NWMI
NORTHWEST MEDICAL ISOTOPES

Chapter 5.0 – Coolant Systems

Construction Permit Application for Radioisotope Production Facility

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Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, Oregon 97330

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Chapter 5.0 – Coolant Systems

Construction Permit Application for Radioisotope Production Facility

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TERMS

Acronyms and Abbreviations

^{234}U	uranium-234
^{235}U	uranium-235
^{236}U	uranium-236
^{237}U	uranium-237
^{238}U	uranium-238
^{239}Pu	plutonium-239
CFR	Code of Federal Regulations
EOI	end of irradiation
I	iodine
IROFS	item relied on for safety
Kr	krypton
Mo	molybdenum
MURR	University of Missouri Research Reactor
NWMI	Northwest Medical Isotopes, LLC
OSTR	Oregon State University TRIGA Reactor
OSU	Oregon State University
RPF	radioisotope production facility
U	uranium
[Proprietary Information]	[Proprietary Information]
Xe	xenon

Units

°C	degrees Celsius
°F	degrees Fahrenheit
BTU	British thermal unit
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
ft^2	square feet
g	gram
hr	hour
in.	inch
$in.^2$	square inch
kW	kilowatt
L	liter
lb	pound
rem	roentgen equivalent in man
W	watt
wk	week
wt%	weight percent

5.0 COOLANT SYSTEMS

5.1 SUMMARY DESCRIPTION

Cooling water systems are used to control the temperature of process solutions in the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF) from process activities and the heat load resulting from radioactive decay of the fission product inventory. The RPF is located at a separate site, independent from the reactors used to irradiate the targets. Therefore, the RPF cooling system does not influence operation of a reactor primary core cooling system.

Chilled water is used as the primary cooling fluid to process vessels. A central process chilled-water loop is used to cool three secondary loops: one large geometry secondary loop in the hot cell, one criticality-safe geometry secondary loop in the hot cell, and one criticality-safe geometry secondary loop in the target fabrication area. The central process chilled-water loop relies on air-cooled chillers, while the secondary loops are cooled by the central chilled-water system through plate-and-frame heat exchangers. Selected process demands require cooling at less than the freezing point of water. These demands are met with water-cooled refrigerant chiller packages, cooled by the secondary chilled water loops.

5.1.1 Irradiated Target Basis

Thermal characteristics of irradiated targets entering the RPF depend on the source reactor and decay time prior to receipt. Heat load estimates are currently based on preliminary calculations for targets irradiated at the Oregon State University (OSU) TRIGA[1] Reactor (OSTR) [Proprietary Information][Proprietary Information] [Proprietary Information] [Proprietary Information]. The calculations are based on the OSTR operating at a power of [Proprietary Information] irradiating a target for [Proprietary Information]. The charged target is assumed to contain [Proprietary Information] comprising:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]

Estimates are limited to prediction of actinides and fission products during irradiation of a fresh uranium target containing a limited set of assumed impurities. Calculations for recycled uranium, a broader set of impurities, and potential activation products are not currently available.

The OSTR calculations resulted in an average power per target of [Proprietary Information]. The preliminary OSTR calculations have been extrapolated to estimate the heat load of a target irradiated at the University of Missouri Research Reactor (MURR). The basis for this extrapolation is discussed in Chapter 4.0, "Radioisotope Production Facility Description," Section 4.2 (biological shielding). Assuming a similar cycle time produces an average target power of [Proprietary Information]. The MURR target (in prototypical reactor locations), radionuclide inventory, and thermal characteristics modeling is underway and will be completed to support the Operating License Application.

[1] TRIGA (Training, Research, Isotopes, General Atomics) is a registered trademark of General Atomics, San Diego, California.

Figure 5-1 describes the variation of heat generation with decay time for an individual average target irradiated at MURR and OSTR over 1 week. Due to location of the RPF relative to the reactor sites, the minimum decay time for receipt of targets [Proprietary Information]. The combination of reactor source and minimum decay time produces an estimated individual target heat load of [Proprietary Information] for MURR and OSTR irradiated targets, respectively.

[Proprietary Information]

Source: [Proprietary Information]

Figure 5-1. [Proprietary Information]

[Proprietary Information]

Source: [Proprietary Information]

Figure 5-2. [Proprietary Information]

Several material-handling steps must occur after the EOI within the reactor before a cask containing irradiated targets can be transported to the RPF. Examples include transfer of targets into the cask, removal of the loaded cask from the reactor pool, assembly of the cask lid, removal of water from the cask, drying the cask, performing the cask leak-check procedure, and cask decontamination and verification. At-reactor handling procedures are projected to require significantly [Proprietary Information] for an individual cask. Independent of the actual cask handling time required, the clock time for EOI of a target batch becomes a datapoint recorded on transfer papers, and a cask will not be unloaded until the minimum decay time after EOI used in safety evaluations has elapsed.

The number of irradiated targets received by the RPF in a single week also varies with the source reactor. The MURR operation is based on irradiating eight targets per week, while the OSTR operation is based on irradiating 30 targets per week. The number of irradiated targets will be optimized as part of the Operating License Application. Figure 5-2 indicates that the total heat load from targets received by the RPF is approximately the same from either reactor as a function of decay time. The weekly heat load from radionuclide decay is estimated at [Proprietary Information]. Therefore, heat load from receipt of MURR targets has been used as an upper bound for irradiated target receipts at the RPF.

The thermal load is characterized by radial heat transfer in a vessel and the uranium concentration of solutions held within vessels throughout the RFP. Increasing the number of targets processed during a given week increases the total liquid volume contained in geometrically favorable vessels (or liquid level height), but does not change the uranium concentration or radial thermal flux.

5.1.2 Vessels Considered for Thermal Characterization

Thermal characteristics of RPF process vessels are evaluated in NWMI-2015-CALC-022, *Maximum Vessel Heat Load, Temperature, and Pressure Estimates*. The vessels listed in Table 5-1 were selected to describe the RPF thermal characteristics. The thermal characteristics of every vessel containing radionuclides in the RPF have not been developed by the preliminary evaluation. However, the selected vessels were considered sufficient to span the range of potential heat generation rates anticipated to be contained in process vessels.

Table 5-1. Vessels Selected to Describe Radioisotope Production Facility Thermal Characteristics (2 pages)

Process location	Description
Vessels Equipped with Water-Cooling Jackets	
Dissolver 1/2 (DS-D-100/200) – Start of dissolution cycle	Dissolver vessel after insertion of dissolver basket. This configuration is included for completeness, but is not yet analyzed. Requires consideration of dissolver basket both before and after process solution added to the dissolver containing a dissolver basket.
Dissolver 1/2 (DS-D-100/200) – End of dissolution cycle	Dissolver solution after dissolution complete, prior to combination with transfer flush water. Assumes Kr/Xe and I isotopes transfer to dissolver offgas equipment during dissolution.
Mo system feed tank 1A/1B (MR-TK-100/140)	Dissolver solution after transfer to Mo system feed vessel, but prior to combination with transfer flush water.
Impure uranium collection tanks (e.g., UR-TK-100A/B) – Input from Mo recovery	Process solution after recovery of Mo isotopes from the uranium-bearing process solution.
Impure uranium collection tanks (e.g., UR-TK-100A/B) – Output to uranium recovery	Uranium-bearing process solution input to uranium recovery after [Proprietary Information].
Ion exchange feed tank 1 (UR-TK-200)	Process solution feed to the first-cycle uranium ion exchange columns after composition adjustment for ion exchange feed.
High-dose waste concentrate collection tank (WH-TK-240)	Accumulated high-dose liquid waste after concentration by the waste handling system concentrator.
Vessels without Water-Cooling Jackets	
Uranium decay tank (e.g., UR-TK-700A) – Input from separation	Uranium-bearing process solution after separation of uranium from other isotopes.
Uranium decay tank (e.g., UR-TK-700A) – Output to target fabrication	Uranium bearing process solution after separation of uranium from other isotopes and [Proprietary Information].

Table 5-1. Vessels Selected to Describe Radioisotope Production Facility Thermal Characteristics (2 pages)

Process location	Description
Solid Transfer Containers (No Cooling Jackets)	
High-dose waste disposal container	High-dose waste concentrate after addition of solidification agent.
Irradiated target in cask at receipt	[Proprietary Information] in annular target cladding on receipt in the transfer cask. Flux based on both internal and external surfaces. Temperature not yet evaluated.
Dissolver basket in air	[Proprietary Information] in dissolver basket for transfer between target disassembly and the target dissolver. Annular configuration between basket wall and lifting post. Flux based on external surface only.

I = iodine.
Kr = krypton.
Mo = molybdenum.
[Proprietary Information]
Xe = xenon.

Three groups of vessels are shown in Table 5-1. The first group contains vessels that include water-cooling jackets to control process solution temperatures. The solution temperature control facilitates solution transfer from one vessel to another, minimizes solution evaporation during storage, or maintains conditions for operation of subsequent unit operations. The second group contains vessels that are not projected to require cooling. The third group contains vessels used for transfer or storage of solid material in air and are not influenced by the cooling water system. Uncooled vessels are included in the evaluation to provide a more complete description of the RPF vessel thermal characteristics.

Heat flux is estimated based on a simple steady-state heat balance for an individual vessel containing a heat-generating material. Only radial heat flow is considered, neglecting heat flow in the axial direction. The simplified heat balance neglects heat losses associated with evaporation of the liquid phase that might be present in the vessel. This type of heat balance is equivalent to modeling each vessel as an unvented vessel, even though most vessels in the RPF will be either open containers or vented by the vessel vent system. The high-dose waste disposal container and irradiated target in the cask at receipt represent the only two process conditions listed in Table 5-1 that are actually closed containers in the RPF.

The irradiated target in the cask at receipt and the dissolver basket in the air process locations are included in Table 5-1, even though the temperatures are not influenced by the coolant system, to indicate vessels will exist with relatively high surface temperatures within the RPF during operation. Estimates of the irradiated target temperature and pressure on receipt at the RPF will be developed as part of the cask licensing activity. Detailed design of the dissolver basket has not been completed. However, a preliminary calculation indicates that a dissolver basket with a lifting post diameter of [Proprietary Information]. The dissolver basket is not currently anticipated to be a completely enclosed vessel with the potential to build pressure on heating. The estimated dissolver basket temperature indicates that the containers of irradiated target material have the potential to achieve relatively high equilibrium temperatures.

5.1.3 Heat Load and Thermal Flux

The volumetric heat load contained by process vessels varies throughout the RPF system as radioisotopes decay, selected radioisotopes are separated, and solution compositions are adjusted by the unit operations. Conservatism is included in the thermal flux estimate by assuming heat transfer is limited to a radial direction and neglecting heat loss from solution evaporation. Table 5-2 provides estimates of the volumetric heat load and radial thermal flux at the containment apparatus wall for selected vessels where cooling water is used to control the process solution temperature shown in Table 5-1.

Table 5-2. Heat Load and Thermal Flux for Selected Water-Cooled Vessels

Process Location	Thermal characteristics				Radial thermal flux W/cm² (BTU/hr-ft²)
	Uranium g U/L	Decay time after EOI	Heat load W/L (W/g U)	Vessel diameter cm (in.)	
Dissolver 1/2 (DS-D-100/200) – Start of dissolution cycle[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Dissolver 1/2 (DS-D-100/200) – End of dissolution cycle	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Mo system feed tank 1A/1B (MR-TK-100/140)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Impure uranium collection tanks (e.g., UR-TK-100A/B) – Input from Mo recovery	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Impure uranium collection tanks (e.g., UR-TK-100A/B) – Output to uranium recovery	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Ion exchange feed Tank 1 (UR-TK-200)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
High dose waste concentrate collection tank (WH-TK-240)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Source: NWMI-2015-CALC-022, *Maximum Vessel Heat Load, Temperature, and Pressure Estimates*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[a] Not evaluated by this calculation. The simplified evaluation methodology was not considered applicable.

[b] High-dose waste vessels collect waste from multiple weeks of process operation that is dominated by a [Proprietary Information] time period. Current plans are based on collecting high-dose waste as concentrate from [Proprietary Information]. Optimization may allow extension of the waste collection time period. Evaluation indicates the accumulated high-dose waste heat load approaches an asymptote of [Proprietary Information].

[c] Based on high-dose waste concentrate tank that is [Proprietary Information] of heat-generating isotopes.

EOI	= end of irradiation.	N/A	= not applicable.
Mo	= molybdenum.	TBD	= to be determined.

Table 5-3 provides similar estimates for selected vessels where cooling water is not provided to control the process solution temperature. The vessels listed in Table 5-2 and Table 5-3 were selected to indicate the range of conditions experienced as process solution is transferred through the RPF process equipment.

Table 5-3. Heat Load and Thermal Flux for Selected Vessels without Water Cooling

Process location	Thermal characteristics				Radial thermal flux W/cm² (BTU/hr-ft²)
	Uranium g U/L	Decay time after EOI	Heat load W/L (W/g U)	Vessel diameter cm (in.)	
Uranium decay tank (e.g., UR-TK-700A) – Input from separation	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Uranium decay tank (e.g., UR-TK-700A) – Output to target fabrication	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
High-dose waste disposal container	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Source: NWMI-2015-CALC-022, *Maximum Vessel Heat Load, Temperature, and Pressure Estimates*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[a] High-dose waste vessels collect waste from multiple weeks of process operation that is dominated by a [Proprietary Information] time period. Current plans are based on collecting high dose waste as concentrate from [Proprietary Information]. Optimization may allow extension of the waste collection time period. Evaluation indicates the accumulated high-dose waste heat load approaches an asymptote of [Proprietary Information].

[b] Based on high-dose waste disposal container that is [Proprietary Information] of heat-generating isotopes.

EOI	= end of irradiation.	N/A	= not applicable.

The heat load of process solutions in unit operations prior to the start of separating uranium from other radionuclides can be characterized by the solution uranium concentration. Planned operating conditions are used to support characterization of the thermal heat load. The process solution uranium concentration at the end of the dissolution cycle [Proprietary Information] is estimated based on the mass of uranium input by a dissolver basket, combined with the volume of acid charged to the dissolver. The resultant dissolver solution is transferred to the molybdenum (Mo) system feed tank, and thermal characteristics are evaluated neglecting mixing with dissolver vessel flush solutions. The uranium concentration in the impure uranium collection tanks [Proprietary Information], ion exchange feed tank [Proprietary Information], and uranium decay tanks [Proprietary Information] represent goal compositions for process solutions during operation.

Three radionuclide decay times, summarized below, are used to describe the RPF thermal characteristics based on currently planned decay limits within the process operation:

- A decay time of [Proprietary Information] (minimum decay time for targets in transfer casks received at the RPF outer door) is used to describe process solutions in the dissolver, Mo system feed tanks, and solution transferred into the impure uranium collection tanks, neglecting the time required for cask receipt, target disassembly, and target dissolution.
- A decay time of [Proprietary Information] (minimum decay time required to control in-growth of plutonium-239 [^{239}Pu] in recycled uranium after separations) is used to describe process solution at the end of the impure uranium collection tank storage period, solution in ion exchange feed tank 1, solution transferred into the uranium decay tanks, and waste entering the high-dose waste concentrate collection tank, neglecting time required to complete separation activities.
- A decay time of [Proprietary Information] (minimum decay time to reduce uranium-237 [^{237}U] in recycled uranium, allowing contact operation and maintenance in the target fabrication system, is used to describe the process solution at the end of the storage period in the uranium decay tanks.

Target heat generation (shown by Figure 5-1) is placed on a unit uranium mass basis to support the estimate of heat load in the selected vessels. The unit uranium mass input is modified to approximate the impact of radionuclide separations that occur in unit operations. The unit mass heat generation shown in Table 5-2 for a dissolver vessel at the start of dissolution cycle [Proprietary Information] represents material containing all radionuclides in an irradiated target at [Proprietary Information]. All isotopes of krypton (Kr), xenon (Xe), and iodine (I) are assumed to be evolved to the dissolver offgas system during dissolution, reducing the unit mass heat generation to [Proprietary Information]. The molybdenum isotopes are assumed to be separated from the dissolver solution by the Mo recovery and purification system, reducing the unit mass heat generation to [Proprietary Information] for solution entering the impure uranium collection tanks. The unit mass heat generation is reduced to [Proprietary Information] after solution in the impure uranium collection tanks is decayed to [Proprietary Information].

The thermal characteristics of recycled uranium process solution after separation in the uranium recovery and recycle system are shown in Table 5-3. Minimal separation of neptunium from uranium is projected to be obtained by the process, and the heat load is approximated by a unit mass heat generation dominated by the isotopes of neptunium and uranium [Proprietary Information] entering the uranium decay tanks. The unit mass heat generation of recycled uranium solution transferred to target fabrication is reduced to [Proprietary Information].

The thermal characteristics of waste handling vessels are not characterized by the process solution uranium concentration and are expected to collect solution containing radionuclides from multiple weeks of operation. The waste handling vessel thermal characteristics are described by the high-dose waste vessels that contain a majority of the waste radionuclides. Weekly input to the high-dose waste vessels is dominated by wastes from the uranium recovery and recycle separation system and described by radionuclides in a target decayed to [Proprietary Information] with isotopes of Kr, Xe, I, and Mo removed.

Accumulation of waste from a week of operations increases the waste vessel heat load that decreases by decay while awaiting waste input from a subsequent week of operation. Current plans are based on accumulating waste from [Proprietary Information]. However, system optimization may increase the goal high-dose waste accumulation time period. Evaluation of the heat load sequence indicates that the waste heat load approaches an asymptote of [Proprietary Information] after accumulating waste for 16 weeks. Therefore, the waste vessel heat loads were characterized by a total heat load of [Proprietary Information] contained in the vessel capacity using current estimates of the vessel dimensions.

5.1.4 Maximum Vessel Temperature and Pressure Estimates

An estimate of vessel temperature has been obtained using an overall heat transfer coefficient obtained from handbook values for a tank on legs containing water and an assumed cell air temperature of 35°C (95°F). Temperatures are estimated assuming no water-cooling system is active, and pressures are estimated assuming each vessel is unvented to approximate maximum values. Note that the preliminary estimate assumes that radial temperature variations within the generating heat material are not significant, which may be appropriate for vessels containing liquids, but could be questionable for containers of heat-generating solids.

The vapor pressure of water at the estimated vessel temperature is used to approximate the maximum pressure. The vapor pressure of water was considered a conservative estimate of the pressure developed within a process apparatus, as the total vapor pressure of a solution is decreased by the addition of nitric acid or uranyl nitrate to the liquid phase.

Table 5-4 provides estimates of the maximum temperature and pressure predicted for selected vessels where cooling water is used to control the process solution temperature shown in Table 5-1. Table 5-5 provides similar estimates for uncooled vessels and the high-dose waste disposal container.

The maximum temperature and pressure that could be observed in representative vessels without operation of the coolant system is shown in Table 5-4 as [Proprietary Information], absolute for the Mo system feed tanks. However, the evaluation approach was not considered applicable to the vessel configuration representing a dissolver at the start of the dissolver cycle. This configuration has the potential to produce higher temperatures and pressures than the vessels that could be evaluated using the current approach.

Table 5-4. Estimate of Maximum Temperature and Pressure in Water-Cooled Vessels (2 pages)

Process location	Radial thermal flux,[a] BTU/hr-ft^2	Maximum heat transfer surface temperature[b] °C (°F)	Estimated maximum unvented vessel pressure[c] lb/in^2, absolute
Dissolver 1/2 (DS-D-100/200) – Start of dissolution cycle[d]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Dissolver 1/2 (DS-D-100/200) – End of dissolution cycle	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Mo system feed tank 1A/1B (MR-TK-100/140)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Impure uranium collection tanks (e.g., UR-TK-100A/B) – Input from Mo recovery	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Impure uranium collection tanks (e.g., UR-TK-100A/B) – Output to U recovery	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Ion exchange feed tank 1 (UR-TK-200)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 5-4. Estimate of Maximum Temperature and Pressure in Water-Cooled Vessels (2 pages)

Process location	Radial thermal flux,[a] BTU/hr-ft^2	Maximum heat transfer surface temperature[b] °C (°F)	Estimated maximum unvented vessel pressure[c] lb/in^2, absolute
High-dose waste concentrate collection tank (WH-TK-240)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Source: NWMI-2015-CALC-022, *Maximum Vessel Heat Load, Temperature, and Pressure Estimates*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015

[a] Radial thermal flux from Table 5-2.

[b] Maximum heat transfer surface temperature assuming overall heat transfer coefficient at walls of 1.8 BTU/hr-ft^2-°F and ambient cell air temperature of 35°C (95°F).

[c] Unvented vessel pressure based on water vapor pressure at the maximum heat transfer surface temperature. Actual estimated water vapor pressure shown in parentheses for pressures less than 14.7 lb/in.^{2}, absolute.

[d] Not evaluated by this calculation. The simplified methodology was not considered applicable.

Mo = molybdenum.
TBD = to be determined.
U = uranium.

Table 5-5. Estimate of Maximum Temperature and Pressure in Vessels without Water Cooling

Process location	Radial thermal flux[a] BTU/hr-ft^2	Maximum heat transfer surface temperature[b] °C (°F)	Estimated maximum unvented vessel pressure[c] lb/in^2, absolute
Uranium decay tank (e.g., UR-TK-700A) – Input from separation	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Uranium decay tank (e.g., UR-TK-700A) – Output to target fabrication	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
High-dose waste disposal container	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Source: NWMI-2015-CALC-022, *Maximum Vessel Heat Load, Temperature, and Pressure Estimates*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[a] Radial thermal flux from Table 5-3.

[b] Maximum heat transfer surface temperature assuming overall heat transfer coefficient at walls of 1.8 BTU/hr-ft^2-°F and ambient cell air temperature of 35°C (95°F).

[c] Unvented vessel pressure based on water vapor pressure at the maximum heat transfer surface temperature. Actual estimated water vapor pressure shown in parentheses for pressures less than 14.7 lb/in.^{2}, absolute.

5.1.5 Potential Impact of Overcooling Process Solutions

Overcooling of uranium-bearing process solutions has the potential to [Proprietary Information]. Precipitation as a solid form effectively increases the uranium concentration of material contained by a process vessel and potentially results in a nuclear criticality. The [Proprietary Information]. Criticality evaluations are described in the following three documents for current equipment configurations of the irradiated target disassembly/dissolution, target fabrication, and uranium recycle separation systems, respectively.

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]

The impact of uranium precipitation upset conditions on nuclear criticality calculations was evaluated by interspersing selected tanks containing [Proprietary Information] among vessels containing uranium at a conservative nominal process concentration. The results indicate that precipitation upset conditions are predicted to remain below an upper subcritical limit of [Proprietary Information] for the configurations evaluated. Therefore, overcooling process solutions is not predicted to pose a nuclear criticality hazard for the current RPF equipment configuration.

5.1.6 Potential Impact on Gas Management System

Coolant system operation has the potential to impact the performance of the gas management system cooled sections. The primary gas management system cooled section controls the decay time provided for noble gases (isotopes of Kr and Xe) by holdup in the dissolver offgas system. The maximum hypothetical accident evaluated in Chapter 13.0, "Accident Analysis," Section 13.2.1 indicates the dose consequences from a bounding release of Kr and Xe isotopes alone is less than 0.15 roentgen equivalent in man (rem). The bounding release of noble gases is less than the performance requirement of 5 rem for an intermediate consequence event defined in Title 10, *Code of Federal Regulations*, Part 70.61, "Performance Requirements" (10 CFR 70.61). Therefore, the cooling water system is not considered to be an item relied on for safety (IROFS) based on the potential impact on the gas management systems.

5.1.7 Conclusion

The evaluation focused on vessels equipped with water cooling jackets. Typical process vessels of a pencil tank configuration are anticipated to be constructed from material similar to Schedule 40 stainless steel pipe. The pressure rating of seamless standard stainless steel pipe ranges from:

- 4-in., Schedule 40 – ~1,500 to 900 lb/in^2, gauge for 37.8 to 398.9°C (100 to 750°F), respectively
- 5-in., Schedule 40 – ~1,350 to 800 lb/in^2, gauge for 37.8 to 398.9°C (100 to 750°F), respectively
- 6-in., Schedule 40 – ~1,200 to 725 lb/in^2, gauge for 37.8 to 398.9°C (100 to 750°F), respectively

The maximum temperature and pressure in vessels without cooling and ventilation is estimated at [Proprietary Information] in Table 5-4 in the Mo system feed tanks, which are projected to be 5-in. diameter pencil tanks.

