated equipment are located within a shielded cell with isolation and confinement capability.

The eight IUs are in operation for at least as long as required to fill the five noble gas storage tanks. The NGRS contains the TOGS contents for at least 40 days before they are discharged to RVZ1 and then, ultimately, to the stack.

13b.2.4.2 Identification of Causes

Most processes covered by this evaluation are performed manually by RPF technicians. The manual nature of these operations makes human error a likely initiator for an event. Another potential cause is failure of the laboratory glassware used in the purification portion of the supercells. The glassware is replaced after every batch, but may possess a manufacturing flaw or sustain undetected damage during handling.

There are several process steps involved in the extraction of the molybdenum product and recycling of the target solution, which are performed in the RPF. A critical equipment malfunction due to human error or other failure in the RPF systems could result in a local liquid spill or release of stored fission product gases. For liquid spills, a vapor release would also be expected, especially for process streams with elevated temperatures. Processes in the RPF were reviewed for the potential of an error or failure that results in a radiological event. The following is a summary of that review:

Spills Inside of a Hot Cell

Liquid or vapor releases from process equipment or piping inside a supercell, UREX hot cell, thermal denitration ~~hot cell~~area, or one of the waste treatment hot cells would be contained by the physical design of these enclosures, and their drainage and ventilation systems. These releases could be caused by equipment failures and human errors such as valve or pump leaks/misalignments, contactor failures in UREX, column failures in MEPS, and corrosion.

Workers would be shielded from any direct gamma radiation by the hot cell biological shielding design. A spill of target solution in any of these cells would be directed to a drain or sump with a geometry that is criticality-safe. The area ventilation system would be shut down and isolated by bubble-tight dampers upon detection of excessive radiation to prevent release outside of the facility.

Radiological consequences to workers, the public, or the environment could result from a spill in one of the hot cells through the release of airborne radioactive material into the ventilation system (prior to the bubble-tight dampers isolating the cell) or penetrations into other portions of the RCA. Radiological spills within the hot cells are mitigated by facility and hot cell controls