The high-dose concentrate collection tank is a standard tank design such that the stainless steel pipe comparison is not applicable. Maximum temperature and pressure for this vessel is estimated at [Proprietary Information]. Standard tank designs are capable of containing process solution at the high-dose concentrate collection tank conditions.

Based on the above comparisons, the maximum temperature and pressure within RPF vessels are anticipated to not result in failure of a process apparatus, and the cooling water system is not selected as an IROFS. The approach used to evaluate vessels was not considered applicable to a dissolver at the start of a dissolver cycle (non-uniform distribution of the heat-generating material). Future evaluation of this vessel configuration has the potential to impact the importance of the coolant system.

5.2 COOLANT SYSTEMS DESCRIPTION

The above analysis and description show that the cooling water system is designed such that the system will function in a manner, whether operational or not, consistent with occupational safety and protection of the public and environment. Therefore, the cooling function is not considered an IROFS. A description of the coolant systems for the RPF is provided in Chapter 9.0, "Auxiliary Systems," Section 9.7.

5.3 REFERENCES

10 CFR 70.61, "Performance Requirements," *Code of Federal Regulations*, Office of the Federal Register, as amended.

[Proprietary Information]

NWMI-2015-CALC-022, *Maximum Vessel Heat Load, Temperature, and Pressure Estimates*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

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Chapter 6.0 – Engineered Safety Features

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Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, OR 97330

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Chapter 6.0 – Engineered Safety Features

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0	6/29/2015	Initial Application	Not required
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2	8/5/2017	Modification based on ACRS comments	C. Haass
3	9/5/2017	Incorporate final comments from NRC Staff and ACRS; full document revision	C. Haass

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TABLES

TERMS

Acronyms and Abbreviations

^{99}Mo	molybdenum-99
^{235}U	uranium-235
ADUN	acid-deficient uranium nitrate
AEC	active engineered control
ANECF	average neutron energy causing fission
ANS	American Nuclear Society
ANSI	American National Standards Institute
CAAS	criticality accident alarm system
CFR	Code of Federal Regulations
CSE	criticality safety evaluation
DBE	design basis earthquake
HEGA	high-efficiency gas adsorber
HEPA	high-efficiency particulate air
HVAC	heating, ventilation, and air conditioning
IEU	intermediate-enriched uranium
IX	ion exchange
IROFS	item relied on for safety
Kr	krypton
LEU	low-enriched uranium
MCNP	Monte-Carlo N-Particle
Mo	molybdenum
NO_2	nitrogen dioxide
NO_x	nitrogen oxide
NRC	U.S. Nuclear Regulatory Commission
NWMI	Northwest Medical Isotopes, LLC
PEC	passive engineered control
PHA	preliminary hazards analysis
RPF	radioisotope production facility
SSC	structures, systems, and components
SPL	single parameter limit
UN	uranium nitride
[Proprietary Information]	[Proprietary Information]
USL	upper subcritical limits
Xe	xenon

Units

°C	degrees Celsius
°F	degrees Fahrenheit
atm	atmosphere
cm	centimeter
cm^3	cubic centimeter
ft	feet
ft^2	square feet
ft^3	cubic feet
g	gram
hr	hour
in.	inch
L	liter
m	meter
m^2	square meter
min	minute
mL	milliliter
mol	mole
rad	radiation absorbed dose
wt%	weight percent
yr	year

6.0 ENGINEERED SAFETY FEATURES

6.1 SUMMARY DESCRIPTION

Engineered safety features are active or passive features designed to mitigate the consequences of accidents and to keep radiological exposures to workers, the public, and environment within acceptable values. The engineered safety features associated with confinement of the process radionuclides and hazardous chemicals for the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF) are summarized in Table 6-1, including the accidents mitigated; structures, systems, and components (SSC) used to provide the engineered safety features; and references to subsequent sections providing a more detailed engineered safety feature description.

Confinement is a general engineered safety feature that is credited as being in place as part of the preliminary hazards analysis (PHA) described in Chapter 13.0, "Accident Analysis." Additional items relied on for safety (IROFS) associated with the confinement system were derived from the accident analyses in Chapter 13.0. The derived IROFS are also listed in Table 6-1, with reference to more detailed descriptions in Section 6.2.1.

The current design approach does not anticipate requiring containment or an emergency cooling system as engineered safety features, as discussed in Sections 6.2.2 and 6.2.3.

Nuclear criticality safety is discussed in Section 6.3. Criticality safety controls are described in Section 6.3.1. The currently defined criticality safety controls are derived from a combination of preliminary criticality safety evaluations (CSE) and accident analyses, which are described in Chapter 13.0. The criticality safety analyses produce a set of features needed to satisfy the double-contingency requirements for nuclear criticality control. These features are evaluated by major systems within the RPF and listed by major system in Section 6.3.1.1, Table 6-6 through Table 6-13. The accident analyses in Chapter 13.0 identify IROFS for the prevention of nuclear criticality, which are summarized in Table 6-2, with reference to more detailed descriptions in Section 6.3.1.2.

Table 6-1. Summary of Confinement Engineered Safety Features (2 pages)

Engineered safety feature	IROFS	Accident(s) mitigated	SSCs providing engineered safety features	Detailed description section
Confinement includes: • Hot cell liquid confinement boundary • Hot cell secondary confinement boundary • Hot cell shielding boundary	 RS-01 RS-03 RS-04	• Equipment malfunction and/or maintenance • Hazardous chemical spills	• Confinement enclosures including penetration seals • Zone I exhaust ventilation system, including ducting, filters, and exhaust stack • Zone I inlet ventilation system, including ducting, filters, and bubble-tight isolation dampers • Ventilation control system • Secondary iodine removal bed • Berms	6.2.1.1 through 6.2.1.6
Confinement IROFS Derived from Accident Analyses and Potential Technical Specifications				
Primary offgas relief system	RS-09	Dissolver offgas failure during dissolution operation	• Pressure relief device • Pressure relief tank	6.2.1.7.1
Active radiation monitoring and isolation of low-dose waste transfer	RS-10	Transfer of high-dose process liquid outside the hot cell shielding boundary	Radiation monitoring and isolation system for low-dose liquid transfers	6.2.1.7.2
Cask local ventilation during closure lid removal and docking preparations	RS-13	Target cladding leakage during shipment	Local capture ventilation system over closure lid during lid removal	6.2.1.7.3
Cask docking port enabler	RS-15	Cask not engaged in cask docking port prior to opening docking port door	Sensor system controlling cask docking port door operation	6.2.1.7.4
Process vessel emergency purge system	FS-03	SSC damage due to hydrogen deflagration or detonation	Backup bottled nitrogen gas supply	6.2.1.7.5
Irradiated target cask lifting fixture	FS-04	Dislodging the target cask shield plug while workers present during target unloading activities	• Cask lifting fixture design that prevents cask tipping • Cask lifting fixture design that prevents lift from toppling during a seismic event	6.2.1.7.6

Table 6-1. Summary of Confinement Engineered Safety Features (2 pages)

Engineered safety feature	IROFS	Accident(s) mitigated	SSCs providing engineered safety features	Detailed description section
Exhaust stack height	FS-05	• Equipment malfunction resulting in liquid spill or spray • Carbon bed fire	• Zone I exhaust stack	6.2.1.7.7
Double-wall piping	CS-09	Solution spill in facility area where spill containment berm is neither practical nor desirable for personnel chemical protection purposes	Double-wall piping for selected transfer lines	6.2.1.7.7
Backflow prevention devices Safe geometry day tanks	CS-18 CS-19	High worker exposure from backflow of high-dose solution	Backflow prevention devices located on process lines crossing the hot cell shielding boundary	6.2.1.7.9
Dissolver offgas iodine removal unit[a]	–	• Potential limiting control for operation • Primary iodine control system during normal operation	Dissolver offgas iodine removal units (DS-SB-600A/B/C)	6.2.1.8
Dissolver offgas primary adsorber[a]	–	• Potential limiting control for operation • Primary noble gas control system during normal operation	Dissolver offgas primary adsorber units (DS-SB-620A/B/C)	6.2.1.8.2
Dissolver offgas vacuum receiver or vacuum pump[a]	–	• Potential limiting control for operation • Motive force for dissolver offgas	• Dissolver offgas vacuum receiver tanks (DS-TK-700A/B) • Dissolver offgas vacuum pumps (DS-P-710A/B)	6.2.1.8.3

[a] Examples of candidate technical specification rather than engineered safety feature.

IROFS = item relied on for safety. SSC = structures, systems, and components.

Table 6-2. Summary of Criticality Engineered Safety Features (2 pages)

Engineered safety feature	IROFS	SSC features providing engineered safety features	Detailed description section
Interaction control spacing provided by passively designed fixtures and workstation placement	CS-04	Defines spacing between SSC components using geometry to prevent nuclear criticality	6.3.1.2.1
Pencil tank, vessel, or piping safe geometry confinement using the diameter of tanks, vessels, or piping	CS-06	Defines dimensions of SSCs using geometry to prevent nuclear criticality	6.3.1.2.2

Table 6-2. Summary of Criticality Engineered Safety Features (2 pages)

Engineered safety feature	IROFS	SSC features providing engineered safety features	Detailed description section
Pencil tank geometry control on fixed interaction spacing of individual tanks	CS-07	Defines spacing between different SSCs using geometry to prevent nuclear criticality	6.3.1.2.3
Floor and sump geometry control on slab depth, and sump diameter or depth for floor dikes	CS-08	Defines sump geometry and dimensions for SSCs using geometry to prevent nuclear criticality	6.3.1.2.4
Double-wall piping	CS-09	Defines transfer line leak confinement in locations where sumps under piping are neither feasible nor desirable	6.3.1.2.5
Closed safe-geometry heating or cooling loop with monitoring and alarm	CS-10	Closed-loop heat transfer fluid systems to prevent nuclear criticality or transfer of high-dose material across shielding boundary in the event of a leak into the heat transfer fluid	6.3.1.2.6
Simple overflow to normally empty safe-geometry tank with level alarm	CS-11	Overflow to prevent nuclear criticality from fissile solution entering non-geometrically favorable ventilation equipment	6.3.1.2.7
Condensing pot or seal pot in ventilation vent line	CS-12	Seal pots to prevent nuclear criticality from fissile solution entering non-geometrically favorable ventilation equipment	6.3.1.2.8
Simple overflow to normally empty safe geometry floor with level alarm in the hot cell containment boundary	CS-13	Overflow to prevent nuclear criticality from fissile solution entering non-geometrically favorable ventilation equipment	6.3.1.2.9
Active discharge monitoring and isolation	CS-14	Information to be provided in the Operating License Application	6.3.1.2.10
Independent active discharge monitoring and isolation	CS-15	Information will be provided in the Operating License Application	6.3.1.2.11
Backflow prevention device	CS-18	Backflow prevention to preclude fissile or high dose solution from crossing shielding boundary to non-geometrically favorable chemical supply tanks and prevent nuclear criticality	6.3.1.2.12
Safe geometry day tanks	CS-19	Alternate backflow prevention device	6.3.1.2.13
Evaporator or concentrator condensate monitoring	CS-20	Prevent nuclear criticality from high-volume transfer to non-geometrically favorable vessels in solutions with normally low fissile component concentrations	6.3.1.2.14
Processing component safe volume confinement	CS-26	Defines volume of SSCs to prevent nuclear criticality	6.3.1.2.15
Closed heating or cooling loop with monitoring and alarm	CS-27	Closed-loop, high-volume heat transfer fluid systems to prevent nuclear criticality or transfer of high-dose material across shielding boundary in the event of a leak into the heat transfer fluid with normally low fissile component concentrations	6.3.1.2.16

IROFS = item relied on for safety. SSC = structures, systems, and components.

6.2 DETAILED DESCRIPTIONS

The PHA used to identify accidents in Chapter 13.0, Section 13.1.3, assumed the following known and credited safety features, or IROFS, are in place for normal operations:

- Hot cell shielding boundary, credited for shielding workers and the public from direct exposure to radiation (a normal hazard of the operation)
- Hot cell confinement boundaries, credited for confining the fissile and high-dose solids, liquids, and gases, and controlling gaseous releases to the environment
- Administrative and passive design features on uranium batch, volume, geometry, and interaction controls on the activities, credited for maintaining normal operations involving the handling of fissile material subcritical (the PHA identified initiators for abnormal operations that require further evaluation for IROFS satisfying the double-contingency principle)

This section provides detailed descriptions of the engineered safety features identified by the accident analyses shown in Chapter 13.0.

6.2.1 Confinement

The PHA was based on a definition for confinement, as follows:

> **Confinement** – An enclosure of the facility (e.g., the hot cell area in the RPF) that is designed to limit the exchange of effluents between the enclosure and its external environment to controlled or defined pathways. A confinement should include the capability to maintain sufficient internal negative pressure to ensure inleakage (i.e., prevent uncontrolled leakage outside the confined area), but need not be capable of supporting positive internal pressure or significantly shielding the external environment from internal sources of direct radiation. Air movement in a confinement area could be integrated into the heating, ventilation, and air conditioning (HVAC) systems, including exhaust stacks or vents to the external environment, filters, blowers, and dampers (ANSI/ANS-15.1, *The Development of Technical Specifications for Research Reactors*).

Confinement describes the low-leakage boundary surrounding radioactive or hazardous chemical materials released during an accident to facility regions surrounding the physical process equipment containing process materials. The confinement systems localize releases of radioactive or hazardous materials to controlled areas and mitigate the consequences of accidents.

The principal design and safety objective of the confinement system is to protect on-site workers, the public, and environment. Personnel protection control features (e.g., adequate shielding and ventilation control) will minimize hazards normally associated with radioactive or chemical materials.

The second design objective is to minimize the reliance on administrative or complex active engineering controls and provide a confinement system that is as simple and fail-safe as reasonably possible.

This subsection describes the confinement systems for the RPF. The RPF confinement areas will consist of hot cell and glovebox enclosures housing process operations, tanks, and piping. Confinement will be provided by a combination of the enclosure boundaries (e.g., walls, floor, and ceiling), enclosure ventilation, and ventilation control system. The enclosure boundaries will restrict bulk quantities of process materials, potentially present in solid or liquid forms, to the confinement and limit in-leakage of gaseous components controlled by the ventilation system. The ventilation and ventilation control systems will restrict the gaseous components (including gas phase components and solid/liquid dispersions) to the confinement. Figure 6-1 provides a simplified schematic of the confinement ventilation system, which is described in more detail as the Zone I ventilation system in Chapter 9.0, "Auxiliary Systems."

[Proprietary Information]

Source: Figure 2-5 of NWMI-2015-SDD-013, *System Design Description for Ventilation*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, March 2015.

Figure 6-1. Simplified Zone I Ventilation Schematic

A typical glovebox enclosure is shown in Figure 6-1, and the inlet does not have an automatic closure on the isolation damper. During development of the final safety analysis and Operating License Application, each glovebox will be evaluated based on inventory of concern (e.g., fission product gases) and hazards to determine if the inlet isolation damper is required to be an IROFS confinement control. Until the analysis is complete, the design of gloveboxes will include a bubble-tight isolation damper, as required, for the hot cells.

The enclosure boundary of the hot cells will also function as biological shielding for operating personnel. Shielding functions of the hot cells are discussed in Chapter 4.0, "Radioisotope Production Facility Description."

Hazardous chemical confinement will be provided by berms located within the RPF to confine spilled material to the vicinity where a spill may originate.

6.2.1.1 Confinement System

Confinement system enclosure structures, ventilation ducting, isolation dampers, and Zone I exhaust filter trains are designated as IROFS. Table 6-3 provides a description of the system component safety functions. Figure 6-2, Figure 6-3, and Figure 6-4 indicate the general location of confinement structure boundaries to the facility ground level, mechanical level, and lower level layouts, respectively. The confinement system is an engineered safety feature that performs the functions identified by IROFS RS-01, RS-03, and RS-04 in Chapter 13.0.

Table 6-3. Confinement System Safety Functions

System, structure, component	Description	Classification
Zone I enclosure inlet isolation dampers and ducting leading from isolation dampers to enclosures	Provide confinement isolation at Zone I/Zone II enclosure boundaries	IROFS
Zone I enclosure exhaust ducting leading from enclosures to the exhaust stack, filters, and exhaust stack	Provides confinement to the confinement exhaust boundary	IROFS
Process vessel vent exhaust ducting leading from process vessels to Zone I exhaust plenum	Provides confinement to the confinement exhaust boundary	IROFS
Ventilation control system	Provides stack monitoring and interlocks to monitor discharge and signal changing on service filter trains during normal and abnormal operation	IROFS
Secondary iodine removal bed	Mitigates a release of the iodine inventory in the dissolver offgas treatment system	IROFS
Hot cells, tank vaults, and glovebox enclosure structures	Provide solid, liquid, gas confinement	IROFS

IROFS = item relied on for safety.

[Proprietary Information]

Source: Figure 2-1 of NWMI-2015-SDD-013, *System Design Description for Ventilation*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, March 2015.

Figure 6-2. Ground Level Confinement Boundary

[Proprietary Information]

Source: Figure 2-2 of NWMI-2015-SDD-013, *System Design Description for Ventilation*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, March 2015.

Figure 6-3. Mechanical Level Confinement Boundary

[Proprietary Information]

Source: Figure 2-3 of NWMI-2015-SDD-013, *System Design Description for Ventilation*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, March 2015.

Figure 6-4. Lower Level Confinement Boundary

During normal operation, passive confinement is provided by the contiguous boundary between the hazardous materials and the surrounding environment and is credited with confining the hazards generated as a result of accident scenarios. The boundary includes the enclosure structures and extension of the structures through the Zone I ventilation components. The intent of the passive boundary is to confine hazardous materials while also preventing disturbance of the hazardous material inventory by external energy sources. This passive confinement boundary extends from the isolation valve downstream of the intake high-efficiency particulate air (HEPA) filter to the exhaust stack.

An event that results in a release of process material to a confinement enclosure will be confined by the enclosure structural components. Each process line that connects with vessels located outside of a confinement boundary with vessels located inside a confinement boundary will be provided with backflow prevention devices to prevent releases of gaseous or liquid material. The backflow prevention devices on piping penetrating the confinement boundary are designed as passive devices and will be located as near as practical to the confinement boundary or take a position that provides greater safety on loss of actuating power.

The consequences of an uncontrolled release within a confinement enclosure, and the off-site consequences of releasing fission products through the ventilation system, will be mitigated by use of an active component in the form of bubble-tight isolation dampers as IROFS on the inlet ventilation ducting to each enclosure.

This engineered safety feature reduces the ducting to the confinement volume that needs to remain intact to achieve enclosure confinement. The dampers will close automatically (fail-closed) on loss of power, and the ventilation system will automatically be placed into the passive ventilation operating mode.

Overall performance assurance of the active confinement components will be achieved through factory testing and in-place testing. Duct and housing leak tests will be performed in accordance with minimum acceptance criteria, as specified in ASME AG-1, *Code on Nuclear Air and Gas Treatment*. Specific owner requirements with respect to acceptable leak rates will be based on the safety analysis.

Berms will employ a passive confinement methodology. Passive confinement will be achieved through a continuous boundary between the hazardous materials and the surrounding area. In the event of an accidental release, the hazardous liquid will be confined to limit the exposed surface area of the liquid.

6.2.1.2 Accidents Mitigated

The hot cell confinement system and shielding boundary are credited as being in place by the accident analysis in Chapter 13.0, Section 13.1.3.1. Accidents mitigated consist of equipment malfunction events that result in the release of radioactive material or hazardous chemicals to a confinement enclosure. The confinement system is also credited with mitigating the impact of a non-specific initiating event resulting in release of the iodine inventory in the dissolver offgas treatment system.

6.2.1.3 Functional Requirements

Functional requirements of the confinement structural components include:

- Capturing and containing liquid or solid releases to prevent the material from exiting the boundary and causing high dose to a worker or member of the public or producing significant environment contamination
- Preventing spills or sprays of radioactive solution that are acidic or caustic from causing adverse exposure to personnel through direct contact with skin, eyes, and mucus membranes where the combination of chemical exposure and radiological contamination would lead to serious injury and long-lasting effects

Functional requirements of the confinement ventilation components include:

- Providing negative air pressure in the hot cell (Zone I) relative to lower zones outside of the hot cell using exhaust fans equipped with HEPA filters and high-efficiency gas adsorbers (HEGA) to reduce the release of radionuclides (both particulate and gaseous) outside the primary confinement boundary to below Title 10, *Code of Federal Regulations*, Part 20, "Standards for Protection Against Radiation" (10 CFR 20) release limits during normal and abnormal operations.
- Mitigating high-dose radionuclide releases to maintain exposure to acceptable levels to workers and the public in a highly reliable and available manner. The hot cell secondary confinement boundary will perform this function using a system of passive and active engineered features to ensure a high level of reliability and availability.
- Removing iodine isotopes present in the process vessel vent under accident conditions to comply with 10 CFR 70.61, "Performance Requirements," for an intermediate consequence release.

Berms confining potential hazardous chemical spills are designed to hold the entire contents of the container in the event the container fails.

6.2.1.4 Confinement Components

The following components are associated with the confinement barriers of the hot cells, tank vaults, and gloveboxes. The specific materials, construction, installation, and operating requirements of these components are evaluated based on the safety analysis.

Confinement structural components include the following.

- Sealed flooring will provide multiple layers of protection from release to the environment.
- Diked areas will contain specific releases. Sumps of appropriate design will be provided with remote operated pumps to mitigate liquid spills by capturing the liquid in appropriate safe-geometry tanks.
- In the molybdenum-99 (^{99}Mo) purification clean room, smaller confinement catch basins will be provided under points of credible spill potential in addition to the sealed floor.
- Entryway doors into a designated liquid confinement area will be sealed against credible liquid leaks to outside the boundary.
- Piping penetrations and air ducts will be located to minimize the potential for liquid leaks across the confinement boundary.

Ventilation system components that are credited include the following.

- Zone I inlet HEPA filters will provide an efficiency of greater than 99.9 percent for removal of radiological particulates from the air that may reverse flow from Zone I to Zone II.
- Zone I ducting will ensure that negative air pressure can be maintained by conveying exhaust air to the stack.
- Bubble-tight dampers will be provided to comply with the requirements of ASME AG-1, Section DA-5141. Ventilation ductwork and ductwork support materials will meet the requirements of ASME AG-1. Supports will be designed and fabricated in accordance with the requirements of ASME AG-1.
- Zone I exhaust train HEPA filters will provide an efficiency of greater than 99.95 percent for removal of radiological particulates from the air that flows to the stack.
- Zone I exhaust train HEGA filters will provide an efficiency of greater than 90% for removal of iodine.
- The Zone I exhaust stack will provide dispersion of radionuclides in normal and abnormal releases at a discharge point of 23 meters (m) (75 feet [ft]) above the building ground level.
- Stack monitoring and interlocks will monitor discharge and signal changing of service filter trains during normal and abnormal operations.

Secondary process offgas treatment iodine removal beds (VV-SB-520) will mitigate an iodine release.

6.2.1.5 Test Requirements

Engineered safety features will be tested to ensure that components maintain operability and can provide adequate confidence that the safety system performs satisfactorily during postulated events. The confinement engineered safety features that initiate the system interlocks are designed to permit testing during plant operation.

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.6 Design Basis

Codes and standards are discussed in Chapter 3.0, "Design of Structures, Systems, and Components." The design bases for Zone I and Zone II ventilation systems are described in Chapter 9.0. The design basis of confinement enclosure structures is described in Chapter 4.0. Chapter 7.0, "Instrumentation and Control Systems," identifies the engineered safety feature-related design basis of the ventilation control system.

The following information was developed for the Construction Permit Application to describe the process offgas secondary iodine removal bed:

- Sorbent bed of [Proprietary Information]
- Iodine removal efficiency greater than [Proprietary Information]
- Nominal superficial gas flow velocity of [Proprietary Information]
- Nominal sorbent bed operating temperature of less than [Proprietary Information]
- Nominal sorbent bed depth of [Proprietary Information]
- Nominal gas relative humidity less than [Proprietary Information]

Additional detailed information on the process offgas iodine retention bed design basis will be developed for the Operating License Application.

Potential variables, conditions, or other items that will be probable subjects of a technical specification associated with the RPF confinement systems and components are discussed in Chapter 14.0, "Technical Specifications."

6.2.1.7 Derived Confinement Items Relied on for Safety

The following subsections describe additional engineered safety features that are derived from the accident analyses described in Chapter 13.0 and are projected technical specifications defining limited conditions for operation.

6.2.1.7.1 IROFS RS-09, Primary Offgas Relief System

IROFS RS-09, "Primary Offgas Relief System," is identified by the accident analysis in Chapter 13.0. As an active engineered control (AEC), the primary offgas relief system will be a component included in the offgas train for the two irradiated target dissolvers. The dissolver offgas system is intended to operate at a pressure that is less than the confinement enclosures to maintain gaseous components generated during dissolution within the vessels and route the gaseous components through the offgas treatment unit operations. The primary offgas relief system, or pressure relief tank, will be used to confine gases to the dissolver and a portion of the dissolver offgas equipment, if the offgas motive force (vacuum pumps) ceases operation during dissolution of a dissolver batch.

Figure 6-5 is a diagram of the dissolver offgas system process, which shows the pressure relief tank position in the offgas treatment equipment train. Figure 6-6 shows the location of the pressure relief tank within the RPF hot cell (identified as "pressure relief").

[Proprietary Information]

Figure 6-5. Dissolver Offgas System Engineered Safety Features

[Proprietary Information]

Figure 6-6. Dissolver Offgas Hot Cell Equipment Location

The pressure relief tank will be evacuated to a specified, subatmospheric pressure prior to initiating dissolution of a target batch and selected valves (indicated as 2, 3, and 4 on Figure 6-5) closed. Valve 1 will be open during normal dissolver operation. An upset during the dissolver operation (e.g., loss of vacuum pump operation) will result in closing Valve 1 and opening Valve 2 to contain dissolver offgas within the dissolver and offgas vessels. Due to the short duration of dissolver operation, dissolution is assumed to go to completion independent of an offgas system upset. The pressure relief tank will contain the offgas as dissolution is completed.

Valves 3, 4, and 5 are provided for upset recovery. After correction of the upset cause, gases collected in the pressure relief tank will be routed to the downstream treatment unit operations via Valve 3 or returned to a caustic scrubber via Valve 4. Liquid condensed in the pressure relief tank as a result of activation will be routed to the dissolver offgas liquid waste collection tank via Valve 5 for disposal.

Accident Mitigated

- Irradiated target dissolver offgas system malfunctions, including loss of power during target dissolution operations

System Components

- Pressure relief valves
- Pressure relief tank (DS-TK-500)

Functional Requirements

- As an AEC, use relief device to relieve pressure from the system to an on-service receiver tank maintained at vacuum with the capacity to hold the gases generated by the dissolution of one batch of targets in the target dissolver
- Prevent a failure of the primary confinement system by capturing gaseous effluents in a vacuum receiver tank

Design Basis

The following information was developed for the Construction Permit Application describing the pressure relief tank.

- Pressure-relief tank sizing is based on a maximum dissolver batch of [Proprietary Information] that has just started dissolution when the pressure relief event is initiated.
- The non-condensable gas volume to the pressure relief tank is equivalent to all nitrogen oxide (NO_x) generated by dissolution, plus the sweep gas flow for flammable hydrogen gas mitigation.
- Worst-case reaction stoichiometry of [Proprietary Information] dissolved is used.
- No credit is taken for reaction of NO_2 with water to produce nitric acid.
- Dissolver gas additions, other than the minimum sweep gas flow for hydrogen mitigation, are terminated by the pressure relief event.
- Gas contained by the pressure relief tank and associated dissolver offgas piping is saturated with water vapor.
- The pressure change from [Proprietary Information], absolute activates the pressure relief tank.

Additional detailed information on the pressure relief tank design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.2 IROFS RS-10, Active Radiation Monitoring and Isolation of Low-Dose Waste Transfer

IROFS RS-10, "Active Radiation Monitoring and Isolation of Low-Dose Waste Transfer," is identified by the accident analyses described in Chapter 13.0. As an AEC, the recirculating stream and the discharge stream of the low-dose waste tank will be simultaneously monitored in a background shielded trunk outside of the hot cell shielded cavity. The continuous gamma instrument will monitor the transfer lines to provide an open permissive signal to dedicated isolation valves.

Accident Mitigated

- Transfer of high-dose process liquid solutions outside the hot cell shielding boundary

System Components

Additional detailed information of the radiation monitor and isolation of low-dose waste transfers will be developed for the Operating License Application.

Functional Requirement

- Maintain worker and public exposure rates within approved limits

Design Basis

Additional detailed information of the radiation monitor and isolation of low-dose waste transfers will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.3 IROFS RS-13, Cask Local Ventilation During Closure Lid Removal and Docking Preparations

IROFS RS-13, "Cask Local Ventilation During Closure Lid Removal and Docking Preparations," is identified by the accident analyses described in Chapter 13.0. As an AEC, a local capture ventilation system will be used over the irradiated target cask closure lid to remove any escaped gases from the worker breathing zone during removal of the closure lid, removal of the shielding block bolts, and installation of the lifting lugs.

Accident Mitigated

- Irradiated target cladding fails during transportation, releasing gaseous radionuclides within the cask containment boundary

System Components

- Use a dedicated evacuation hood over the top of the cask during containment closure lid removal
- Remove gases to the Zone I secondary confinement system for processing

Functional Requirement

- Prevent exposure to workers by evacuating any high-dose gaseous radionuclides from the worker breathing zone and preventing immersion of the worker in a high-dose environment

Design Basis

The following information was developed for the Construction Permit Application describing the cask local ventilation system:

- Use the local capture ventilation system to evacuate and backfill the cask with fresh air (from a protected pressurized source such as a compressed bottle) until the atmospheres are within approved safety limits

Additional detailed information on the cask local ventilation system design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.4 IROFS RS-15, Cask Docking Port Enabling Sensor

IROFS RS-15, "Cask Docking Port Enabling Sensor," is identified by the accident analyses described in Chapter 13.0. As an AEC, the cask docking port will be equipped with sensors that detect when a cask is mated with the cask docking port door.

Accident Mitigated

- Cask lift failure occurs after shield plug removal (but before target basket removal) with targets inside the cask

System Components

- Enabling contact signal and positive closure signal when the sensor does not sense a cask mated to the cask docking port, causing the cask docking port door to close

Functional Requirement

- Prevent the cask docking port door from being opened and allowing a streaming radiation path to areas accessible by workers

Design Basis

Detailed information on the system design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.5 IROFS FS-03, Process Vessel Emergency Purge System

IROFS FS-03, "Process Vessel Emergency Purge System," is identified by the accident analyses described in Chapter 13.0. Hydrogen gas will be evolved from process solutions through radiolytic decomposition of water in the high radiation fields. An air purge to the vapor space of selected tanks will be provided by the facility air compressors to control the hydrogen concentration from radiolysis in vessel vapor space to below the flammability limit for hydrogen. As an AEC, an emergency backup set of bottled nitrogen gas will be provided for all tanks that have the potential to evolve significant volumes of hydrogen gas through the radiolytic decomposition of water (in both a short- and long-term storage condition).

Accident Mitigated

- Hydrogen deflagration or detonation in a process vessel

System Components

Information will be provided in the Operating License Application.

Functional Requirement

- Prevent development of an explosive hydrogen-air mixture in the tank vapor spaces to prevent the deflagration or detonation hazard

Design Basis

The following information was developed for the Construction Permit Application describing the process vessel emergency purge system:

- Monitor the purge pressure going into the individual tanks and open an isolation valve on low pressure (setpoint to be determined) to restore the continuous sweep of the system using nitrogen
- Provide sweep gas sufficient for the facility to allow repair of a compressed gas system outage
- Activate by sensing low pressure on the normal sweep air system, introducing a continuous purge of nitrogen from a reliable emergency backup station of bottled nitrogen into each affected vessel near the bottom (e.g., through a liquid level detection leg) of the vessel
- Dilute hydrogen as it rises to the top of the vessel and is vented to the respective vent system

Additional detailed information on the process vessel emergency purge system design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.6 IROFS FS-04, Irradiated Target Cask Lifting Fixture

IROFS FS-04, "Irradiated Target Cask Lifting Fixture," is identified by the accident analyses described in Chapter 13.0. As a passive engineered control (PEC), the irradiated target cask lifting fixture will be designed to prevent the cask from tipping within the fixture and the fixture itself from toppling during a seismic event.

Accident Mitigated

- Dislodged irradiated target shipping cask shield plug in the presence of workers during target unloading activities

System Components

Detailed information on the system components will be developed for the Operating License Application.

Functional Requirements

Detailed information on the system functional requirements will be developed for the Operating License Application.

Design Basis

Detailed information on the system design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.7 IROFS FS-05, Exhaust Stack Height

IROFS FS-05, "Exhaust Stack Height," is identified by the accident analyses described in Chapter 13.0.

Accidents Mitigated

- Process solution spills and sprays
- Carbon bed fire

System Component

- Zone I exhaust stack

Functional Requirement

- Provide an offgas release height for ventilation gases consistent with the stack height used as input to mitigated dose consequence evaluations.

Design Basis

The Zone I exhaust stack height is 23 m (75 ft).

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.8 IROFS CS-09, Double Wall Piping

[Proprietary Information]

Figure 6-7. Proposed Location of Double-Wall Piping (Example)

IROFS CS-09, "Double Wall Piping," is identified by the accident analyses in Chapter 13.0. This IROFS has both a confinement and nuclear criticality prevention function. As a PEC, the piping system conveying fissile solution between credited confinement locations will be provided with a double-wall barrier to contain any spills that may occur from the primary confinement piping. This IROFS will be used at those locations that pass through the facility, where creating a spill containment berm under the piping is neither practical nor desirable for personnel chemical protection purposes. Figure 6-7 provides an example location where IROFS CS-09 will be applied (e.g., the transfer line between the recycle uranium decay tanks and the [Proprietary Information]).

Accident Mitigated

- Leak in piping that passes between confinement enclosures

System Components

The following double-wall piping segments are identified at this time:

- Transfer piping containing fissile solutions traversing between hot cell walls
- Transfer piping connecting the uranium product transfer send tank (UR-TK-720) and uranyl nitrate storage tank (TF-TK-200)
- Other locations to be identified in final design

Functional Requirements

- Double-wall piping prevents personnel injury from exposure to acidic or caustic licensed material solutions conveyed in the piping that runs outside a confinement enclosure
- Double-wall piping routes pipe leaks to a critically-safe leak collection tank or berm as a nuclear criticality control feature

Design Basis

The double-wall piping arrangement is designed to gravity drain to a safe-geometry set of tanks or to a safe geometry berm.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.7.9 IROFS CS-18, Backflow Prevention Devices, and IROFS CS-19, Safe-Geometry Day Tanks

IROFS CS-18, "Backflow Prevention Devices," and IROFS CS-19, "Safe-Geometry Day Tanks," are identified by the accident analyses in Chapter 13.0. As a PEC or AEC, chemical and gas addition ports to fissile process solution systems will enter a confinement enclosure through a backflow prevention device. Backflow prevention devices and safe-geometry day tanks will provide alternatives for preventing process addition backflow across confinement boundaries. The device may be an anti-siphon break, an overloop seal, or other active engineering feature that addresses the conditions of backflow and prevents fissile solution from entering non-safe geometry systems or high-dose solutions from exiting the hot cell shielding boundary in an uncontrolled manner. Therefore, these IROFSs have both a confinement and a nuclear criticality prevention function.

Accident Mitigated

- Backflow of process material located inside a confinement boundary to vessel located outside confinement via connected piping due to process upset.

System Components

System component information will be provided in the Operating License Application.

Functional Requirements

- Prevent fissile solutions and/or high dose solutions from backflowing from the tank into systems outside the confinement boundaries that may lead to accidental nuclear criticality or high exposures to workers
- Provide each hazardous location with an engineered backflow prevention device that provides high reliability and availability for that location
- Locate the backflow prevention device features for high-dose product solutions inside the confinement boundaries
- Support the backflow prevention devices with safe-geometry day tanks located inside the confinement boundary
- Direct spills from the backflow prevention device to a safe-geometry confinement berm

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.8 Dissolver Offgas Systems

6.2.1.8.1 Dissolver Offgas Iodine Removal Unit

A significant fraction of iodine entering the RPF in targets is projected to be released to dissolver offgas during target dissolution. The dissolver offgas iodine removal units will be included in the RPF as the primary SSCs for controlling the release of iodine isotopes to the environment or facility areas occupied by workers. Components of the dissolver offgas system, beginning with the iodine removal unit, will also be used to treat vent gas from the target disassembly system. Target disassembly vent gas is treated by dissolver offgas components for the Construction Application Permit configuration as a measure to mitigate the unverified potential for a release of fission gas radionuclides during target transportation.

Figure 6-5 (Section 6.2.1.7.1) shows the iodine removal unit position in the offgas treatment equipment train. The dissolver offgas iodine removal unit location in the facility is shown in Figure 6-6 (identified as "primary fission gas treatment").

Accidents Mitigated

- Projected limiting control for operation
- Required for normal operation and not for accident mitigation

System Components

- Iodine removal unit A (DS-SB-600A)
- Iodine removal unit B (DS-SB-600B)
- Iodine removal unit C (DS-SB-600C)

Functional Requirement

- Remove iodine isotopes from the dissolver offgas during normal operations such that the dose to workers complies with 10 CFR 20.1201, "Occupational Dose Limits for Adults," and the dose to the public complies with 10 CFR 20.1301, "Dose Limits for Individual Members of the Public."

Design Basis

The following information was developed for the Construction Permit Application describing each individual iodine removal unit:

- Sorbent bed of [Proprietary Information]
- Iodine removal efficiency greater than [Proprietary Information]
- Nominal superficial gas flow velocity of [Proprietary Information]
- Nominal sorbent bed operating temperature of [Proprietary Information]
- Nominal sorbent bed depth of [Proprietary Information], providing iodine removal capacity of greater than 1 year (yr).

Additional detailed information on the iodine removal unit design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.8.2 Dissolver Offgas Primary Adsorber

Noble gases (krypton [Kr] and xenon [Xe]) entering the RPF in targets are projected to be released to dissolver offgas during target dissolution. The dissolver offgas primary adsorber units will be included in the RPF as the primary SSCs for controlling the release of noble gas isotopes to the environment or facility areas occupied by workers. Components of the dissolver offgas system will also be used to treat vent gas from the target disassembly system. Target disassembly vent gas is treated by dissolver offgas components for the Construction Application Permit configuration as a measure to mitigate the unverified potential for a release of fission gas radionuclides during target transportation.

Figure 6-5 (Section 6.2.1.7.1) shows the primary adsorber position in the offgas treatment equipment train. The dissolver offgas primary adsorber location in the facility is shown in Figure 6-6 (identified as "primary fission gas treatment").

Accidents Mitigated

- Projected limiting control for operation
- Required for normal operation and not for accident mitigation

System Components

- Primary adsorber A (DS-SB-620A)
- Primary adsorber B (DS-SB-620B)
- Primary adsorber C (DS-SB-620C)

Functional Requirement

- Delay the release of noble gas isotopes via the dissolver offgas during normal operations such that the dose to workers complies with 10 CFR 20.1201 and the dose to the public complies with 10 CFR 20.1301.

Design Basis

The following information was developed for the Construction Permit Application describing each individual primary adsorber unit:

- Sorbent bed of [Proprietary Information]
- Nominal sorbent bed operating temperature of [Proprietary Information]
- Nominal gas relative humidity less than [Proprietary Information]
- Average gas flow rate of [Proprietary Information]
- Nominal superficial gas flow velocity of [Proprietary Information]
- Delay time for release of Xe isotopes of 10 days and Kr isotopes of 8 hours (hr) (additional delay time is provided by the secondary adsorber)

Additional detailed information on the primary adsorber unit design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.8.3 Dissolver Offgas Vacuum Receiver/Vacuum Pump

The dissolver offgas vacuum pump will provide the motive force for transferring offgas, generated in the dissolvers and disassembly equipment during operation, through the dissolver offgas equipment train while maintaining dissolver vessels at a pressure less than the equipment enclosure pressure. Vacuum receiver tanks will be provided as part of the motive force system to allow the vacuum pumps to cycle on and off less frequently and accommodate the wide variations in gas flow rate associated with a target dissolution cycle.

Figure 6-5 (Section 6.2.1.7.1) shows the vacuum receiver tank and vacuum pump positions in the offgas treatment equipment train. The vacuum receiver tank and vacuum pump location in the facility is shown in Figure 6-3 in the vicinity of equipment identified for the process offgas secondary iodine removal bed.

Accidents Mitigated

- Projected limiting control for operation
- Required for normal operation and not for accident mitigation

System Components

- Vacuum receiver tank A (DS-TK-700A)
- Vacuum receiver tank B (DS-TK-700B)
- Vacuum pump A (DS-P-710A)
- Vacuum pump B (DS-P-710B)

Functional Requirements

- Maintain the dissolver vessel gas space at a pressure less than the dissolver vessel enclosure pressure throughout the target dissolution cycle
- Accommodate pressure drops associated with dissolver offgas unit operations over the range of gas flow rates generated in both dissolvers and the target disassembly equipment vent throughout a target dissolution cycle

Design Basis

The following information was developed for the Construction Permit Application describing the vacuum receiver tanks and vacuum pump:

- Minimum inlet setpoint pressure of [Proprietary Information]
- Maximum inlet setpoint pressure of [Proprietary Information]
- Outlet pressure of [Proprietary Information]
- Maximum sustained gas flow into [Proprietary Information]
- Receiver tank provides a [Proprietary Information] with the vacuum pump off and inlet at the maximum sustained gas flow

Additional detailed information on the vacuum receiver tank and vacuum pump design basis will be developed for the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.2.1.9 Exhaust System

The ventilation exhaust system is described in Chapter 9.0, Section 9.1.2. Additional detailed information will be developed for the Operating License Application, including:

- Describing changes in operating conditions in response to potential accidents and the mitigation of accident radiological consequences
- Demonstrating how dispersion or distribution of contaminated air to the environment or occupied spaces is controlled
- Identifying the design bases for location and operating characteristics of the exhaust stacks

6.2.1.10 Effluent Monitoring System

Each RPF exhaust stack will include an effluent monitoring system. The monitoring system sample lines are designed to comply with ANSI N13.1, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*. Additional detailed information on the effluent monitoring systems will be developed for the Operating License Application.

6.2.1.11 Radioactive Release Monitoring

The effluent monitoring system will provide flow rate, temperature, and composition inputs for dispersion modeling of releases from the exhaust stacks. These inputs will provide the capability for calculating potential exposures as a basis for actions to ensure that the public is protected during both normal operation and accident conditions. Additional detailed information on radioactive release monitoring will be developed for the Operating License Application.

6.2.1.12 Confinement System Mitigation Effects

Detailed information describing the confinement system mitigation effects will be developed for the Operating License Application. This information will compare the radiological exposures to the facility staff and the public with and without the confinement system engineered safety feature. The comparison will be based on analyses showing airflow rates, reduction in quantities of airborne radioactive material by filter systems, system isolation, and other parameters that demonstrate the effectiveness of the system.

6.2.2 Containment

Containment for the RPF is defined based on NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors - Format and Content*, Part 1 interim staff guidance.

> *Containments are required as an engineered safety feature on the basis of the radioisotope production facility design, operating characteristics, accidents scenarios, and location. A potential scenario for such a release could be a significant loss of integrity of the radioisotope extraction system or the irradiated fuel processing system. The containment is designed to control the release to the environment of airborne radioactive material that is released in the facility even if the accident is accompanied by a pressure surge or steam release.*

The NUREG-1537 Part 1 interim staff guidance has been applied to the RPF target processing systems. The current accident analysis described in Chapter 13.0 has not identified a need for a containment system as an engineered safety feature.

6.2.3 Emergency Cooling System

An emergency cooling system for the RPF is defined by NUREG-1537 Part 1 interim staff guidance.

> *In the event of the loss of any required primary or normal cooling system, an emergency cooling system may be required to remove decay heat from the fuel to prevent the failure or degradation of the gas management system, the isotope extraction system, or the irradiated fuel processing system.*

An evaluation of RPF cooling requirements provided in Chapter 5.0, "Coolant Systems," indicates that an emergency cooling system will not be required to avoid rupture of the primary process vessels. In addition, the current accident analysis described in Chapter 13.0 has not identified a need for an emergency cooling system as an engineered safety feature.

6.3 NUCLEAR CRITICALITY SAFETY IN THE RADIOISOTOPE PRODUCTION FACILITY

The RPF design will provide adequate protection against criticality hazards related to the storage, handling, and processing of SNM outside a reactor. This is accomplished by:

- Including equipment, facilities, and procedures to protect health and minimize danger to life or property
- Ensuring that the design provides for criticality control, including adherence to the double-contingency principle
- Incorporating a criticality monitoring and alarm system into the facility design

For the Construction Permit Application, the design has assumed that a nuclear criticality accident is a high-consequence event independent of whether shielding or other isolation is available between the source of radiation and facility personnel. While not considered likely at this time, justification for considering criticality events as other than a high-consequence event will be provided in the Operating License Application, if this assumption is changed for specific locations by future design activities.

The nuclear criticality safety program defines the programmatic elements that work in concert to maintain criticality controls throughout the operating life of the RPF. The nuclear criticality safety program and facility design are developed based on the following American National Standards Institute/American Nuclear Society (ANSI/ANS) standards, with exceptions described in U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 3.71, *Nuclear Criticality Safety Standards for Fuels and Material Facilities*.

- ANSI/ANS-8.1, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*
- ANSI/ANS-8.3, *Criticality Accident Alarm System*
- ANSI/ANS-8.7, *Nuclear Criticality Safety in the Storage of Fissile Materials*
- ANSI/ANS-8.10, *Criteria for Nuclear Criticality Safety Controls in Operations With Shielding and Confinement*
- ANSI/ANS-8.19, *Administrative Practices for Nuclear Criticality Safety*
- ANSI/ANS-8.20, *Nuclear Criticality Safety Training*
- ANSI/ANS-8.22, *Nuclear Criticality Safety Based on Limiting and Controlling Moderators*
- ANSI/ANS-8.23, *Nuclear Criticality Accident Emergency Planning and Response*
- ANSI/ANS-8.24, *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations*
- ANSI/ANS-8.26, *Criticality Safety Engineer Training and Qualification Program*

For the Construction Permit Application, no deviations from standards or requirements have been identified that would require development of equivalent requirements for the RPF.

NWMI commits to the following standards and guides during design and construction:

- ANSI/ANS-8.1 – Nuclear criticality safety practices, including administrative practices, technical practices, and validation of a calculational method

- ANSI/ANS-8.3 – Criticality accident alarm system (CAAS) placement analysis and procedure development; the standard is used as modified by NRC Regulatory Guide 3.71
- ANSI/ANS-8.19 – NWMI nuclear criticality safety program development as it applies to organization, administration, roles, and responsibilities
- ANSI/ANS-8.20 – Nuclear criticality safety staff and contractor qualification and training procedure development
- ANSI/ANS-8.24 – Validation of a calculational method
- NUREG-1520, *Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility* – Guidance for meeting 10 CFR 70.61
- NUREG/CR-4604, *Statistical Methods for Nuclear Material Management* – Guidance for normality testing of the data from critical experiment calculations
- NUREG/CR-6698, *Guide for Validation of Nuclear Criticality Safety Calculational Methodology* – Guidance for validation of a calculational method

The nuclear criticality safety program includes the following elements:

- Responsibilities
- Criticality safety evaluations
- Criticality safety control implementation
- Nuclear criticality safety training
- Criticality safety assessments
- Criticality prevention specifications
- Operating procedures and maintenance work
- Criticality safety postings
- Fissile material container labeling, storage, and transport
- Criticality safety nonconformance response
- Criticality safety configuration control
- Criticality detector and alarm system
- Criticality safety guidelines for firefighting
- Emergency preparedness plan and procedures

Components of the nuclear criticality safety program specifically implemented during the design and construction phases of the RPF will include:

- Nuclear criticality safety program policy
- Nuclear criticality safety program procedure
- Nuclear criticality safety evaluation procedure
- Nuclear criticality safety technical/peer review procedure
- Nuclear criticality safety engineer training and qualification procedure
- Nuclear criticality safety validation procedure

Preliminary descriptions of the nuclear criticality safety program elements developed for the Construction Permit Application are summarized below. Modifications to the nuclear criticality safety program elements are anticipated as the design matures and will be included in the Operating License Application.

Responsibilities

This element describes the responsibilities of management and staff in implementing the nuclear criticality safety program.

- General facility management will ensure that the nuclear safety function is as independent as practical from the facility operating functions.
- A Nuclear Criticality Safety Manager will be assigned and responsible for overall coordination, maintenance, and management of the nuclear criticality safety program.
- A Criticality Safety Representative will be assigned who is qualified to interpret criticality safety requirements and serve as a liaison between custodians of fissionable material and other operations, advising operating personnel and supervisors on questions concerning conformance to criticality safety requirements.
- Qualified Criticality Safety Engineers will responsible for performing criticality analyses and evaluations of systems, maintaining current verified and validated criticality computer codes, advising staff on technical aspects of criticality controls, and supporting/participating in inspections and management assessments.
- Operations management will be responsible for establishing the responsibility for criticality safety throughout the operations organization, communicating criticality safety responsibilities for each individual involved in operations, ensuring that controls identified by CSEs are implemented, ensuring each worker has necessary training and qualifications, and ensuring that procedures that include controls significant to criticality safety are prepared before operations commence.
- Supervisors and workers will be responsible for completing training before performing fissile material operations, understanding and ensuring compliance with all applicable criticality safety controls, and reporting any proposed change in fissile material operations to the Criticality Safety Representative for evaluation and approval before the operation commences.

Criticality Safety Evaluations

This element describes the process for preparing CSEs that demonstrate fissile material operation will be subcritical under both normal and credible abnormal conditions.

- CSEs will determine, identify, and document the controlled parameters and associated limits on which criticality safety depends.
- CSEs will be required to evaluate normal operations, and contingent and upset conditions.
- Preliminary CSEs prepared for the Construction Permit Application, including verification and validation of supporting computer codes, are described in Section 6.3.1.1 and provide examples of the CSEs.
- Design changes impacting criticality will be reviewed by the Criticality Safety Representative.
- CSEs will be independently reviewed to confirm the technical adequacy of the evaluation prior to commencing new or modified fissile material operations.

Nuclear criticality safety limits established for controlled parameters in the NWMI facility processes will ensure that all nuclear processes are subcritical, including an adequate margin of subcriticality for safety in accordance with the Interim Staff Guidance augmenting NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria*, Part 2, Section 6.b.3 (NRC, 2012). Monte-Carlo N Particle (MCNP) calculation results used to set limits on parameters are compared to the upper subcritical limit (USL) established in the NWMI MCNP code validation report ([Proprietary Information]), after applying a 2σ calculation uncertainty.

The USL includes the method bias and uncertainty established in [Proprietary Information] and a 0.05 Δk margin of subcriticality. In addition, the area of applicability, also established in [Proprietary Information], is checked to ensure that the NWMI RPF process model physics and materials are within the bands of applicability. If either the physics or materials are outside the bands of applicability, an additional margin of subcriticality will be applied.

Criticality Safety Control Implementation

This element describes the process for implementing criticality safety controls defined by the CSEs.

- Implementation includes confirming that:
  - All required engineered criticality safety controls are maintained by a configuration management system.
  - Equipment dimensions, volumes, or other features relied on for controls are with limits documented in the CSEs.
  - Administrative criticality safety controls from CSEs are implemented in written operating and maintenance procedures.
- Fissile material inventories will be monitored and incorporated into implementation of criticality safety controls.
- Access to fissionable material will be controlled.

Nuclear Criticality Safety Training

This element describes the training program for nuclear criticality safety based on the worker's duties and responsibilities.

- This training program is developed and implemented with input from the nuclear criticality safety staff, training staff, and management, with a focus on:
  - Knowledge of the physics associated with nuclear criticality safety
  - Analysis of jobs and tasks to determine the knowledge a worker must have to perform tasks efficiently
  - Design and development of learning objectives based on the analysis of jobs and tasks that reflect the knowledge, skills, and abilities needed by the worker
  - Implementation of revised or temporary operating procedures
  - Testing methods to demonstrate competence in training materials dependent on an individual's responsibility
  - Training records maintenance
- General training on criticality hazards and alarm responses will be provided to all RPF personnel and visitors.
- Operators responsible for some aspect of nuclear criticality safety will:
  - Satisfy defined minimum initial qualifications
  - Complete an initial criticality safety training course designed for operators
  - Perform periodic requalification training
- Management, operations supervisor, and technical staff responsible for some aspect of nuclear criticality safety will:
  - Satisfy defined minimum initial qualifications
  - Complete an initial criticality safety training course designed for managers and engineers

  - Perform periodic requalification training

- The Criticality Safety Representative will:
  - Satisfy defined minimum initial qualifications
  - Complete an initial criticality safety program designed for the Criticality Safety Representative
  - Demonstrate competence in understanding facility nuclear criticality controls and procedures
  - Perform periodic requalification training

- Criticality Safety Engineers will be trained and qualified in accordance with ANSI/ANS-8.26.

Nuclear criticality safety staff members and contract support will meet the qualification and training requirements specified in the NWMI nuclear criticality safety qualification and training program. The NWMI nuclear criticality safety qualification and training program is compliant with ANSI/ANS 8.26.

Criticality Safety Assessments

This element describes the periodic criticality safety inspections and assessments conducted to ensure that the criticality safety program is maintained at an adequate level for the RPF.

- Annual criticality safety inspections will be conducted to satisfy the requirement of ANSI/ANS-8.1 and 8.19 for operational reviews to be conducted at least annually.

- Procedures will be developed for performing periodic criticality safety inspections. The facility Criticality Safety Representative and inspection team will comprise individuals (typically from Engineering) who are knowledgeable of criticality safety, and who, to the extent practicable, are not immediately responsible for the operation being inspected.

- Facility inspections are conducted to verify that the facility configuration and activities comply with the nuclear criticality safety program. Facility inspections generally consist of observation of task preparation and verification of field procedures and training.

- Management assessments will be conducted of the nuclear criticality safety program. These assessments will be led by the Nuclear Criticality Safety Manager, with assistance from other members of the criticality safety staff. The criticality safety staff is independent of the operating organization and not directly responsible for the operations.

- Records generated during performance of criticality safety inspections and assessments will be included in a criticality safety inspection report or specialty assessment report.

An audit to assess the overall effectiveness of the nuclear criticality safety program will be performed at least once every three years. The audit will be led by a qualified senior criticality safety engineer from outside the NWMI organization. The senior nuclear criticality safety engineer conducting the audit will be independent of the NWMI program and will not have participated in any nuclear criticality safety evaluation that will be a subject of the audit. In addition to the triennial audit from an outside organization, NWMI senior management will perform periodic audits of the NWMI nuclear criticality safety program. The senior manager will be chosen from an NWMI organization other than the nuclear criticality safety group. The NWMI Quality Assurance Manager will select and assign auditors who are independent of the NWMI nuclear criticality safety program.

Criticality Prevention Specifications

This element describes the requirements for the criticality prevention specifications used to implement limits and controls established in the CSEs for safe handling of fissionable material and implement the ANSI/ANS-8 series requirement for clear communication of criticality safety limits and controls.

- Each criticality prevention specification will:
  - Be based on an approved CSE and refer to the CSE used as a specification source
  - Be prepared by either the Criticality Safety Representative of a qualified Criticality Safety Engineer
  - Emphasize limits controllable by the operator
  - Have clear and unambiguous meaning and be written, to the extent practical, using operations terminology with common units of measure

Operating Procedures and Maintenance Work

This element describes the requirements for implementing nuclear criticality controls in written procedures for operations and maintenance work.

- Procedures will meet the intent of ANSI/ANS-8.19.
- Procedures for operations and maintenance work will be prepared according to approved procedure control programs, developed and maintained to reflect changes in operations, and written so that no single inadvertent failure to follow a procedure can cause a criticality accident.
- Operating procedures will include:
  - Controls and limits significant to nuclear criticality safety of the operation
  - Periodic revisions, as necessary
  - Periodic review of active procedures by supervisors
- Operating procedures will be supplemented by criticality safety postings on equipment or incorporated in operating checklists.
- Maintenance work procedures associated with SSCs affecting nuclear criticality safety will be reviewed by the Criticality Safety Representative or a Criticality Safety Engineer for compliance with nuclear criticality safety limits based on current RPF conditions present prior to initiating each maintenance evolution.

Criticality Safety Postings

- Criticality safety postings will be developed for the Operating License Application.

Fissile Material Container Labeling, Storage, and Transport

- Fissile material container labeling, storage, and transport will be developed for the Operating License Application.

Criticality Safety Nonconformance Response

This element describes the response to deviations from defined nuclear criticality safety controls.

- Deviations from procedures and unforeseen alterations in process conditions that affect criticality safety will be immediately reported to management and the Criticality Safety Representative or a Criticality Safety Engineer.
- NWMI management will provide the required notifications of the deviation to the U.S. Nuclear Regulatory Commission Operations Center.

- The Criticality Safety Representative or a Criticality Safety Engineer will support an investigative team comprising, at a minimum, the Operations Manager and operations personnel familiar with the operation in question during the development of a recovery plan for safely returning to compliance with the procedures.
- The deviation will be corrected per the recovery plan and the incident documented.
- Action is to be taken to ensure that a similar situation does not exist in another part of the facility and to prevent recurrence of the nonconformance.

Criticality Safety Configuration Control

This element describes the criticality safety configuration controls.

- The primary criticality safety control, performed at the start of a proposed activity or equipment change, is for the Criticality Safety Representative to confirm if an existing active CSE is applicable.
- All dimensions, nuclear properties, and other features on which reliance is placed will be documented and verified prior to beginning operations, and control will be exercised to maintain them.
- The nuclear criticality safety staff will provide technical guidance for the design of equipment and processes and for the development of operating procedures.
- All proposed criticality safety-related changes to design or process configuration will be reviewed by a Criticality Safety Representative or Criticality Safety Engineer to ensure that the change can be performed under an approved CSE.
- All operational changes that impact criticality safety will be documented and include proper approval designation.
- The project manager will request a CSE applicability review at the earliest practical stage of a project to determine if there could be criticality safety impacts. If the potential exists for the physical configuration or operating parameters for new or revised equipment to affect criticality safety, the drawings and process control plans will be reviewed and approved by a Criticality Safety Representative or Criticality Safety Engineer, in compliance with standard engineering practices and procedures.
- Facility and process change control will include the following.
  - The change management process will be in accordance with ANSI/ANS-8.19.
  - All dimensions, nuclear properties, and other features on which reliance is placed will be documented and verified prior to beginning operations, and control will be exercised to maintain them.
  - Changes that involve or could affect nuclear criticality controls will be evaluated under 10 CFR 50.59, "Changes, Tests, and Experiments."
  - Changes include new designs, operation, or modification to existing SSCs, computer programs, processes, operating procedures, or management measures.
  - Changes that involve or could affect nuclear criticality controls will be reviewed and approved by the Criticality Safety Representative.
  - Prior to implementing the change, the process will be determined to be subcritical (with an approved margin for safety) under both normal and credible accident scenarios.

Testing and Calibration of Active Engineered Controls

- Testing and calibration of AECs will be developed for the Operating License Application.

Criticality Safety Guidelines for Firefighting

- Criticality safety guidelines for firefighting will be developed for the Operating License Application.

Emergency Preparedness Plan and Procedures

This element describes the response to criticality accidents.

- The CAAS will be used as described in Section 6.3.1.1 and provides for detection and annunciation of criticality accidents.
- Emergency procedures will be prepared and approved by management.
- Facility and off-site organizations expected to respond to emergencies will be informed of conditions that might be encountered.
- Procedures will:
  - Designate evacuation routes that are clearly identified and follow the quickest, most direct routes practical
  - Include assessment of exposure to individuals
  - Designate personnel assembly stations outside the areas to be evacuated.
- A method to account for personnel will be established and arrangements made in advance for the care and treatment of injured and exposed personnel.
- The possibility of personnel contamination by radioactive material will be considered.
- Personnel will be trained in evaluation methods, informed of routes and assembly stations, and drills performed at least annually.
- Instrumentation and procedures will be provided for determining radiation in an evacuated area following a criticality accident and information collected in a central location.
- Emergency procedures will be maintained for each area in which special nuclear material is handled, used, or stored to ensure that all personnel withdraw to an area of safety on sounding the alarm.
- Emergency procedures will include conducting drills to familiarize personnel with the evacuation plan, designation of responsible individuals to determine the cause of the alarm, and placement of radiation survey instruments in accessible locations for use in such an emergency.
- The current emergency procedures for each area will be retained as a record for as long as licensed special nuclear material is handled, used, or stored in the area.
- Superseded sections of emergency procedures will be retained for three years after the section is superseded.
- Fixed and personnel accident dosimeters will be provided in areas that require a CAAS.
- Dosimeters will be readily available to personnel responding to an emergency and a method provided for prompt on-site dosimeter readouts.

6.3.1 Criticality Safety Controls

The following sections describe criticality safety controls based on information developed for the Construction Permit Application. Section 6.3.1.1 summarizes the results of preliminary CSEs that define PECs and AECs credited to satisfy the double-contingency control principle. Section 6.3.1.2 summarizes IROFS related to preventing a nuclear criticality identified by the accident analyses described in Chapter 13.0.

6.3.1.1 Preliminary Criticality Safety Evaluations

A series of calculations were performed to support the Construction Permit Application investigating parameters associated with prevention of nuclear criticality in the current equipment configuration of major process systems. The calculations are described in the following documents:

- NWMI-2015-CRITCALC-001, *Single Parameter Subcritical Limits for 20 wt% ^{235}U – Uranium Metal, Uranium Oxide, and Homogenous Water Mixtures*
- NWMI-2015-CRITCALC-002, *Irradiated Target Low-Enriched Uranium Material Dissolution*
- NWMI-2015-CRITCALC-003, *55-Gallon Drum Arrays*
- NWMI-2015-CRITCALC-005, *Target Fabrication Tanks, Wet Processes, and Storage*
- NWMI-2015-CRITCALC-006, *Tank Hot Cell*

Calculations were performed using the MCNP 6.1 code (LA-CP-13-00634, *MCNP6 User Manual*). Validation of the MCNP 6.1 code used in the calculations is described in [Proprietary Information]. The validation report documents the methodology and results for the bias and bias uncertainty values calculated for homogeneous and heterogeneous uranium systems for the MCNP 6.1 code system. The bias is expressed as USLs calculated using a facility-specific [Proprietary Information]. The primary focus of the validation was to determine the bias and bias uncertainty for intermediate-enriched uranium (IEU) systems. However, sufficient experiments for low-enriched uranium (LEU) and high-enriched uranium were included to demonstrate that there is no variation in the USL with varying enrichment. Similarly, the primary focus of the validation was on thermal neutron energy systems. Sufficient experiments for intermediate and fast energy experiments were also included to demonstrate that there is no variation in the USL with increasing neutron energy.

The purpose of the computer code validation is to determine values of k_{eff} that are demonstrated to be subcritical (at or below the USL) for areas of applicability similar to systems or operations being analyzed. The USL is defined by Equation 6-1.

$$USL = 1.0 - Bias - Bias\ Uncertainty - Margin\ of\ Subcriticality \qquad \text{Equation 6-1}$$

[Proprietary Information] rearranges Equation 6-1 to produce a criterion for model cases that are considered acceptable as subcritical, as shown by Equation 6-2, and incorporates the margin of subcriticality in the USL as required by ANSI/ANS-8.1.

$$k_{eff} + (2 \times \sigma_{calc}) \leq USL \qquad \text{Equation 6-2}$$

where k_{eff} is the MCNP calculated k-effective and σ_{calc} is the MCNP calculation uncertainty.

[Proprietary Information]

[Proprietary Information] indicates the validation is appropriate for homogeneous and heterogeneous IEU systems. A summary of the area of applicability is provided in Table 6-4. For systems outside the validation area of applicability, an increased margin of subcriticality value may be warranted, depending on the specific problem being analyzed. The analyst must document any extrapolation beyond the validation area of applicability, and justification must be documented for no adjustments to the margin of subcriticality when extrapolating.

Table 6-4. Area of Applicability Summary

Parameter	Area of Applicability
Fissile material	[Proprietary Information]
Fissile material form	[Proprietary Information]
$H/^{235}U$ ratio	[Proprietary Information]
Average neutron energy causing fission	[Proprietary Information]
Enrichment	[Proprietary Information]
Moderating materials	[Proprietary Information]
Reflecting materials	[Proprietary Information]
Absorber materials	[Proprietary Information]
Geometry	[Proprietary Information]

[a] Source: [Proprietary Information].

ANECF = average neutron energy causing fission.

The RPF was divided into 13 activity groups for development of preliminary CSEs of the activities and associated equipment. Controlled nuclear criticality safety parameters vary with the activity group and are summarized in Table 6-5. A minimum of two nuclear criticality safety parameters are controlled to satisfy the double-contingency principle.

Table 6-5. Controlled Nuclear Criticality Safety Parameters

Nuclear parameter	NWMI criticality safety evaluation (NWMI-2015-CSE[a])												
	01	02	03	04	05	06	07	08	09	10	11	12	13
Mass	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y[b]	Y	Y
Geometry	Y	Y	Y	Y	Y	Y[c]	Y[c]	Y	N	Y	Y	Y	Y
Moderation	Y	N	N	N	N	N	N	N	N	N	N	N	N
Interaction	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Volume	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	Y
Concentration/ density	N	Y[d]	Y[d]	Y[d]	Y[d]	N	N	N	Y[e]	Y[e]	Y[e]	N	N
Reflection	N	N	N	N	N	N	N	N	N	N	N	N	N
Absorbers	N	N	N	N	N	N	N	N	N	N	N	N	N
Enrichment[f]	N	N	N	N	N	N	N	N	N	N	N	N	N

[a] Derived from the indicated CSE reference document.
[b] Limited by nature of process in the air filtration.
[c] Limited by target design.
[d] Controlled through input fissile mass.
[e] Limited by total uranium mass allowed in the system.
[f] Facility license limited to ≤20 wt% ^{235}U.

^{235}U = uranium-235.
CSE = criticality safety evaluation.
N = no.
NWMI = Northwest Medical Isotopes, LLC.
Y = yes.

The preliminary CSEs define a series of PECs, AECs, and administrative controls that are credited to satisfy the double-contingency control principle for prevention of nuclear criticality events such that at least two changes in process conditions must occur before criticality is possible. PECs, AECs, and administrative controls are described for the 13 activity groups in the following referenced tables:

- NWMI-2015-CSE-01, *Irradiated Target Handling and Disassembly* (Table 6-6)
- NWMI-2015-CSE-02, *Irradiated Low-Enriched Uranium Target Material Dissolution* (Table 6-7)
- NWMI-2015-CSE-03, *Molybdenum-99 Recovery* (Table 6-8)
- NWMI-2015-CSE-04, *Low-Enriched Uranium Target Material Production* (Table 6-9)
- NWMI-2015-CSE-05, *Target Fabrication Uranium Solution Processes* (Table 6-9)
- NWMI-2015-CSE-06, *Target Finishing* (Table 6-9)
- NWMI-2015-CSE-07, *Target and Can Storage and Carts* (Table 6-9)
- NWMI-2015-CSE-08, *Hot Cell Uranium Purification* (Table 6-10)
- NWMI-2015-CSE-09, *Waste Liquid Processing* (Table 6-11)
- NWMI-2015-CSE-10, *Solid Waste Collection, Encapsulation, and Staging* (Table 6-11)
- NWMI-2015-CSE-11, *Offgas and Ventilation* (Table 6-12)
- NWMI-2015-CSE-12, *Target Transport Cask or Drum Handling* – The shipping packages dictate design features that must be properly implemented for legal over-the-road transport. This CSE does not impose or credit additional passive controls other than those already incorporated in the respective shipping packages.

- NWMI-2015-CSE-13, *Analytical Laboratory* (Table 6-13)

The CSEs will be updated for final design and the Operating License Application.

Criticality controls are selected based on the following order of preference:

- Passive engineered controls
- Active engineered controls
- Enhanced administrative controls
- Administrative controls

Note that a number of features listed in the preliminary CSEs are duplicated in multiple activity groups (e.g., the floor of cells is verified to be flat, with no collection points deeper than 3.5 centimeters [cm]). Duplications are included in the current listings to clearly identify minor dimension variations that may exist in the defined features for different activity groups.

Table 6-6. [Proprietary Information] Double-Contingency Controls

Identifier[a]	Feature description and basis
CSE-01-PDF1	[Proprietary Information]
CSE-01-PDF2	[Proprietary Information]
CSE-01-PDF3	[Proprietary Information]
CSE-01-AC1	[Proprietary Information]
CSE-01-AC2	[Proprietary Information]
CSE-01-AC3	[Proprietary Information]
CSE-01-AC4	[Proprietary Information]

[a] [Proprietary Information].

HEPA = high-efficiency particulate air.
SPL = single parameter limit.

**Table 6-7. [Proprietary Information]
Double-Contingency Controls (2 pages)**

Identifier[a]	Feature description and basis
CSE-02-PDF1	[Proprietary Information]
CSE-02-PDF2	[Proprietary Information]
CSE-02-PDF3	[Proprietary Information]
CSE-02-PDF4	[Proprietary Information]
CSE-02-PDF5	[Proprietary Information]
CSE-02-PDF6	[Proprietary Information]
CSE-02-PDF7	[Proprietary Information]
CSE-02-PDF8	[Proprietary Information]
CSE-02-AEF1	[Proprietary Information]
CSE-02-AC1	[Proprietary Information]
CSE-02-AC2	[Proprietary Information]

[a] [Proprietary Information]

[Proprietary Information] = [Proprietary Information]

[Proprietary Information]

Table 6-8. [Proprietary Information] Double-Contingency Controls (2 pages)

Identifier[a]	Feature description and basis
CSE-03-PDF1	[Proprietary Information]
CSE-03-PDF2	[Proprietary Information]
CSE-03-PDF3	[Proprietary Information]
CSE-03-PDF4	[Proprietary Information]
CSE-03-PDF5	[Proprietary Information]
CSE-03-PDF6	[Proprietary Information]
CSE-03-PDF7	[Proprietary Information]
CSE-03-PDF8	[Proprietary Information]
CSE-03-PDF9	[Proprietary Information]
CSE-03-PDF10	[Proprietary Information]
CSE-03-PDF11	[Proprietary Information]
CSE-03-PDF12	[Proprietary Information]
CSE-03-AEF1	[Proprietary Information]
CSE-03-AC1	[Proprietary Information]

[a] [Proprietary Information].

IX = ion exchange.
Mo = molybdenum.
[Proprietary Information] = [Proprietary Information].

[Proprietary Information]

Table 6-9. [Proprietary Information] Double-Contingency Controls (8 pages)

Identifier	Feature description and basis
CSE-04-PDF1[a]	[Proprietary Information]
CSE-04-PDF2[a]	[Proprietary Information]
CSE-04-PDF3[a]	[Proprietary Information]
CSE-04-PDF4[a]	[Proprietary Information]
CSE-04-PDF5[a]	[Proprietary Information]
CSE-04-PDF6[a]	[Proprietary Information]
CSE-04-PDF7[a]	[Proprietary Information]
CSE-04-PDF8[a]	[Proprietary Information]
CSE-04-PDF9[a]	[Proprietary Information]
CSE-04-PDF10[a]	[Proprietary Information]
CSE-04-PDF11[a]	[Proprietary Information]
CSE-04-PDF12[a]	[Proprietary Information]
CSE-04-PDF13[a]	[Proprietary Information]
CSE-04-PDF14[a]	[Proprietary Information]
CSE-04-PDF15[a]	[Proprietary Information]
CSE-04-PDF16[a]	[Proprietary Information]
CSE-04-AEF1[a]	[Proprietary Information]
CSE-04-AC1[a]	[Proprietary Information]
CSE-04-AC2[a]	[Proprietary Information]
CSE-04-AC3[a]	[Proprietary Information]
CSE-04-AC4[a]	[Proprietary Information]
CSE-04-AC5[a]	[Proprietary Information]
CSE-04-AC6[a]	[Proprietary Information]
CSE-04-AC7[a]	[Proprietary Information]
CSE-05-PDF1[b]	[Proprietary Information]
CSE-05-PDF2[b]	[Proprietary Information]
CSE-05-PDF3[b]	[Proprietary Information]
CSE-05-PDF4[b]	[Proprietary Information]
CSE-05-PDF5[b]	[Proprietary Information]
CSE-05-PDF6[b]	[Proprietary Information]
CSE-05-PDF7[b]	[Proprietary Information]
CSE-05-PDF8[b]	[Proprietary Information]

Table 6-9. [Proprietary Information] Double-Contingency Controls (8 pages)

Identifier	Feature description and basis
CSE-05-AEF1[b]	[Proprietary Information]
CSE-05-AEF2[b]	[Proprietary Information]
CSE-05-AEF3[b]	[Proprietary Information]
CSE-05-AC1[b]	[Proprietary Information]
CSE-05-AC2[b]	[Proprietary Information]
CSE-05-AC3[b]	[Proprietary Information]
CSE-06-PDF1[c]	[Proprietary Information]
CSE-06-PDF2[c]	[Proprietary Information]
CSE-06-AC1[c]	[Proprietary Information]
CSE-06-AC2[c]	[Proprietary Information]
CSE-06-AC3[c]	[Proprietary Information]
CSE-06-AC4[c]	[Proprietary Information]
CSE-06-AC5[c]	[Proprietary Information]
CSE-06-AC6[c]	[Proprietary Information]
CSE-07-PDF1[d]	[Proprietary Information]
CSE-07-PDF2[d]	[Proprietary Information]
CSE-07-PDF3[d]	[Proprietary Information]
CSE-07-PDF4[d]	[Proprietary Information]
CSE-07-AC1[d]	[Proprietary Information]
CSE-07-AC2[d]	[Proprietary Information]
CSE-07-AC3[d]	[Proprietary Information]
CSE-07-AC4[d]	[Proprietary Information]
CSE-07-AC5[d]	[Proprietary Information]
CSE-07-AC6[d]	[Proprietary Information]
CSE-07-AC7[d]	[Proprietary Information]

[a] [Proprietary Information]
[b] [Proprietary Information]
[c] [Proprietary Information]
[d] [Proprietary Information]

ADUN = acid-deficient uranium nitrate.
DBE = design basis earthquake.
U = uranium.
UN = uranium nitride.
[Proprietary Information] = [Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

Table 6-10. [Proprietary Information] Double-Contingency Controls (2 pages)

Identifier[a]	Feature description and basis
CSE-08-PDF1	[Proprietary Information]
CSE-08-PDF2	[Proprietary Information]
CSE-08-PDF3	[Proprietary Information]
CSE-08-PDF4	[Proprietary Information]
CSE-08-PDF5	[Proprietary Information]
CSE-08-PDF6	[Proprietary Information]
CSE-08-PDF7	[Proprietary Information]
CSE-08-PDF8	[Proprietary Information]
CSE-08-PDF9	[Proprietary Information]
CSE-08-PDF10	[Proprietary Information]
CSE-08-PDF11	[Proprietary Information]
CSE-08-PDF12	[Proprietary Information]
CSE-08-AEF1	[Proprietary Information]
CSE-08-AC1	[Proprietary Information]
CSE-08-AC2	[Proprietary Information]

[a] [Proprietary Information]

DBE = design basis earthquake.

IX = ion exchange.

[Proprietary Information]

Table 6-11. [Proprietary Information] Double-Contingency Controls (3 pages)

Identifier	Feature description and basis
CSE-09-AEF1[a]	[Proprietary Information]
CSE-09-AC1[a]	[Proprietary Information]
CSE-09-AC2[a]	[Proprietary Information]
CSE-09-AC3[a]	[Proprietary Information]
CSE-10-PDF1[b]	[Proprietary Information]
CSE-10-AEF1[b]	[Proprietary Information]
CSE-10-AC1[b]	[Proprietary Information]
CSE-10-AC2[b]	[Proprietary Information]
CSE-10-AC3[b]	[Proprietary Information]
CSE-10-AC4[b]	[Proprietary Information]
CSE-10-AC5[b]	[Proprietary Information]
CSE-10-AC6[b]	[Proprietary Information]
CSE-10-AC7[b]	[Proprietary Information]
CSE-10-AC8[b]	[Proprietary Information]
CSE-10-AC9[b]	[Proprietary Information]

[a] [Proprietary Information]
[b] [Proprietary Information]

^{235}U = uranium-235.
HIC = high-integrity container.
RPF = Radioisotope Production Facility.
SPL = single parameter limit.
U = uranium.

[Proprietary Information]

[Proprietary Information]

Table 6-12. [Proprietary Information] Double-Contingency Controls (2 pages)

Identifier[a]	Feature description and basis
CSE-11-PDF1	[Proprietary Information]
CSE-11-PDF2	[Proprietary Information]
CSE-11-PDF3	[Proprietary Information]
CSE-11-PDF4	[Proprietary Information]
CSE-11-PDF5	[Proprietary Information]
CSE-11-PDF6	[Proprietary Information]
CSE-11-PDF7	[Proprietary Information]
CSE-11-PDF8	[Proprietary Information]
CSE-11-AEF1	[Proprietary Information]
CSE-11-AC1	[Proprietary Information]

[a] [Proprietary Information]

DBE = design basis earthquake.
HEPA = high-efficiency particulate air.
Mo = molybdenum.
NO_x = nitrogen oxide.

[Proprietary Information]

Table 6-13. [Proprietary Information] Double-Contingency Controls (2 pages)

Identifier[a]	Feature description and basis
CSE-13-PDF1	[Proprietary Information]
CSE-13-PDF2	[Proprietary Information]
CSE-13-PDF3	[Proprietary Information]
CSE-13-AC1	[Proprietary Information]
CSE-13-AC2	[Proprietary Information]
CSE-13-AC3	[Proprietary Information]
CSE-13-AC4	[Proprietary Information]
CSE-13-AC5	[Proprietary Information]
CSE-13-AC6	[Proprietary Information]

[a] [Proprietary Information]

R&D = research and development.
RPF = Radioisotope Production Facility.
SPL = single parameter limit.
U = uranium.

[Proprietary Information]

Each of the preliminary CSEs indicates that the process areas evaluated will be within the detector and alarm coverage of the CAAS. Evaluation of the CAAS coverage will be performed after final design is complete and prior to facility startup. To ensure the CAAS coverage is adequate for the facility, NWMI will conduct a coverage analysis using the minimum accident of concern that produces a detector response when the dose rate at the detector is equivalent to 20 rad/min at 2 m (6.6 ft) from the reacting material. Using the source from the minimum accident of concern, NWMI will conduct one-dimensional deterministic computations, when practical, to evaluate CAAS coverage. For areas of the facility where the use of one-dimensional deterministic computations is not practical, NWMI will use 3D Monte Carlo analysis to determine adequate CAAS coverage.

The CAAS will be designed to meet the following.

- The facility CAAS:
  - Will be capable of detecting a criticality that produces an absorbed dose in soft tissue of 20 radiation dose absorbed (rad) of combined neutron and gamma radiation at an unshielded distance of 2 m from the reacting material within 1 minute; two detectors will cover each area needing CAAS coverage
  - Will use gamma and neutron sensitive radiation detectors that energize clearly audible alarm signals if an accidental criticality occurs
  - Will comply with ANSI/ANS-8.3, as modified by NRC Regulatory Guide 3.71
  - Will be appropriate for the type of radiation detected, the intervening shielding, and the magnitude of the minimum accident of concern
  - Will be designed to remain operational during design basis accidents
  - Will be clearly audible in areas that must be evacuated or there will be alternative notification methods that are documented to be effective in notifying personnel that evaluation is necessary
- Operations will be rendered safe, by shutdown and quarantine, if necessary, in any area where CAAS coverage has been lost and not restored within a specified number of hours. The number of hours will be determined on a process-by-process basis, because shutting down certain processes, even to make them safe, may carry a larger risk than being without a CAAS for a short time. Compensatory measures (e.g., limiting access, halting SNM movement, or restoring CAAS coverage with an alternate instrument) when the CAAS is not functional will be determined for inclusion in the Operating License Application.
- Emergency power will be provided to the CAAS by the uninterruptable power supply system.

6.3.1.2 Derived Nuclear Criticality Safety Items Relied on for Safety

The following subsections describe engineered safety features that are derived from the accident scenarios that could result in a nuclear criticality, as described in Chapter 13.0.

6.3.1.2.1 IROFS CS-04, Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement

IROFS CS-04, "Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement," is identified by the accident analyses in Chapter 13.0. During handling of uranium solids and solutions outside of processing systems under normal conditions, the material will be handled in safe masses controlled by either physical measurement or batch limits on well characterized devices.

Solid uranium will be handled outside of processing systems during:

- Receipt and processing of fresh uranium (and presumably shipment of spent uranium back to the supplier)
- [Proprietary Information]
- Fabrication of targets using [Proprietary Information] LEU target material (including movement of LEU target material to and from the fabrication workstation and handling of the completed targets)
- Disassembly of targets following irradiation
- Laboratory sampling and analysis activities (albeit in smaller quantities).

Each activity is assigned a mass or batch limit for safe handling.

Accident Mitigated

The accident occurs when a safe mass or batch limit is exceeded beyond some bounding extent based on the management measures on the control. Note that this accident involves normal condition criticality controlled limits for safe handling, and the upset represents failure of an associated administrative control. The most limiting activity would involve processing the LEU target material from [Proprietary Information]. If the IROFS fails, accidental nuclear criticality is possible without additional control.

System Components

As a PEC, fixed interaction control fixtures or workstations will be provided for holding or processing approved containers containing approved quantities of uranium metal, [Proprietary Information], batches of targets, and batches of samples.

Functional Requirements

The fixtures are designed to hold only the approved container or batch and are fixed with 2-ft edge-to-edge spacing from all other fissile material containers, workstations, or fissile solution tanks, vessels, and ion exchange (IX) columns. Where LEU target material is handled in open containers, the design will prevent spills from readily spreading to an adjacent workstation or storage location.

Design Basis

Final workstation and fixture spacing will be determined in final design when all process upsets are evaluated. Workstations with interaction controls include the following (not an all-inclusive listing):

- [Proprietary Information]
- [Proprietary Information]
- Target basket fixture that provides safe spacing of a batch of targets from one another in the target receipt cell

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.2 IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement Using the Diameter of Tanks, Vessels, or Piping

IROFS CS-06, "Pencil Tank, Vessel, or Piping Safe Geometry Confinement using the Diameter of Tanks, Vessels, or Piping," is identified by the accident analyses in Chapter 13.0. The PHA in Chapter 13.0 identified a number of individual potential initiating events that could lead to a spill of fissile solution from the geometrically safe confinement tanks, vessels, or piping that provide the primary safety functions of the processes. Four processing systems will handle fissile solutions:

- Target fabrication (from the [Proprietary Information])
- Target dissolution system
- First stage of molybdenum recovery and purification
- Entire uranium recovery and recycle system

Three of these systems will be at least partially located within the hot cell wall boundary due to the high-dose of the fission products. Initiating events include the general categories of tank, vessel, or piping failure due to operator error (valves out of position), valves leaking, equipment leaking (pumps, piping, vessels, etc.), high pressure events from various causes including high temperature solutions (locked in boundary valves), hydrogen detonation, and exothermic reactions with the wrong resins or reagents used in the respective systems. Some of the initiators result in small leaks that are identified and mitigated (e.g., pump seal and small valve leaks). Over the life of the facility, these types of leaks are to be expected, but do not challenge the overall safety of RPF operations.

Accident Mitigated

The accident of concern involves fissile process solution in quantities necessary to sustain accidental nuclear criticality. Larger catastrophic leaks or ruptures of equipment must occur for enough material to be released. Such leaks would represent a failure of the safe-geometry confinement IROFS for the respective equipment. Thus, scenarios leading to this accident sequence involve the failure of these IROFS. Due to the nature of the process, the worst-case accident involves the tanks with the largest capacity and the highest normal case concentrations.

System Components

As a PEC, pencil tanks and other standalone vessels are designed and will be fabricated with a safe-geometry diameter for safe storage and processing of fissile solutions. The safe diameters of various tanks, vessels, or components will be provided in the Operating License Application.

Functional Requirements

The safety function of safe diameter vessels is also one of confinement of the contained solution. The safe-geometry confinement of fissile solutions will prevent accidental nuclear criticality, a high consequence event. The safe-geometry confinement diameter will conservatively include the outside diameter of the tank wall or out to the outside diameter of any heating or cooling jackets (or any other void spaces that may inadvertently capture fissile solution) on the vessels. Where insulation is used on the outside wall of a vessel, the insulation will be closed foam or encapsulated type (so as not to soak up solution during a leak) and will be compatible with the chemical nature of the contained solution.

Design Basis

The safe-geometry diameter of tanks, vessels, and piping will be determined in final design after finalizing the reference CSEs. Note that preliminary vessel sizes for activity groups are listed in the double-contingency parameters described in Section 6.3.1.1.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.3 IROFS CS-07, Pencil Tank Geometry Control on Fixed Interaction Spacing of Individual Tanks

IROFS CS-07, "Pencil Tank Geometry Control on Fixed Interaction Spacing of Individual Tanks," is identified by the accident analyses in Chapter 13.0 (see description in Section 6.3.1.2.2).

Accident Mitigated

See description in Section 6.3.1.2.2.

System Components

As a PEC, pencil tanks and other standalone vessels (controlled with safe geometry or volume constraints) are designed and will be fabricated with a fixed interaction spacing for safe storage and processing of the fissile solutions. Tanks, vessels, and components requiring fixed interaction control spacing of the barrels within each set of pencil tanks and between various tanks, vessels, or components will be provided in the Operating License Application.

Functional Requirements

The safety function of fixed interaction spacing of individual tanks in pencil tanks and between other single processing vessels or components is designed to minimize interaction of neutrons between vessels such that under normal and credible abnormal process upsets, the systems remain subcritical. The fixed interaction control of tanks, vessels, or components containing fissile solutions will prevent accidental nuclear criticality, a high consequence event. The fixed interaction spacing will be measured from the outside of the respective tanks, vessels, or component or from the outside of any heating or cooling jackets (or any other void spaces that may inadvertently capture fissile solution) on the vessels or component. The fixed interaction control distance from the safe slab depth spill containment berm will also be specified where applicable.

Design Basis

Actual interaction control parameters will be defined during final design. In addition, the following generic interaction control parameters apply during design.

- Connecting piping between fissile material components will not exceed a cross-sectional density to be determined during final evaluation of systems.
- Edge-to-edge spacing between fissile material-bearing vessels and components and the concrete reflector presented by the hot cell shielding walls will be fixed at a distance to be determined during final evaluation of all components.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.4 IROFS CS-08, Floor and Sump Geometry Control on Slab Depth, Sump Diameter or Depth for Floor Dikes

IROFS CS-08, "Floor and Sump Geometry Control on Slab Depth, Sump Diameter or Depth for Floor Dikes," is identified by the accident analyses described in Chapter 13.0 (see description in Section 6.3.1.2.2).

Accident Mitigated

See description in Section 6.3.1.2.2.

System Components

As a PEC, the floor under designated tanks, vessels, and workstations will be constructed with a spill containment berm using a safe-geometry slab depth, and one or more collection sumps with diameters or depths, to be determined in final design.

Functional Requirements

The safety function of a spill containment berm is to contain spilled fissile solution from systems overhead and prevent an accidental nuclear criticality if one of the tanks or related piping leaks, ruptures, or overflows (if so equipped with overflows to the floor). Each spill containment berm will be sized for the largest single credible leak associated with overhead systems. The sump will have a monitoring system to alert the operator that the IROFS has been used and may not be available for a follow-on event. A spill containment berm is operable if it contains reserve volume for the largest single credible spill. Spill containment berm sizes and locations will be determined during final design.

Design Basis

The safe-geometry slab depth under designated tanks, vessels, and workstations will be determined during final design after finalizing the reference CSEs. Note that the preliminary slab depth for the activity groups are listed in the double-contingency parameters described in Section 6.3.1.1.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.5 IROFS CS-09, Double-Wall Piping

IROFS CS-09, "Double Wall Piping," is identified by the accident analyses described in Chapter 13.0. As a PEC, a piping system for conveying fissile solution between confinement structures will be provided with a double-wall barrier to contain any spills that may occur from the primary piping.

Accident Mitigated

- Leak in piping that passes between confinement enclosures

System Components

IROFS CS-09 is used at the locations listed below that pass through the facility where creating a spill containment berm under the piping is neither practical nor desirable for personnel chemical protection purposes. The following double-wall piping segments are identified for criticality safety:

- Transfer piping containing fissile solutions traversing between hot cell walls
- Transfer piping connecting the uranium product transfer send tank (UR-TK-720) and the uranyl nitrate storage tank (TF-TK-200)
- Any other locations in final design where fissile solution piping exits a safe-slab spill containment berm and enters another

Functional Requirements

The safety function of this PEC is to safely contain spilled fissile solution from system piping and prevent an accidental nuclear criticality if the primary confinement piping leaks or ruptures. The double-wall piping arrangement will maintain the safe-geometry diameter of the solution. The double-wall piping will also function as a barrier to prevent fissile solution from soaking into the concrete from lines passing through concrete walls where required by the criticality safety analysis (e.g., see PDF2 of Table 6-9). The secondary safety function of double-wall piping is to prevent personnel injury from exposure to acidic or caustic licensed material solutions that are conveyed in the piping.

Design Basis

The double-wall piping arrangement is designed to gravity-drain to a safe-geometry set of tanks or a safe-geometry containment berm.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.6 IROFS CS-10, Closed Safe Geometry Heating/Cooling Loop with Monitoring and Alarm

IROFS CS-10, "Closed Safe Geometry Heating or Cooling Loop with Monitoring and Alarm," is identified by the accident analyses in Chapter 13.0. As a PEC, a closed-loop, safe-geometry heating or cooling loop with monitoring for uranium process solution or high-dose process solution will be provided to safely contain fissile process solution that leaks across the heat transfer fluid boundary if the primary boundary fails.

Accidents Mitigated

The dual-purpose safety function of the closed-loop system is to prevent (1) fissile process solution from causing accidental nuclear criticality, and (2) high-dose process solution from exiting the hot cell containment, confinement, or shielded boundary (or to prevent low-dose solution from exiting the facility, for systems located outside of the hot cell containment, confinement, or shielded boundary), and causing excessive dose to workers and the public, and/or causing a release to the environment.

System Components

The closed loop steam and cooling water loop design is described in Chapter 9.0.

Functional Requirements

The heat exchanger materials will be compatible with the harsh chemical environment of the tank or vessel process (this may vary from application to application). Sampling of the heating or cooling media (e.g., steam condensate conductivity, cooling water radiological activity, or uranium concentration) will be conducted to alert the operator that a breach has occurred, and that additional corrective actions are required to identify and isolate the failed component and restore the closed loop integrity. Discharged solutions from this system will be handled as potentially fissile and sampled prior to discharge to a non-safe geometry.

Design Basis

The closed loop steam and cooling water loop design is described in Chapter 9.0.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.7 IROFS CS-11, Simple Overflow to Normally Empty Safe Geometry Tank with Level Alarm

IROFS CS-11, "Simple Overflow to Normally Empty Safe Geometry Tank with Level Alarm," is identified by the accident analyses described in Chapter 13.0. As a PEC, a simple overflow line will be installed below the level of the process vessel ventilation port and any chemical addition ports (where an anti-siphon safety feature will be installed) for each vented tank containing fissile or potentially fissile process solution for which this IROFS is assigned.

Accident Mitigated

The overflow drain will prevent the process solution from entering the respective non-geometrically favorable sections of the process ventilation system and any chemical addition ports (where chemical addition ports enter through anti-siphon devices).

System Components

Locations of the overflow and overflow collection tanks will be provided with the final design.

Functional Requirements

The safety function of this feature is to prevent accidental nuclear criticality in non-geometrically favorable sections of the process ventilation system. The overflow will be directed to a safe-geometry storage tank. The overflow storage tank will normally be maintained empty. The overflow storage tank will be equipped with a level alarm to inform the operator when use of the IROFS has been initiated, so that actions can be taken to restore operability of the safety feature by emptying the tank.

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.8 IROFS CS-12, Condensing Pot or Seal Pot in Ventilation Vent Line

IROFS CS-12, "Condensing Pot or Seal Pot in Ventilation Vent Line," is identified by the accident analyses described in Chapter 13.0. As a PEC, a safe-geometry condensing pot or seal pot will be installed downstream of each tank for which this IROFS is assigned to capture and redirect liquids to a safe-geometry tank or flooring area with safe-geometry sumps. One such condensing or seal pot may service several related tanks within the safe-geometry boundary of the ventilation system.

The condensing or seal pot will prevent fissile solution from flowing into the respective non-geometrically favorable process ventilation system by directing the solution to a safe-geometry tank or flooring area with safe-geometry sumps.

Accident Mitigated

Where independent seal or condensing pots are credited, the drains of the seal or condensing pots must be directed to independent locations to prevent a common clog or over-capacity condition from defeating both.

System Components

Locations of the condensing pots or seal pots and associated drain points will be provided with the final design.

Functional Requirements

The safety function of the condensing or seal pots is to prevent accidental nuclear criticality in non-geometrically favorable sections of the process ventilation system. The safe-geometry tank or sumps will be equipped with a level alarm to inform the operator when use of the IROFS has been initiated. Each individual tank or vessel operation must be evaluated for required overflow capacity to ensure that a suitable overflow volume is available. A monitoring and alarm circuit will be provided so that common overflow tanks or safe slab flooring or sumps can be used for multiple tanks or vessels, and limiting conditions of operation will be defined to ensure that the IROFS is made available in a timely manner or operations are suspended following an overflow event of a single tank.

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.9 IROFS CS-13, Simple Overflow to Normally Empty Safe Geometry Floor with Level Alarm in the Hot Cell Containment Boundary

IROFS CS-13, "Simple Overflow to Normally Empty Safe Geometry Floor with Level Alarm in the Hot Cell Containment Boundary," is identified by the accident analyses described in Chapter 13.0. As a PEC, a simple overflow line will be installed above the high alarm setpoint for each vented tank containing fissile or potentially fissile process solution for which this IROFS is assigned. The overflow will be directed to one or more safe-geometry flooring configurations with safe-geometry sumps.

Accident Mitigated

This IROFS prevents accidental criticality by ensuring that overflowing fissile solutions are captured in a safe-geometry slab configuration with safe-geometry sumps.

System Components

System component information will be provided in the Operating License Application.

Functional Requirements

The floor areas (separated as needed to support operations in different hot cell areas) will normally be maintained empty. The floor area(s) will be equipped with a sump level alarm to inform the operator when use of the IROFS has been initiated.

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.10 IROFS CS-14, Active Discharge Monitoring and Isolation

IROFS CS-14, "Active Discharge Monitoring and Isolation," is identified by the accident analyses described in Chapter 13.0. Additional detailed information describing active discharge monitoring and isolation will be developed for the Operating License Application.

System Components

System component information will be provided in the Operating License Application.

Functional Requirements

Functional requirements information will be provided in the Operating License Application.

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.11 IROFS CS-15, Independent Active Discharge Monitoring and Isolation

IROFS CS-15, "Independent Active Discharge Monitoring and Isolation," is identified by the accident analyses described in Chapter 13.0. Additional detailed information describing independent active discharge monitoring and isolation will be developed for the Operating License Application.

System Components

System component information will be provided in the Operating License Application.

Functional Requirements

Functional requirements information will be provided in the Operating License Application.

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.12 IROFS CS-18, Backflow Prevention Device

IROFS CS-18, "Backflow Preventions Device," is identified by the accident analyses described in Chapter 13.0.

See description in Section 6.2.1.7.9.

Accident Mitigated

See description in Section 6.2.1.7.9.

System Components

See description in Section 6.2.1.7.9.

Functional Requirements

See description in Section 6.2.1.7.9.

Design Basis

See description in Section 6.2.1.7.9.

Test Requirements

See description in Section 6.2.1.7.9.

6.3.1.2.13 IROFS CS-19, Safe-Geometry Day Tanks

IROFS CS-19, "Safe Geometry Day Tanks," is identified by the accident analyses described in Chapter 13.0. See description in Section 6.2.1.7.9.

Accident Mitigated

See description in Section 6.2.1.7.9.

System Components

See description in Section 6.2.1.7.9.

Functional Requirements

See description in Section 6.2.1.7.9.

Design Basis

See description in Section 6.2.1.7.9.

Test Requirements

See description in Section 6.2.1.7.9.

6.3.1.2.14 IROFS CS-20, Evaporator/Concentrator Condensate Monitoring

IROFS CS-20, "Evaporator/Concentrator Condensate Monitoring," is identified by the accident analyses described in Chapter 13.0. As an AEC, the condensate tanks will use a continuous active uranium detection system to detect high carryover of uranium that shuts down the evaporator feeding the tank. The purpose of this system is to (1) detect an anomaly in the evaporator or concentrator indicating high uranium content in the condenser (due to flooding or excessive foaming), and (2) prevent high concentration uranium solution from being available in the condensate tank for discharged to a non-favorable geometry system or in the condenser for leaking to the non-safe geometry cooling loop.

Accident Mitigated

The safety function of this IROFS is to prevent an accidental nuclear criticality because of excessive uranium in the condensate carryover to a non-geometrically favorable waste collection tank.

System Components

System components consist of:

- Condensate sample tank 1A (UR-TK-340)
- Condensate delay tank 1 (UR-TK-360)
- Condensate sample tank 1B (UR-TK-370)
- Condensate sample tank 2A (UR-TK-540)
- Condensate delay tank 2 (UR-TK-560)
- Condensate sample tank 2B (UR-TK-570)
- Condensate sampling systems
- Condensate monitors

Functional Requirements

The detection system works by continuously monitoring condensate uranium content and detecting high uranium concentration, and then shutting down the evaporator to isolate the condensate from the condenser and condensate tank. At a limiting setpoint, the uranium monitor detecting device will close an isolation valve in the inlet to the evaporator (or otherwise secures the evaporator) to stop the discharge of high uranium content solution into the condenser and condensate collection tank. The uranium monitor is designed to produce a valve-open permissive signal that fails to an open state, closing the valve on loss of electrical power. The isolation valve is designed to fail-closed on loss of instrument air, and the solenoid is designed to fail-closed on loss of signal. Locations where these IROFS are used will be determined during final design.

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.15 IROFS CS-26, Processing Component Safe Volume Confinement

IROFS CS-26, "Processing Component Safe Volume Confinement," is identified by the accident analyses described in Chapter 13.0 (see description in Section 6.3.1.2.2).

Accident Mitigated

See description in Section 6.3.1.2.2.

System Components

As a PEC, some processing components (e.g., pumps, filter housings, and IX columns) will be controlled to a safe volume for safe storage and processing of the fissile solutions. Components that may be controlled to a safe volume will be described in the Operating License Application.

Functional Requirements

The safety function of a safe-volume component is also one of confinement of the contained solution. The safe-volume confinement of fissile solutions will prevent accidental nuclear criticality, a high-consequence event. The safe-volume confinement will conservatively include the outside diameter of any heating or cooling jackets (or any other void spaces that may inadvertently capture fissile solution) on the component. Where insulation is used on the outside wall of the component, the insulation will be closed-foam or encapsulated type (so as not to soak up solution during a leak) and will be compatible with the chemical nature of the contained solution.

Design Basis

The safe-volume confinement components will be determined in final design after finalizing the referenced CSEs.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.1.2.16 IROFS CS-27, Closed Heating or Cooling Loop with Monitoring and Alarm

IROFS CS-27, "Closed Heating or Cooling Loop with Monitoring and Alarm," is identified by the accident analyses in Chapter 13.0. As a PEC, closed cooling water loops with monitoring for breakthrough of process solution will be provided on the evaporator or concentrator condensers to contain process solution that leaks across this boundary, if the boundary fails. This IROFS will be applied to those high-heat capacity cooling jackets (requiring very large loop heat exchangers) servicing condensers where the leakage is always from the cooling loop to the condenser. The inherent characteristics of the leak path will reduce back-leakage into the closed loop system, and the risk of product solutions entering the condenser will be very low by evaporator and concentrator design.

System Components

The purpose of this safety function is to monitor the health of the condenser cooling jacket to ensure that in the unlikely event that a condenser overflow occurs, fissile and/or high-dose process solution will not flow into this non-safe-geometry cooling loop and cause nuclear criticality. The closed loop will also isolate any high-dose fissile product solids, from the same event, from penetrating the hot cell shielding boundary, and any high-dose fission gases from penetrating the hot cell shielding boundary during normal operations.

Functional Requirements

The heat exchanger materials will be compatible with the harsh chemical environment of the tank or vessel process (this may vary from application to application). Sampling of the cooling media (e.g., cooling water radiological activity, or uranium concentration) will be conducted to alert the operator that a breach has occurred, and that additional corrective actions are required to identify and isolate the failed component and restore the closed-loop integrity. Closed-loop pressure will also be monitored to identify a leak from the closed loop to the process system. Discharged solutions from this system will be handled as potentially fissile and sampled prior to discharge to a non-safe geometry.

Design Basis

Design basis information will be provided in the Operating License Application.

Test Requirements

The above analysis is based on information developed for the Construction Permit Application. Additional detailed information on test requirements will be developed for the Operating License Application.

6.3.2 Surveillance Requirements

A review of surveillance requirements to ensure the availability and reliability of safety controls when required to perform safety functions will be included in the Operating License Application.

6.3.3 Technical Specifications

The technical specifications will be provided in the Operating License Application.

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10 CFR 50.59, "Changes, Tests, and Experiments," *Code of Federal Regulations*, Office of the Federal Register, as amended.

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[Proprietary Information]

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Chapter 7.0 – Instrumentation and Control Systems

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 3
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Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, OR 97330

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Chapter 7.0 – Instrumentation and Control Systems

Construction Permit Application for Radioisotope Production Facility

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REVISION HISTORY

Rev	Date	Reason for Revision	Revised By
0	6/29/2015	Initial Application	Not required
1	6/26/2017	Incorporate changes based on responses to NRC Requests for Additional Information	C. Haass
2	8/5/2017	Modification based on ACRS comments	C. Haass
3	9/5/2017	Incorporate final comments from NRC Staff and ACRS; full document revision	C. Haass

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TERMS

Acronyms and Abbreviations

^{99}Mo	molybdenum-99
ADUN	acid-deficient uranyl nitrate
ALARA	as low as reasonably achievable
BMS	building management system
CAAS	criticality accident alarm system
CAM	continuous air monitor
CFR	Code of Federal Regulations
CGD	commercial grade dedication
COTS	commercial off-the-shelf
DCS	digital control system
ESF	engineered safety feature
FPC	facility process control
HMI	human-machine interface
I	iodine
I&C	instrumentation and control
IEEE	Institute of Electrical and Electronics Engineers
IROFS	items relied on for safety
ISA	integrated safety analysis
IX	ion exchange
Kr	krypton
LEU	low-enriched uranium
Mo	molybdenum
NAVLAP	National Voluntary Laboratory Accreditation
NO_x	nitrogen oxide
NRC	U.S. Nuclear Regulatory Commission
NWMI	Northwest Medical Isotopes, LLC
PLC	programmable logic controller
RAM	radiation area monitor
RPF	Radioisotope Production Facility
SDOE	secure development and operational environment
SIF	safety instrumented function.
SIL	safety integrity level.
SIS	safety instrumented system
SNM	special nuclear material
SSC	structures, systems, and components
TCE	trichloroethylene
U.S.	United States
[Proprietary Information]	[Proprietary Information]
UPS	uninterruptible power supply
V&V	verification and validation
Xe	xenon

Units

m	meter
min	minute
rad	radiation absorbed dose

7.0 INSTRUMENTATION AND CONTROL SYSTEMS

7.1 SUMMARY DESCRIPTION

The Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF) preliminary instrumentation and control (I&C) configuration includes the special nuclear material (SNM) preparation and handling processes (e.g., target fabrication, and uranium recovery and recycle), radioisotope extraction and purification processes (e.g., target receipt and disassembly, target dissolution, molybdenum [Mo] recovery and purification, and waste handling), process utility systems, criticality accident alarm system (CAAS), and systems associated with radiation monitoring.

The SNM processes will be enclosed predominately by hot cells except for the target fabrication area. The facility process control (FPC) system will provide monitoring and control of the process systems within the RPF. In addition, the FPC system will provide monitoring of safety-related components within the RPF. The process strategy for the RPF involves the use of batch or semi-batch processes with relatively simple control steps.

The building management system (BMS) will monitor the RPF ventilation system and mechanical utility systems. The BMS primary functions will be to monitor the facility ventilation system and monitor and control (turn on and off) the mechanical utility systems.

Engineered safety feature (ESF) systems will operate on actuation of an alarm setpoint reached for a specific monitoring instrument/device. For redundancy, this will be in addition to the FPC system or BMS ability to actuate ESF as needed. Each ESF safety function will use hard-wired analog controls/interlocks to protect workers, the public, and environment. The ESF parameters and alarm functions will be integrated into and monitored by the FPC system or BMS.

The preliminary concept for the RPF I&C system configuration is shown in Figure 7-1. The green circles identify the FPC and the BMS distributed process control or programmable logic controller (PLC) systems. The solid lines and dashed lines show how the SNM processes, support systems, utilities, radiation and criticality systems, and building functions relate to the FPC and BMS and to local human-machine interface (HMI) stations. Solid lines indicate the control functions, and dashed lines indicate the monitoring functions.

The FPC system will perform as the overall production process controller. This system will monitor and control the process instrumented functions within the RPF, including monitoring of process fluid transfers and controlled inter-equipment pump transfers of process fluids. Process control systems are described further in Section 7.3.

The fire protection system will have its own central alarm panel (green circle). The fire protection system will report the status of the fire protection equipment to the central alarm station and the RPF control room. The fire protection system is discussed further in Section 7.2.3.5.

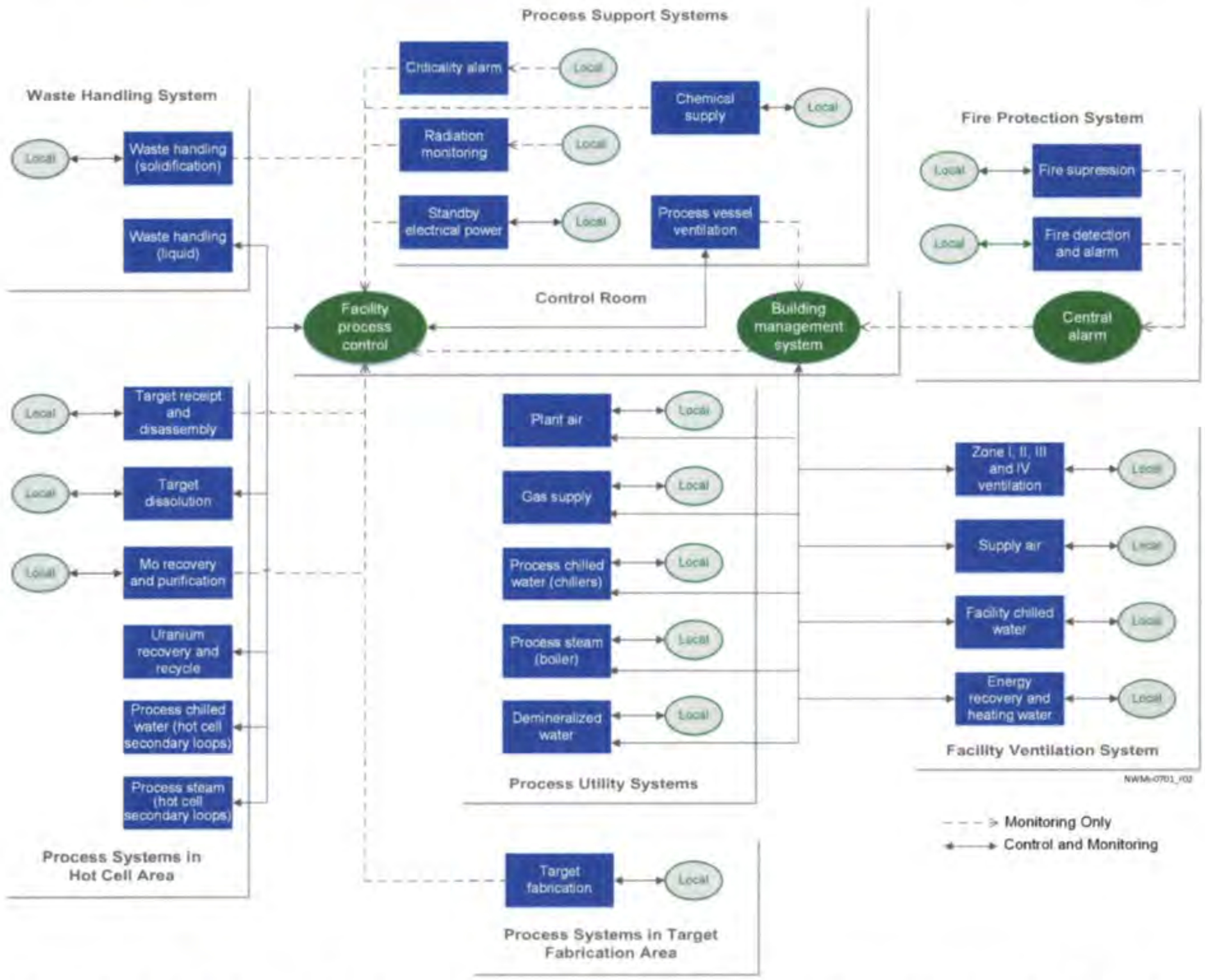

Figure 7-1. Radioisotope Production Facility Instrumentation and Control System Configuration

Special nuclear material preparation and handling processes – The FPC system will control and/or monitor the SNM preparation and handling processes, the following.

- **Target fabrication** – Batch processes located in the target fabrication area will be controlled by operators at local HMIs, with surveillance monitoring in the control room.
- **Uranium recovery and recycle** – Batch processes located inside the hot cell area will be monitored and controlled by operators in the control room.

Radioisotope extraction and purification processes – The FPC system will control and/or monitor the radioisotope production processes, including the following.

- **Target receipt and disassembly** – Hardware/target movement located in irradiated target basket receipt bay area, target cask preparation airlock, target receipt hot cell, and target disassembly hot cell will normally be controlled by operators at local HMIs, with surveillance monitoring in the control room.
- **Target dissolution** – Batch process located inside the dissolution hot cell will occur at local HMIs in the operating gallery, and offgas operations in the tank hot cell will be controlled by operators in the control room, with surveillance monitoring at both locations.

- **Mo recovery and purification** – Batch processes located inside the Mo hot cells will be controlled by operators at a local HMI in the operating gallery, with surveillance monitoring in the control room.
- **Waste handling** – This system includes liquid waste handling, liquid waste solidification, and solid waste handling. Operators in the control room will control liquid waste handling, while operators at local HMIs in the low-dose liquid solidification room (W107) will monitor and control liquid waste solidification, and solid waste nondestructive examination and solidification.

Process utility and support systems – The FPC system will control and monitor the process utility and process support systems. Operators in the control room will control the following subsystems:

- Process chilled water hot cell secondary loops
- Process steam hot cell secondary loops
- Process vessel ventilation system

Operators at local HMIs will control the following subsystems, with surveillance monitoring in the control room using the FPC system or BMS.

- Plant air system
- Gas supply system
- Process chilled water chillers
- Process steam boilers
- Demineralized water system
- Chemical supply system
- Standby electrical power system

Criticality accident alarm system – The CAAS will be provided as an integrated vendor package. The detectors and alarm response are integral to the individual units/locations. The FPC system will monitor the CAAS status in the control room. The CAAS is described further in Section 7.3.

Radiation monitoring system – The FPC system will monitor the various radiation monitoring systems, including continuous air monitors (CAM), air samplers, radiation area monitors (RAM), and exhaust stack monitors. The CAMs and RAMs will be strategically placed throughout the RPF to alert personnel of any potential radiation hazards. The CAMs and RAMs will alarm in the control room and locally at locations throughout the RPF. The radiation monitoring systems are described further in Section 7.6.

Facility ventilation system and mechanical utility systems – The control function for most of the RPF ventilation system and mechanical utility systems will be local HMIs and hard-wired interlocks for the ESF functions. The BMS will monitor the systems and provide ventilation and mechanical utility system status as an input to the FPC process controls.

The following subsystems will be monitored by the BMS:

- Facility ventilation Zones I, II, III, and IV
- Supply air system
- Facility chilled water system
- Energy recovery and heating water

Safety-Related Components and Engineering Safety Features

The ESF safety functions will operate independently from the FPC systems as hard-wired analog controls or interlocks. The FPC system will be a digital control system (DCS) that monitors safety-related components within the RPF. The ESFs will be integrated into the FPC systems and provide a common point of HMI, monitoring, and alarming at the control room and, as necessary, local HMI workstations.

Control Console and Display Instruments

The control room will be the primary interface location for the RPF support systems and provide centralized process controls, monitoring, alarms, and acknowledgement. Mechanical utility systems with vendor packages and integrated controls will be controlled at associated local HMIs. The BMS will provide primarily on/off control and system monitoring from the control room.

The tank hot cell processes will be controlled primarily in the control room, with surveillance monitoring of the FPC subsystems. The FPC system will have annunciation, alarms, and HMI displays. From the consoles, operators will view and trend essential measurement values from the HMI display, and evaluate real-time data from the essential measurements used to control and monitor the RPF process. This system is further described in Section 7.5.

Process utility and support systems with vendor package and integrated controls will be operated at associated local HMIs. These systems are discussed further in Section 7.5. Local HMIs are anticipated in the following locations:

- Irradiated target basket receipt bay A/B (R102A/B)
- Cask preparation airlock (R012)
- Operating gallery (G101 A/B/C)
- Target fabrication (T104 A/B)
- Low-dose liquid waste solidification (W107)
- Chemical supply room (L102)
- Local to equipment with integrated control systems

7.2 DESIGN OF INSTRUMENTATION AND CONTROL SYSTEMS

The design criteria and the codes and standards for I&C systems are outlined in Chapter 3.0, "Design of Structures, Systems, and Components," and discussed below.

7.2.1 Design Criteria

The applicable design criteria and guidelines that apply to the RPF I&C systems are summarized in column one of Table 7-1. Additional, design criteria for I&C systems are provided in Chapter 3.0. The detailed and specific design criteria for I&C systems will be confirmed in the Operating License Application.

7.2.2 Design Basis and Safety Requirements

The design basis for I&C systems used in the RPF are presented in the second column of Table 7-1. The second column maps the criteria to I&C systems or components and how compliance will be ensured. Note that the FPC system callouts may also apply to the BMS. The design basis requirements for facility and process systems are described in Chapter 4.0, "Radioisotope Production Facility Description," and Chapter 9.0, "Auxiliary Systems."

The I&C system will use hard-wired interlocks for actuated engineered safety functions. Section 7.4 summarizes the I&C ESFs.

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
IEEE 379-2014, *IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems* **Description**: Application of the single-failure criterion to electrical power, instrumentation, and control portions of nuclear power generating safety systems. **Keywords**: Actuator, cascaded failure, common-cause failure, design basis event, detectable failure, effects analysis, safety system, single-failure criterion, system actuation, system logic	**Application:** • Design of FPC system, ESFs, and other instrumentation SSCs that are identified as IROFS **Compliance:** • Ensure FPC system is a DCS designed, rated, and approved for use in safety instrumented systems, as determined by ANSI/ISA 84.00.01 • Use a safety PLC, as recognized by IEC 61508, in the FPC system with redundant power supplies, processors, and input/output channels • Evaluate controls that are classified as IROFS in Chapters 6.0 and 13.0, or NWMI-2015-SAFETY-002, against single-failure criteria **Exception:** • NUREG-1537 allows for sharing and combining of systems and components with justification • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
IEEE 577-2012, *IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Facilities* **Description**: Sets minimum acceptable requirements for the performance of reliability analyses for safety systems when used to address the reliability considerations discussed in industry standards and guidelines. The requirement that a reliability analysis be performed does not originate with this standard. However, when reliability analysis is used to demonstrate compliance with reliability requirements, this standard describes an acceptable response to the requirements. **Keywords**: Nuclear facilities, reliability analysis, safety systems	**Application:** • Use for design of FPC system, ESFs, and other instrumentation SSCs that are identified as IROFS **Compliance:** • Perform a reliability analysis of the proposed design solution for IROFS functions, as identified in Chapters 6.0 and 13.0, or NWMI-2015-SAFETY-002. The analysis can be qualitative or quantitative in nature, as described in the standard

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
IEEE 603-2009, *IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations* **Description**: Establishes minimum functional and design criteria for the power, instrumentation, and control portions of nuclear power generating station safety systems. Criteria are to be applied to those systems required to protect public health and safety by functioning to mitigate the consequences of design basis events. The intent is to promote appropriate practices for design and evaluation of safety system performance and reliability. The standard is limited to safety systems; many of the principles may have applicability to equipment provided for safe shutdown, post-accident monitoring display instrumentation, preventive interlock features, or any other systems, structures, or equipment related to safety. **Keywords**: Actuated equipment, associated circuits, Class 1E, design, failure, maintenance bypass, operating bypass, safety function, sense and command features, sensor	**Application:** • Use for design of FPC system, ESFs, and other instrumentation SSCs that are identified as IROFS • Apply minimum functional and design criteria to safety systems **Compliance:** • Ensure design conforms to the practices detailed in the standard for the IROFS functions identified in Chapters 6.0 and 13.0, or NWMI-2015-SAFETY-002 **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
IEEE 384-2008, *IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits* **Description**: Describes independence requirements of circuits and equipment comprising or associated with Class 1E systems. Identifies criteria for independence that can be achieved by physical separation, and electrical isolation of circuits and equipment that are redundant. The determination of what is to be considered redundant is not addressed. **Keywords**: Associated circuit, barrier, Class 1E, independence, isolation, isolation device, raceway, separation	**Application:** • Use for design of FPC system, ESFs, and other instrumentation SSCs that are identified as IROFS • Apply minimum criteria for separation and independence of systems in a physical way **Compliance:** • Ensure design conforms to the practices detailed in the standard for the IROFS functions identified in Chapters 6.0 and 13.0, or NWMI-2015-SAFETY-002 **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
IEEE 323-2003, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations* **Description**: Identifies requirements for qualifying Class 1E equipment and interfaces that are to be used in nuclear power generating stations. The principles, methods, and procedures are intended for use in qualifying equipment, maintaining and extending qualification, and updating qualification, as required, if the equipment is modified. The qualification requirements of the standard demonstrate and document the ability of equipment to perform safety function(s) under applicable service conditions, including design basis events, reducing the risk of common-cause equipment failure. **Keywords**: Age conditioning, aging, condition monitoring, design basis event, equipment qualification, qualification methods, harsh environment, margin, mild environment, qualified life, radiation, safety-related function, significant aging mechanism, test plan, test sequence, type testing	**Application:** • Use for equipment qualification when needed to qualify equipment for applications or environments to which the equipment may be exposed • Use for qualification of Class 1E equipment located in harsh environments and for certain post-accident monitoring equipment; may also be used for the qualification of equipment in mild environments **Compliance:** • Ensure design conforms to the practices detailed in the standard for those systems determined to be Class IE and located in harsh environments for safety functions identified in Chapters 6.0 and 13, or NWMI-2015-SAFETY-002 • Apply to SSCs within the hot cell area; not all safety components reside in the hot cell area • Apply standard using a graded approach **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
IEEE 344-2004, *IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations* **Description**: Identifies recommended practices for establishing procedures that will yield data to demonstrate that the Class 1E equipment can meet performance requirements during and/or following one safe shutdown earthquake event, preceded by a number of operating basis earthquake events. This recommended practice may be used to establish tests, analyses, or experience-based evaluations that will yield data to demonstrate Class 1E equipment performance claims or to evaluate and verify performance of devices and assemblies as part of an overall qualification effort. Common methods currently in use for seismic qualification by test are presented. Two approaches to seismic analysis are described: one based on dynamic analysis, and the other on static coefficient analysis. Two approaches to experience-based seismic evaluation are described, one based on earthquake experience and the other on test experience. **Keywords**: Class 1E, earthquake, earthquake experience, equipment qualification, inclusion rules, nuclear, operating basis earthquake, prohibited features, qualification methods, required response spectrum, response spectra, safe shutdown earthquake, safety function, seismic, seismic analysis, test response spectrum, test experience	**Application:** • Apply seismic design requirements for equipment used in Class 1E systems **Compliance:** • Use in design of FPC system, ESFs, and other instrumentation SSCs that are identified as a Class 1E system **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
IEEE 338-2012, ***IEEE Standard for Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems*** **Description**: Provides criteria for the performance of periodic surveillance testing of nuclear power generating station safety systems. The scope of periodic surveillance testing consists of functional tests and checks, calibration verification, and time response measurements, as required, to verify that the safety system performs its defined safety function. Post-maintenance and post-modification testing are not covered by this document. This standard amplifies the periodic surveillance testing requirements of other nuclear safety-related IEEE standards. **Keywords**: Functional tests, IEEE 338, periodic testing, risk-informed testing, surveillance testing	**Application:** • Use for design of FPC system, ESFs, and other instrumentation SSCs that are identified as IROFS • Use methods and criteria to establish a periodic surveillance program **Compliance:** • Ensure design conforms to the practices detailed in the standard for the IROFS functions identified in Chapters 6.0 and 13.0, or NWMI-2015-SAFETY-002 **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
IEEE 497-2010, ***IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations*** **Description**: Establishes criteria for variable selection, performance, design, and qualification of accident monitoring instrumentation, and includes the requirements for display alternatives for accident monitoring instrumentation, documentation of design bases, and use of portable instrumentation. **Keywords**: Accident monitoring, display criteria, selection criteria, type variables	**Application:** • Use as selection, design, performance, qualification, and display criteria for accident monitoring instrumentation • Apply guidance on the use of portable instrumentation and for examples of accident monitoring display configurations **Compliance:** • Ensure design conforms to standard for the monitoring functions determined to be required for health and safety of workers or the public during normal operation and design basis accidents **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
IEEE 7-4.3.2-2010, ***IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations*** **Abstract**: Specifies additional computer-specific requirements to supplement IEEE 603-2009. The standard defines the term computer as a system that includes computer hardware, software, firmware, and interfaces, and establishes minimum functional and design requirements for computers used as components of a safety system. **Keywords**: Commercial-grade item, diversity, safety systems, software, software tools, software verification and validation	**Application:** • In conjunction with IEEE 603-2009, use to establish minimum functional and design requirements for computers that are components of a safety system • Design FPC system as a DCS, and apply this standard to system development, specifically software development • Apply standard to CGD and implement an approach **Compliance:** • Develop FPC system software using this standard **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
IEEE 828-2012, ***IEEE Standard for Configuration Management in Systems and Software Engineering*** **Description**: Establishes minimum requirements for configuration management in systems and software engineering. This standard applies to any form, class, or type of software or system, and explains configuration management, including identifying and acquiring configuration items, controlling changes, reporting the status of configuration items, and performing software builds and release engineering. This standard addresses what configuration management activities are to be done, when they are to happen in the life-cycle, and what planning and resources are required. The content areas for a configuration management plan are also identified. The standard supports IEEE STD 12207 and ISO/IEC/IEEE 15288, and adheres to the terminology in ISO/IEC/IEEE STD 24765 and the information item requirements of IEEE STD 15939. **Keywords**: Change control, configuration accounting, configuration audit, configuration item, IEEE 828, release engineering, software builds, software configuration management, system configuration management	**Application:** • Use to establish configuration management processes, define how configuration management is to be accomplished, and identify who is responsible for performing specific activities, when the activities are to happen, and what specific resources are required • Design FPC system as a DCS, and apply standard during the development of software for systems with IROFS functions **Compliance:** • Develop FPC system software using this standard for safety function implementation
IEEE 1028-2008, ***IEEE Standard for Software Reviews and Audits*** **Description**: Identifies five types of software reviews and audits, together with procedures required for the execution of each type. This standard is concerned only with reviews and audits; procedures for determining the necessity of a review or audit are not defined, and the disposition of the results of the review or audit is not specified. Types included are management reviews, technical reviews, inspections, walk-throughs, and audits. **Keywords**: Audit, inspection, review, walk-through	**Application:** • Use to identify minimum acceptable requirements for systematic software reviews • Identify organizational means for conducting a review and documenting the findings • Design FPC system as a DCS, and apply standard during the development of software for systems with IROFS functions **Compliance:** • Develop FPC system using this standard
ANS 10.4-2008, ***Verification and Validation of Non-Safety-Related Scientific and Engineering Computer Programs for the Nuclear Industry*** **Description**: Provides guidelines for V&V of non-safety-related scientific and engineering computer programs developed for use by the nuclear industry. Scope is restricted to research and other non-safety-related, noncritical applications. **Keywords**: Software integrity level, software life-cycle, validation, verification, V&V	**Application:** • Perform software V&V to build quality into the software during the software life-cycle • Use to verify and validate software development for non-safety-related systems • Use for software development in the RPF that is not safety significant (e.g., not safety-related or IROFS) **Compliance:** • Develop non-safety-related software using this standard

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
ANSI/ISA 67.04.01-2006, ***Setpoints for Nuclear Safety-Related Instrumentation*** **Description**: Defines requirements for assessing, establishing, and maintaining nuclear safety-related and other important instrument setpoints associated with nuclear power plants or nuclear reactor facilities. **Keywords**: Setpoint, drift, analog channel, reliability analysis	**Application:** • Use methods and criteria to establish setpoints for safety systems and to maintain the documentation • Apply to the design of the FPC system and other instrumentation SSCs that are identified as IROFS for the RPF **Compliance:** • Ensure design conforms to the practices detailed in the standard for IROFS functions with inherent setpoints identified in Chapters 6.0 and 13.0, or NWMI-2015-SAFETY-002
ANSI/ISA 84.00.01-2004, ***Functional Safety: Safety Instrumented Systems for the Process Industry Sector*** **Part 1: "Framework, Definitions, System, Hardware and Software Requirements"** **Part 2: "Guidelines for the Application of ANSI/ISA-84.00.01-2004 Part 1 (IEC 61511-1 Mod) – Informative"** **Part 3: "Guidance for the Determination of the Required Safety Integrity Levels – Informative"** **Description**: Provides requirements for the specification, design, installation, operation, and maintenance of a safety instrumented system, so the system can be confidently entrusted to place and/or maintain the process in a safe state. This standard has been developed as a process sector implementation of IEC 61508. **Keywords**: Safety instrumented system (SIS), safety integrated level (SIL), safety instrumented function (SIF)	**Application:** • Apply to the design of safety systems (standard specifically designed for industrial processes) • Standard is made up of three parts: – Use Part 1 to lay the groundwork for the safety system life-cycle, overall structure of safety systems, definitions used, and to implement safety system design engineering – Use Part 2 guidance for the specification, design, installation, operation, and maintenance of safety instrumented functions and related safety instrumented systems, as defined in Part 1 – Use Part 3 to develop underlying concepts of risk in relation to safety integrity, identify tolerable risk, and determine the safety integrity levels of the safety functions • Design physical hardware of the FPC system based on this standard and IEC 61508 • Evaluate the IROFS functions required to be implemented by the FPC system using Parts 1, 2, and 3 of this standard • Use to demonstrate reliability and risk reduction of the FPC system, while having similar or higher documented and tested ability to reduce risk as fulfillment through other channels **Compliance:** • Use for the design and implementation for IROFS functions that are required of the FPC system

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
NUREG-0700, *Human-System Interface Design Review Guidelines* **Description**: Provides guidance to the NRC on the evaluation of human factors engineering aspects of nuclear power plants in accordance with NUREG-0800. Detailed design review procedures are provided in NUREG-0711. As part of the review process, the interfaces between plant personnel and the plant systems and components are evaluated for conformance with human factors engineering guidelines. **Keywords**: Display, HMI, human-interface system, human-system interface	**Application:** • Use comprehensive design review guidance to develop information displayed in human-interface systems • Develop informative and effective designs that will assist operators in the performance of their duties **Compliance:** • Design FPC system to provide information to operators in a display format • Display development used in connection with the FPC system will be provided in the Operating License Application
NUREG/CR-6463, *Review Guidelines on Software Languages for Use in Nuclear Power Plant Safety Systems* **Description**: Provides guidance to the NRC on auditing programs for safety systems written in the following six high-level languages: Ada, C and C++, PLC Ladder Logic, Sequential Function Charts, Pascal, and PL/M. The guidance could also be used by those developing safety significant software as a basis for project-specific programming guidelines. **Keywords**: Pascal, C, Ladder Logic, PL/M, Ada, C++, PLC, programming, sequential function charts	**Application:** • Use guidance to review high-integrity software in a nuclear facility • Develop FPC system as a DCS, with associated programming development needs for the RPF • Use guideline as a means to review FPC system programming code **Compliance:** • Develop FPC system software programs using this guidance **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
NUREG/CR-6090, *The Programmable Logic Controller and Its Application in Nuclear Reactor Systems* **Abstract**: Outlines recommendations for review of the application of PLCs to the control, monitoring, and protection of nuclear reactors. **Keywords**: PLC, programming, protection systems	**Application:** • Use guidance to implement PLCs for nuclear application and as a forum for what constitutes good practices of previously installed systems • Use guidance during selection process for hardware, failure analysis, and product life-cycle within the facility **Compliance:** • Design FPC system to use a PLC-type DCS • Select design and implement PLCs based on this guide, as applicable **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
EPRI TR-106439, ***Guideline on Evaluation and Acceptance of Commercial Grade Digital Equipment for Nuclear Safety Applications*** **Description**: Provides a consistent, comprehensive approach for the evaluation and acceptance of commercial digital equipment for nuclear safety systems. **Keywords**: Commercial off-the-shelf (COTS), programming, software, commercial grade dedication	**Application:** • Use to identify appropriate critical characteristics with subsequent verification through testing, analysis, vendor assessments, and careful review of operating experience • Use guidance for digital upgrades to safety-related systems and for non-safety-related applications that require high reliability or are compatible with utility-specific change processes, including graded approaches for quality assurance **Compliance:** • Ensure that digital systems components that require CGD apply the guidance of this standard, as applicable
Regulatory Guide 1.152, ***Criteria for Use of Computers in Safety Systems of Nuclear Power Plants*** **Description**: Describes a method that the NRC staff deems acceptable for complying with NRC regulations for promoting high functional reliability, design quality, and a secure development and operational environment for the use of digital computers in the safety systems of nuclear power plants. **Keywords**: Secure development and operational environment (SDOE), computers	**Application:** • Use for I&C system designs with computers in safety-related systems that make extensive use of advanced technology • Use for RPF designs (that are expected to be significantly and functionally different from current day process designs) with microprocessors, digital systems and displays, fiber optics, multiplexing, and different isolation techniques to achieve sufficient independence and redundancy **Compliance:** • Develop FPC system and associated HMI using this guidance **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
Regulatory Guide 1.53, ***Application of the Single-Failure Criterion to Safety Systems*** **Description**: Provides methods acceptable to the NRC staff for satisfying NRC regulations with respect to the application of the single-failure criterion to the electrical power and I&C portions of nuclear power plant safety systems. **Keywords**: IEEE 379-2014, single-failure criterion	**Application:** • Apply single-failure criterion to safety-related I&C systems • Apply to end-devices used by the FPC system that are identified as IROFS **Compliance:** • Evaluate FPC system, ESFs, and IROFS end-devices using this guidance

Table 7-1. Instrumentation and Control System Design Criteria (9 pages)

Design criteria description[a]	Design bases as applied to RPF
Regulatory Guide 1.97, ***Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants*** **Description**: Provides a method that the NRC staff considers acceptable for use in complying with NRC regulations with respect to satisfying criteria for accident monitoring instrumentation in nuclear power plants. **Keywords**: IEEE 497-2010, accident monitoring	**Application:** • Use this guidance for development of accident monitoring for the RPF **Compliance:** • Design FPC system, CAAS, CAMs, and RAMs using this guidance **Exception:** • The RPF is not considered a nuclear power reactor but a production facility. The facility will not have all of the systems detailed in this standard and guidance will be applied as appropriate.
Regulatory Guide 5.71, ***Cyber Security Programs for Nuclear Facilities*** **Description**: Provides an approach that the NRC staff deems acceptable for complying with NRC regulations regarding the protection of digital computers, communications systems, and networks from a cyberattack, as defined by 10 CFR 73.1. **Keywords**: Cybersecurity, 10 CFR 73.54(a)(2), design basis threat	**Application:** • Use this guidance for development of cybersecurity protections **Compliance:** • Design the FPC system and associated HMI based on this guidance

[a] Full references provided in Section 7.7.

CAAS	=	criticality accident alarm system.
CAM	=	continuous air monitor.
CFR	=	Code of Federal Regulations.
CGD	=	commercial grade dedication.
COTS	=	commercial off-the-shelf.
DCS	=	digital control system.
ESF	=	engineered safety feature.
FPC	=	facility process control.
HMI	=	human-machine interface.
I&C	=	instrumentation and control.
IEEE	=	Institute of Electrical and Electronics Engineers.
IROFS	=	items relied on for safety.
NRC	=	U.S. Nuclear Regulatory Commission.
PLC	=	programmable logic controller.
RAM	=	radiation alarm monitor.
RPF	=	Radioisotope Production Facility.
SDOE	=	secure development and operational environment.
SIF	=	safety instrumented function.
SIL	=	safety integrity level.
SIS	=	safety instrumented system.
SSC	=	structures, systems, and components.
V&V	=	verification and validation.

Specific requirements will be developed during the next stages of design for the Operating License Application. The I&C design will be expanded and analyzed to document fulfillment of the design criteria and design basis requirements for the Operating License Application.

7.2.3 System Description

As described in Section 7.1, the RPF I&C system basic components include the FPC system, ESF actuation systems, control console and HMI display instruments, and BMS. These systems provide an interface for the operator to monitor and control those systems. The FPC system will be a DCS that functions independently. The items relied on for safety (IROFS)/ESF safety functions will be activated via hardwire (analog) interlocks.

7.2.3.1 Facility Process Control System

The FPC system controls and monitors the target fabrication system, hot cell area (e.g., Mo recovery and purification, uranium recovery and recycle system), process utility and support systems, and waste handling activities. The FPC system functions also include radiation monitoring, CAAS, HMIs, safe shutdown control and initiation, supervisory information, and alarms. The BMS is a subsystem to the FPC system and monitors the facility ventilation system.

The primary control location of the FPC system is in the control room. The control room FPC system operates with a standby redundant system structure. The standby workstations provide redundant hardware with identical PLC software systems as automatic backup control systems. The primary and backup PLC systems monitor each other. This backup control system minimizes the likelihood of downtime during Mo production processing.

7.2.3.2 Engineered Safety Feature Actuation Systems

The operator will have direct visualization of critical values and the ability to observe status of the features described in Table 7-13 (Section 7.4.1). The engineered safety feature actuation system dedicated displays will perform the following functions:

- **Static display** – This display will show critical measurement values and perform the function of an annunciator panel. This fixed display panel will not provide any interactive control functionality.
- **Alarm/event annunciator display panel** – This panel will display any event or alarm that is defined for the process. The display will enable the operator to acknowledge current events and alarms, and will provide a historical record of events.
- **Dynamic interface display panel or HMI** – This panel will enable the operator to perform tasks, change modes, enable/disable overrides, and other tasks that require operator input to allow, perform, or modify a task or event.

The set of displays will be arranged in a workstation. This workstation will also include a keyboard and mouse that will be used to interface with the system.

7.2.3.3 Control Room/Human-Machine Interface Description

The operator will have direct visualization of critical values and the ability to input control functions into the FPC system. The FPC system dedicated displays will perform the following functions:

- **Static display** – This display will show critical measurement values and perform the function of an annunciator panel. This fixed display panel will not provide any interactive control functionality.
- **Alarm/event annunciator display panel** – This panel will display any event or alarm that is defined for the process. The display will enable the operator to acknowledge current events and alarms, and will provide a historical record of events.
- **Dynamic interface display panel or HMI** – This panel will enable the operator to perform tasks, change modes, enable/disable overrides, and other tasks that require operator input to allow, perform, or modify a task or event.

The set of displays will be arranged in a workstation. This workstation will also include a keyboard and mouse that will be used to interface with the system.

7.2.3.4 Building Management System

The BMS will control the facility ventilation system and receive indications from the fire protection, FPC, and process vessel ventilation systems. The primary purpose of the BMS is to control the air balance of the facility ventilation system and to shut down the facility ventilation system in the event of receiving an alarm from the fire protection system or off-normal conditions indicated by the FPC.

The operator will have direct visualization of critical values and the ability to input control functions into the BMS. The BMS dedicated displays will perform the following functions in the control room:

- **Static display** – This display will show critical measurement values and perform the function of an annunciator panel. This fixed display panel will not provide any interactive control functionality.
- **Alarm/event annunciator display panel** – This panel will display any event or alarm that is defined for the process. The display will enable the operator to acknowledge current events and alarms, and will provide a historical record of events.
- **Dynamic interface display panel or HMI** – This panel will enable the operator to perform tasks, change modes, enable/disable overrides, and other tasks that require operator input to allow, perform, or modify a task or event.

The set of displays will be arranged in a workstation. This workstation will also include a keyboard and mouse that will be used to interface with the system.

7.2.3.5 Fire Protection System

The fire protection system will report the status of the fire protection equipment to the central alarm station and the RPF control room with sufficient information to identify the general location and progress of a fire within the protected area boundaries. Initiating devices for the fire detection and alarm subsystem, including monitoring devices for the fire suppression subsystem, will indicate the presence of a fire within the facility.

Once an initiating device activates, signals will be sent to the fire alarm control panel. The fire alarm control panel will transmit signals to the central alarm station and perform any ancillary functions. As an example, signals from the fire control panel may initiate actions such as shutdown of the ventilation equipment or actuating the deluge valves. The fire protection system is described in Chapter 9.0, Section 9.3.

7.2.3.6 Facility Communication Systems

The RPF communication systems will relay information within the facility during normal and emergency conditions. The systems are designed to enable the RPF operator on duty to be in communication with the supervisor on duty, health physics staff, and other personnel required by the technical specifications, and to enable the operator, or other staff, to announce the existence of an emergency in all areas of the RPF complex. Two-way communication will be provided between all operational areas and the control room. Facility communications system is described in Chapter 9.0, Section 9.4.

7.2.3.7 Analytical Laboratory System

The analytical laboratory will support the production of the Mo product and recycle of uranium. Samples from the process will be collected, transported to the laboratory, and prepared in the laboratory gloveboxes and hoods, depending on the analysis to be performed. The analytical laboratory equipment will be provided as vendor package units. Control room monitoring of the analytical laboratory will be limited to the facility systems, including ventilation and radiation monitoring systems. Analytical laboratory system is described in Chapter 9.0, Section 9.7.3.

7.2.4 System Performance Analysis

The RPF I&C system will monitor the processes and ESFs when required. The IROFS will be managed by the FPC system. The FPC system will provide the central decision-making processor that evaluates monitored parameters from the various plant instrumentation and from the radiation monitoring systems of the CAMs, CAAS, and RAMs. The analysis herein discusses safety as it relates to the IROFS design criteria and design basis. Potential variables, conditions, or other items that will be probable subjects of technical specifications associated with the RPF I&C systems are provided in Chapter 14.0, "Technical Specifications."

7.2.4.1 Facility Trip and Alarm Design Basis

The design basis information for the FPC system trip functions is based on the following two requirements from Title 10, *Code of Federal Regulations*, Part 70 (10 CFR 70), "Domestic Licensing of Special Nuclear Material."

- **Double-contingency principle** – Process designs should incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible (baseline design criteria of 10 CFR 70.64, "Requirements for New Facilities or New Processes at Existing Facilities," paragraph [9]).
- The safety program will ensure that each IROFS will be available and reliable to perform its intended function when needed and in the context of the performance requirements of this section (10 CFR 70.61, "Performance Requirements," paragraph [e]).

The FPC system trip and alarm annunciation are protective functions and will be part of the overall protection and safety monitoring systems for the RPF. The specific equipment design basis for the instrumentation and equipment used for the FPC system trip and alarming functions is discussed in Section 7.2.2.

The following discussion relates to the design basis used for monitoring specific signal values for RPF trips and alarms, requirements for performance, requirements for specific modes of operation of the RPF and the FPC system, and the general design criteria noted in Table 7-1.

7.2.4.1.1 Safety Functions Corresponding Protective or Mitigative Actions for Design Basis Events

IEEE 603-2009, *IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations* (Sections 4a and 4b). The results of the integrated safety analysis (ISA) for the RPF structures, systems, and components (SSC) are discussed in Chapter 13.0, "Accident Analysis." Conditions that require monitoring and the subsequent action to be taken are described in Chapter 13.0.

7.2.4.1.2 Variable Monitored to Control Protective or Mitigative Action

IEEE 603-2009 (Section 4d). The list of variables to be monitored in the RPF to eliminate or reduce the exposure for the operator will be provided in the Operating License Application.

7.2.4.1.3 Functional Degradation of Safety System Performance

IEEE 603-2009 (Section 4h). These design requirements will be factored in and will be evaluated in the Operating Licensing Application.

7.2.4.2 Analysis

7.2.4.2.1 Facility Process Control System Trip Function Conformance to Applicable Criteria

The FPC system will perform a trip as a protective function as part of the RPF safety analysis. The associated design criteria are discussed in Sections 7.2.1 and 7.2.2. The following discussions relate to conformance to the criteria for the FPC system trip function.

7.2.4.2.2 General Functional Requirement Conformance

IEEE 603-2009 (Section 5). The FPC system will initiate and control ESF activation and isolation, in addition to the ability of the ESF systems to perform the same, when the system detects an off-normal event appropriate for activation. The FPC system trips are discussed in Section 7.2.4.1. These monitored values and subsequent trips are a result of the preliminary accident analysis in Chapter 13.0 and provide a means to mitigate or reduce the consequences from the design basis accident to acceptable levels.

7.2.4.2.3 Requirements on Bypassing Trip Functions Conformance

IEEE 603-2009 (Sections 5.8, 5.9, 6.6, and 6.7). Trip override or bypass is recognized as a design requirement. Channel bypass will be allowed based on the nature of the signal. No channel bypass will be allowed without a visual indication on the FPC system display and recording the bypass event in the historical log.

7.2.4.2.4 Requirements on Setpoint Determination and Multiple Setpoint Conformance

IEEE 603-2009 (Section 6.8). Table 7-1 discusses the criteria to be used for setpoint derivation. Setpoints will be calculated in accordance with ISA-RP-67.04.02, *Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation*.

7.2.4.2.5 Requirements for Completion of Trip Conformance

IEEE 603-2009 (Section 5.2). The ESF and the interaction of a mitigative action going to completion will be provided in the design. The FPC system will monitor for a complete trip of the ESF. This information will be available on the operator display for the FPC system and at the local HMI terminals near the hot cell. An alarm/event annunciation will be displayed to the operator. Section 7.4.1 describes the activation of the ESF, alarm/event strategy, and operator requirements to manually reset the system after a facility trip.

7.2.4.2.6 Requirements for Manual Control of Trip Conformance

IEEE 603-2009 (Section 6.2). The FPC system will have the ability to perform a manual activation of the ESF. Section 7.4.1 describes the activation of the ESF, alarm/event strategy, and operator requirements to manually reset the system after a facility trip.

7.2.4.3 Conclusion

The I&C systems for the RPF will meet the stated design criteria and design basis requirements outlined in NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*. A crosswalk of the I&C subsystems, along with a cross-reference to specific design criteria, is presented in Table 7-2.

Table 7-2. Instrumentation and Control Criteria Crosswalk with Design Basis Applicability and Function Means (4 pages)

Criteria[a]	Design basis applicability	Functional means
IEEE 379 Single failure criterion	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	• Safety DCS preapproved platform • Redundant independent isolation components • Redundant operator interface workstations • Redundant sensors • Alternative manual means for ESF initiation
IEEE 577 Reliability analysis criterion	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	• Safety DCS pre-approved platform for an SIS • Redundant independent isolation components • Redundant operator interface workstations • Redundant sensors • Alternative manual means for ESF initiation
IEEE 603 Standard criteria safety system	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	See Section 7.3 for details.
IEEE 384 Independence of Class 1E equipment and circuits	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	• IEEE 603 and IEEE 379 were used during development of the Construction Permit Application. • Additional details will be developed for the Operating License Application.
IEEE 323 Qualifying Class 1E Equipment	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	• Standard supports selection and qualification of equipment to be Class 1E use qualified. • This standard will be reevaluated in the Operating License Application for applicability.
IEEE 344 Recommended practice for seismic qualification	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	• Standard supports selection and qualification of equipment to be Class 1E use qualified. • Standard will be reevaluated in the Operating License Application for applicability.
IEEE 338 Criteria for the periodic surveillance testing of safety systems	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	• Standard supports selection of equipment; which resulted in the use of general design criteria (presented in Chapter 3.0) during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.

Table 7-2. Instrumentation and Control Criteria Crosswalk with Design Basis Applicability and Function Means (4 pages)

Criteria[a]	Design basis applicability	Functional means
IEEE 497 Criteria for accident monitoring instruments	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • CAAS • RAMs • CAMs	• Standard supports selection of accident monitoring equipment (e.g., radiation monitoring, annunciation), which resulted in the use of general design criteria (presented in Chapter 3.0) during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
IEEE 7-4.3.2 Criteria for digital computers in safety systems	• FPC system • FPC system display • HMI displays	• Programming software must comply with these criteria and with the NWMI Software Quality Assurance Plan (prepared during development of the Operating License Application), which will be developed per the design criteria outlined in Chapter 3.0 and this standard. • Software and hardware used for the displays for the FPC system and HMI must also follow guidelines set forth in this standard. • Standard will be reevaluated in the Operating License Application for applicability.
IEEE 828 Configuration management in systems and software engineering	• FPC system • FPC system display • HMI displays	• Complies with IEEE 7-4.3.2 and the NWMI Software Quality Assurance Plan • Standard will be reevaluated in the Operating License Application for applicability.
IEEE 829 Software and system test documentation	• FPC system • FPC system display • HMI displays	• Complies with IEEE 7-4.3.2 and the NWMI Software Quality Assurance Plan • Standard will be reevaluated in the Operating License Application for applicability.
IEEE 1012 Criteria for software verification and validation	• FPC system • FPC system display • HMI displays	• Complies with IEEE 7-4.3.2 and the NWMI Software Quality Assurance Plan • Standard will be reevaluated in the Operating License Application for applicability.
IEEE 1028 Software reviews and audits	• FPC system • FPC system display • HMI displays	• Complies with IEEE 7-4.3.2 and the NWMI Software Quality Assurance Plan • Standard will be reevaluated in the Operating License Application for applicability.
ANS-10.4 Verification and validation for non-safety software	• FPC system • FPC system display • HMI displays	• Complies with IEEE 7-4.3.2 and the NWMI Software Quality Assurance Plan • Standard will be reevaluated in the Operating License Application for applicability.

Table 7-2. Instrumentation and Control Criteria Crosswalk with Design Basis Applicability and Function Means (4 pages)

Criteria[a]	Design basis applicability	Functional means
ANSI/ISA 67.04.01 Setpoints for nuclear safety-related instruments	• FPC system • FPC system IROFS end devices	• Incorporated into overall design and the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
ANSI/ISA 84.00.01, Parts 1, 2, and 3 Functional safety: safety instrumented systems for the process industry sector	• FPC system • FPC system display • HMI displays	• Standard supports the design and development of non-safety-related systems that rely on safety, reliability, and functionality and was used during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
NUREG-0700 Human-system interface design review guidelines	• FPC system • FPC system display • HMI displays	• Standard supports the design and development of non-safety-related systems that pertain to control room arrangement, screen developments, and operator interface, and was used during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
NUREG/CR-6463 Review guidelines on software languages for use in nuclear power plant safety systems	• FPC system	• Standard supports the design, development, and review of safety-related software and was used during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
NUREG/CR-6090 PLC and applications in nuclear reactor systems	• FPC system	• Standard supports the design, development, and review of safety-related and non-safety-related software and was used during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
EPRI TR-106439 Guideline on evaluation/acceptance of commercial grade digital equipment for nuclear safety applications	• FPC system display • HMI displays	• Standard supports the design, development, and review of safety-related systems that pertain to obtaining software or hardware for the FPC system, HMI displays, and data acquisition systems, and was used during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.

Table 7-2. Instrumentation and Control Criteria Crosswalk with Design Basis Applicability and Function Means (4 pages)

Criteria[a]	Design basis applicability	Functional means
Regulatory Guide 1.152 Criteria for use of computers in safety systems	• FPC system • FPC system display • HMI displays	• Standard supports the design and development of redundant safety PLC platforms, FPC system redundant HMI workstations, and operator interface workstations, and was used during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
Regulatory Guide 1.53 Single failure criterion evaluation for safety systems	• FPC system • FPC system display • FPC system IROFS end devices • ESFs • ESFs manual isolation	• Standard supports the design and development of high-integrity safety PLCs, redundant channels for ESFs, redundant operator interface workstations, redundant sensors, and alternative manual means for ESF initiation, and was used during development of the Construction Permit Application. • Standard will be reevaluated in the Operating License Application for applicability.
Regulatory Guide 5.71 Cybersecurity programs for nuclear facilities	• FPC system • FPC system display • HMI display	• Criteria require the development of a design approach and implementation for cybersecurity. • Standard will be reevaluated in the Operating License Application for applicability.

[a] Full references are provided in Section 7.7.

CAAS	= criticality accident alarm system.	IROFS	= items relied on for safety.
CAM	= continuous air monitor.	NWMI	= Northwest Medical Isotopes, LLC.
DCS	= digital control system.	PLC	= programmable logic controller.
ESF	= engineered safety feature.	RAM	= radiation alarm monitor.
FPC	= facility process control.	SIS	= safety instrumented system.
HMI	= human-machine interface.		

7.3 PROCESS CONTROL SYSTEMS

The process control systems for the RPF will include SNM preparation and handling processes and radioisotope production processes. SNM preparation and handling processes include uranium recovery and recycle, and target fabrication. Radioisotope production processes include target receipt and disassembly, target dissolution, Mo recovery and purification, and waste handling.

The RPF process control system includes interlocks (both hardwired [ESF] and computer logic) to implement an automatic action on a parameter approaching or being outside its setting. Interlocks are defined as specific set of conditions or parameters that need to be met for an activity to occur. An example of an interlock is the shutting down a pump on a tank high-level alarm signal or switching to a spare unit or process train based on a change in parameters (and corresponding alarm). In addition to interlocks, the RPF will also implement a permissive philosophy that allows HMI operations to be enabled once the control room has confirmed the prerequisites conditions have been completed. Permissives differ from interlocks in that permissives require manual approval via a switch (or similar) that must be satisfied for an activity to occur. Interlocks are engineered features, and permissives are administrative features. The permissive and interlocks will be described in more detail in the Operating License Application.

The RPF process control will be administered by the FPC system and is described in Section 7.2.3. The FPC system will perform the following high-level process functions.

- **Monitor the remote valve position for routing process fluid for inter-equipment process fluid transfers** – For specific transfers identified by the operator, the FPC system will provide a permissive to allow for the active pump in that circuit to be energized once the operator has manually configured the routing.
- **Monitor and control inter-equipment process fluid transfers in the RPF** – For transport requiring a pump, the FPC system will control the ability of the pump to be energized. For specific transfers, the FPC system will provide controlled fluid flow transfers based on a closed-loop flow control. The operator will initialize the transfer of fluids.
- **Other process fluid transfers**, including:
  - Dissolved low-enriched uranium (LEU) solution to the Mo recovery and purification system
  - Uranium solution to the uranium recovery and recycle system
  - Liquid wastes to the waste handling system

The I&C system for process utilities and support systems and for the ventilation systems will be described in more detail in the Operating License Application. The process systems described below provide for reliable control of the SNM preparation and handling process and the radioisotope production processes, and include:

- Range of operation of the sensor that is sufficient to cover the expected range of variation of the monitored variable during normal and transient process operation
- Reliable information about the status and magnitude of the process variable necessary for the full operating range of the radioisotope production and SNM recovery and recycle processes
- Reliable operation in the normal range of environmental conditions anticipated within the facility
- Safe state during loss of electrical power

Potential variables, conditions, or other items that will be probable subjects of technical specifications associated with the RPF process control systems are discussed in Chapter 14.0.

7.3.1 Uranium Recovery and Recycle System

The uranium recovery and recycle system will process raffinate from the Mo recovery and purification system for recycle to the target fabrication system. Two cycles of uranium purification will be included to separate uranium from unwanted fission products using ion exchange. The first ion exchange cycle will separate the bulk of the fission product contaminant mass from the uranium product. Product will exit the ion exchange column as a dilute uranium stream that is concentrated to control the stored volume of process solutions. Uranium from the first cycle will then be purified by a nearly identical second cycle system to further reduce fission product contaminants to satisfy product criteria. Each ion exchange system feed tank will include the capability of adding a reductant and modifying the feed chemical composition such that adequate separations are achieved, while minimizing uranium losses.

Due to the variety of process activities performed during uranium recovery and recycle, the system description is divided into the following subsystems:

- Impure uranium collection
- Primary ion exchange
- Primary concentration
- Secondary ion exchange
- Secondary concentration
- Uranium recycle
- Uranium decay and accountability
- Spent ion exchange resin
- Waste collection

7.3.1.1 Design Criteria

Design criteria for the uranium recovery and recycle I&C systems are described in Section 7.2.

7.3.1.2 Design Basis and Safety Requirements

The design basis and safety requirements for the uranium recovery and recycle I&C systems are described in Section 7.2. The ESFs for this system are listed in Chapter 6.0, "Engineered Safety Features."

7.3.1.3 System Description

The uranium recovery and recycle I&C system will be defined in the Operating License Application. The strategy and associated parameters for the system are provided below. Preliminary process sequences are provided in Chapter 4.0 to communicate the control strategy for normal operations, which sets the requirements for the process monitoring and control equipment, and the associated instrumentation.

Normal operating functions will be performed remotely using the FPC system in the control room. Table 7-3 lists the anticipated control parameters, monitoring parameters, and primary control locations for each subsystem. In addition, the implementation of IROFS CS-14, CS-15, CS-20, CS-27, and RS-10 interlocks for this system are under development. Details of the control system (e.g., interlocks and permissive signals), nuclear and process instruments, control logic and elements, indication, alarm, and control features will be developed for the Operating License Application.

Table 7-3. Uranium Recovery and Recycle Control and Monitoring Parameters (2 pages)

Subsystem name	Control parameters (automatic/manual)	Monitoring parameters	Primary control location
Impure uranium collection	• Flowrate (A) • Pump actuation (M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Density • Differential pressure • Flowrate • Level • Pressure • Temperature • Valve position	Control room
Primary ion exchange	• Flowrate (A) Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Analyzer, uranium • Density • Differential pressure • Flowrate • Flowrate totalizer • Level • Pressure • Temperature • Valve position	Control room
Primary concentration	• Density (A) • Flowrate (A) • Level (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Analyzer, uranium • Density • Differential pressure • Flowrate • Level • Pressure • Temperature • Valve position	Control room
Secondary ion exchange	• Flowrate (A) Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Analyzer, uranium • Density • Differential pressure • Flowrate • Flowrate totalizer • Level • Pressure • Temperature • Valve position	Control room
Secondary concentration	• Density (A) • Flowrate (A) • Level (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Analyzer, uranium • Density • Differential pressure • Flowrate • Level • Pressure • Temperature • Valve position	Control room
Uranium recycle	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Valve actuation (A/M)	• Density • Differential pressure • Flowrate • Level • Pressure • Temperature • Valve position	Control room

Table 7-3. Uranium Recovery and Recycle Control and Monitoring Parameters (2 pages)

Subsystem name	Control parameters (automatic/manual)	Monitoring parameters	Primary control location
Uranium decay and accountability	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Density • Differential pressure • Flowrate • Level • Pressure • Temperature • Valve position	Control room
Spent ion exchange resin	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Valve actuation (A/M)	• Analyzer, uranium • Differential pressure • Flowrate • Level • Pressure • Valve position	Control room
Waste collection	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Density • Differential pressure • Flowrate • Level • Pressure • Valve position	Control room

Table 7-4 provides a preliminary listing of the interlocks and permissive signals that have been identified. These devices will be further developed and detailed information will be provided in the Operating License Application.

Table 7-4. Uranium Recycle and Recovery System Interlocks and Permissive Signals (4 pages)

Interlock or permissive input	Hard-wired or PLC	Safety Interlock
Impure uranium collection tank (UR-TK-100A) low-level switch (typical of eight tanks)	PLC	N/A
Impure uranium collection tank (UR-TK-100A) high-level switch (typical of eight tanks)	PLC	N/A
Impure uranium collection tank (UR-TK-100A) high-temperature switch (typical of eight tanks)	PLC	N/A
IX feed tank 1 (UR-TK-200) low-level switch	PLC	N/A
IX feed tank 1 (UR-TK-200) high-level switch	PLC	N/A
IX feed tank 1 (UR-TK-200) high-temperature switch	PLC	N/A
IX column 1A (UR-IX-240) high-uranium alarm (AAH-252)	PLC	N/A
IX column 1A U solution filter (UR-F-250) high-differential pressure alarm	PLC	N/A
IX column 1A waste filter (UR-F-255) high-differential pressure alarm	PLC	N/A
IX column 1B (UR-IX-260) high-uranium alarm (AAH-272)	PLC	N/A
IX column 1B U solution filter (UR-F-270) high-differential pressure alarm	PLC	N/A

Table 7-4. Uranium Recycle and Recovery System Interlocks and Permissive Signals (4 pages)

Interlock or permissive input	Hard-wired or PLC	Safety Interlock
IX Column 1B Waste Filter (UR-F-275) high-differential pressure alarm	PLC	N/A
Concentrator 1 feed tank (UR-TK-300) low-level switch	PLC	N/A
Concentrator 1 feed tank (UR-TK-300) high-level switch	PLC	N/A
Concentrator 1 (UR-Z-320) low-liquid level alarm	PLC	N/A
Concentrator 1 (UR-Z-320) high-liquid level alarm	PLC	N/A
Concentrator 1 (UR-Z-320) demister high-differential pressure alarm	PLC	N/A
Concentrator 1 (UR-Z-320) condenser high-differential pressure alarm	PLC	N/A
Concentrator 1 (UR-Z-320) condenser high-offgas temperature alarm	PLC	N/A
Condensate sample tank 1A (UR-TK-340) high-liquid level alarm	PLC	N/A
Condensate sample tank 1A (UR-TK-340) high-uranium switch (AE-356)	Hard-wired	Reroute condensate transfer to UR-TK-300 (position V-396, close V-397) Close IX column eluent addition control valves (V-244 and V-264)
Condensate delay tank 1 (UR-TK-370) high-liquid level alarm	PLC	N/A
Condensate sample tank 1B (UR-TK-340) high-liquid level alarm	PLC	N/A
Condensate sample tank 1B (UR-TK-370) high-uranium switch (AE-386)	Hard-wired	Permissive to route condensate to WH-TK-420 (position V-496, open V-397) Permissive to open IX column eluent addition control valves (V-244 and V-264)
IX feed tank 2A (UR-TK-400) low-level switch	PLC	N/A
IX feed tank 2A (UR-TK-400) high-level switch	PLC	N/A
IX feed tank 2A (UR-TK-400) high-temperature switch	PLC	N/A
IX feed tank 2B (UR-TK-420) low-level switch	PLC	N/A
IX feed tank 2B (UR-TK-420) high-level switch	PLC	N/A
IX feed tank 2B (UR-TK-420) high-temperature switch	PLC	N/A
IX column 2A (UR-IX-460) high-uranium alarm (AAH-472)	PLC	N/A
IX column 2A U solution filter (UR-F-470) high-differential pressure alarm	PLC	N/A
IX column 2A waste filter (UR-F-475) high-differential pressure alarm	PLC	N/A
IX column 2B (UR-IX-480) high-uranium alarm (AAH-492)	PLC	N/A

Table 7-4. Uranium Recycle and Recovery System Interlocks and Permissive Signals (4 pages)

Interlock or permissive input	Hard-wired or PLC	Safety Interlock
IX column 2B U solution filter (UR-F-490) high-differential pressure alarm	PLC	N/A
IX column 2B waste filter (UR-F-495) high-differential pressure alarm	PLC	N/A
Concentrator 2 feed tank (UR-TK-500) low-level switch	PLC	N/A
Concentrator 2 feed tank (UR-TK-500) high-level switch	PLC	N/A
Concentrator 2 (UR-Z-520) low-liquid level alarm	PLC	N/A
Concentrator 2 (UR-Z-520) high-liquid level alarm	PLC	N/A
Concentrator 2 (UR-Z-520) demister high-differential pressure alarm	PLC	N/A
Concentrator 2 (UR-Z-520) condenser high-differential pressure alarm	PLC	N/A
Concentrator 2 (UR-Z-520) condenser high-offgas temperature alarm	PLC	N/A
Condensate sample tank 2A (UR-TK-540) high-liquid level alarm	PLC	N/A
Condensate sample tank 2A (UR-TK-540) high-uranium switch (AE-556)	Hard-wired	Reroute condensate transfer to UR-TK-500 (position V-596, close V-597) Close IX column eluent addition control valves (V-464 and V-484)
Condensate delay tank 2 (UR-TK-560) high-liquid level alarm	PLC	N/A
Condensate sample tank 2B (UR-TK-570) high-liquid level alarm	PLC	N/A
Condensate sample tank 2B (UR-TK-570) high-uranium switch (AE-586)	Hard-wired	Permissive to route condensate to WH-TK-420 (position V-596, open V-597) Permissive to open IX column eluent addition control valves (V-464 and V-484)
Concentrate receiver tank (UR-TK-600) high-liquid level alarm	PLC	N/A
Concentrate receiver tank (UR-TK-600) high-temperature alarm	PLC	N/A
Product sample tank (UR-TK-620) high-liquid level alarm	PLC	N/A
Product sample tank (UR-TK-620) high-temperature alarm	PLC	N/A
Uranium rework tank (UR-TK-660) high-liquid level alarm	PLC	N/A
Uranium rework tank (UR-TK-660) high-temperature alarm	PLC	N/A
Uranium decay tank (UR-TK-700A) high-liquid level alarm (typical of 17 tanks)	PLC	N/A
Uranium decay tank (UR-TK-700A) high-temperature alarm (typical of 17 tanks)	PLC	N/A

Table 7-4. Uranium Recycle and Recovery System Interlocks and Permissive Signals (4 pages)

Interlock or permissive input	Hard-wired or PLC	Safety Interlock
Uranium accountability tank (UR-TK-720) high-liquid level alarm	PLC	N/A
Uranium accountability tank (UR-TK-720) high-temperature alarm	PLC	N/A
Spent resin tank A (UR-TK-820A) high-liquid level alarm	PLC	N/A
Spent resin tank A (UR-TK-820A) high-temperature alarm	PLC	N/A
Spent resin tank B (UR-TK-820B) high-liquid level alarm	PLC	N/A
Spent resin tank B (UR-TK-820B) high-temperature alarm	PLC	N/A
Resin transfer liquid tank (UR-TK-850) high-liquid level alarm	PLC	N/A
IX waste collection 1 tank (UR-TK-900) high-liquid level alarm	PLC	N/A
IX waste collection 1 tank (UR-TK-900) high-temperature alarm	PLC	N/A
IX waste collection 2 tank (UR-TK-920) high-liquid level alarm	PLC	N/A
IX waste collection 2 tank (UR-TK-920) high-temperature alarm	PLC	N/A

IX = ion exchange.
PLC = programmable logic controller.
TBD = to be determined.

7.3.1.4 System Performance Analysis and Conclusion

The system performance analysis and conclusion for each process system will be provided in the Operating License Application.

7.3.2 Target Fabrication System

The target fabrication system will produce LEU targets from fresh LEU material and recycled uranyl nitrate. The system will commence with the receipt of fresh LEU from the U.S. Department of Energy, and end with packaging new targets for shipment to the university research reactor facilities.

Due to the variety of process activities performed during target fabrication, the system description is divided into the following subsystems.

- Fresh uranium receipt and dissolution
- Nitrate extraction
- Acid-deficient uranyl nitrate (ADUN) concentration
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- Target fabrication waste
- Target assembly
- [Proprietary Information]
- New target handling

7.3.2.1 Design Criteria

Design criteria for the target fabrication I&C systems are described in Section 7.2.

7.3.2.2 Design Basis and Safety Requirements

The design basis and safety requirements for the target fabrication I&C systems are described in Section 7.2. The ESFs for this system are listed in Chapter 6.0.

7.3.2.3 System Description

The target fabrication I&C system will be defined in the Operating License Application. The strategy and associated parameters for the I&C system are provided below. Preliminary process sequences are provided in Chapter 4.0 to communicate the control strategy for normal operations, which sets the requirements for the process monitoring and control equipment, and the associated instrumentation.

Normal operating functions will be performed remotely using the FPC system HMI in the target fabrication area. Table 7-5 lists the anticipated control parameters, monitoring parameters, and primary control location for each subsystem. In addition, the implementation of IROFS CS-14, CS-15, CS-20, CS-27, and RS-10 interlocks for this system are under development. Details of the control system (e.g., interlocks and permissive signals), nuclear and process instruments, control logic and elements, indication, alarm, and control features will be developed for the Operating License Application.

Table 7-5. Target Fabrication System Control and Monitoring Parameters (2 pages)

Subsystem name	Control parameters (automatic/manual)	Monitoring parameters	Primary control location
Fresh uranium receipt and dissolution (100-series tag numbers)	• Current (A) • Conductivity (A) • Flow totalizer (A) • Heater actuation (A/M) • Level (A) • Pump actuation (A/M) • Temperature (A) • Valve actuation (A/M)	• Conductivity • Density • Differential pressure • Flowrate • Level • Pressure • Temperature	Local
Nitrate extraction (200-series tag numbers)	• Analyzer, pH (A) • Contactor actuation (M) • Flow totalizer (A) • Flowrate (A) • Level (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Analyzer, pH • Density • Differential pressure Flowrate • Level • Pressure • Pump motor speed • Temperature	Local
ADUN concentration (300-series tag numbers)	• Conductivity (A) • Density (A) • Flowrate (A) • Level (A) • Pump actuation (A/M) • Pump motor speed (A) • Valve actuation (A/M)	• Conductivity • Density • Flowrate • Level • Pressure • Temperature	Local

Table 7-5. Target Fabrication System Control and Monitoring Parameters (2 pages)

Subsystem name	Control parameters (automatic/manual)	Monitoring parameters	Primary control location
[Proprietary Information] (400-series tag numbers)	• Level (A) • Pump actuation (A/M) • Tank agitator actuation (A/M) • Tank agitator speed (A) • Temperature (A) • Valve actuation (A/M)	• Flowrate • Level • Pressure • Temperature	Local
[Proprietary Information] (500-series tag numbers)	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M) • Vibration dispersion assembly actuation (M)	• Density • Differential pressure • Pressure • Level • Temperature • Vibration	Local
[Proprietary Information] (600-series tag numbers)	• Analyzer, hydrogen (A) • Analyzer, oxygen (A) • Flow totalizer (A) • Level (A) • Tank agitator speed (M) • Temperature (A) • Valve actuation (A/M)	• Analyzer, hydrogen • Analyzer, oxygen • Flowrate • Level • Pressure • Temperature	Local
Target fabrication waste (700-series tag numbers)	• Flowrate (A) • Level (A) • Pump actuation (A/M) • Pump motor speed (A) • Valve actuation (A/M)	• Density • Flowrate • Level • Pressure • Temperature	Local
Target assembly	TBD	TBD	Local
[Proprietary Information]	TBD	TBD	Local
New target handling	TBD	TBD	Local

ADUN = acid-deficient uranyl nitrate.
LEU = low-enriched uranium.
TBD = to be determined.

Table 7-6 provides a listing of the target fabrication I&C system interlocks and permissive signals that have been identified. These devices will be further developed and detailed information will be provided in the Operating License Application.

Table 7-6. Target Fabrication System Interlocks and Permissive Signals (2 pages)

Interlock or permissive input	Hard-wired or PLC	Safety interlock
Dissolver column (TF-D-100) high-temperature switch	PLC	N/A
Uranium dissolution heat exchanger (TF-E-120) chilled water return high-conductivity switch	Hard-wired	Close chilled water return control valve (XV-122) on high conductivity
Uranium dissolution heat exchanger (TF-E-120) low-differential pressure alarm	PLC	N/A
Uranyl nitrate storage tank (TF-TK-200) level switch	PLC	N/A
ADUN evaporator condenser (TF-E-350) chilled water return high-conductivity switch	Hard-wired	Close chilled water return control valve (HV-352) on high conductivity
ADUN product heat exchanger (TF-E-360) low-differential pressure alarm	PLC	N/A
ADUN product heat exchanger (TF-E-360) chilled water return high-conductivity switch	Hard-wired	Close chilled water return control valve (HV-361) on high conductivity
ADUN evaporator reboiler (TF-E-330) steam condensate high-conductivity switch	Hard-wired	Close steam condensate control valve (XV-333) on high conductivity
ADUN storage tank (TF-TK-400) low-level switch	PLC	N/A
ADUN storage tank (TF-TK-405) low-level switch	PLC	N/A
ADUN storage tank (TF-TK-410) low-level switch	PLC	N/A
ADUN storage tank (TF-TK-415) low-level switch	PLC	N/A
ADUN storage tank (TF-TK-400) high-level switch	PLC	N/A
ADUN storage tank (TF-TK-405) high-level switch	PLC	N/A
ADUN storage tank (TF-TK-401) high-level switch	PLC	N/A
ADUN storage tank (TF-TK-415) high-level switch	PLC	N/A
[Proprietary Information] (TF-TK-480) high-level switch	PLC	N/A
[Proprietary Information] (TF-C-500) high-temperature switch	PLC	N/A
Silicone oil heater (TF-E-550) outlet high-temperature switch	Hard-wired	N/A
[Proprietary Information] (TF-Z-660) high-temperature switch	Hard-wired	N/A
[Proprietary Information] (TF-Z-661) high-temperature switch	Hard-wired	N/A
[Proprietary Information] (TF-Z-662) high-temperature switch	Hard-wired	N/A
[Proprietary Information] (TF-Z-663) high-temperature switch	Hard-wired	N/A
[Proprietary Information] (TF-Z-660) door closed switch	PLC	N/A
[Proprietary Information] (TF-Z-661) door closed switch	PLC	N/A

Table 7-6. Target Fabrication System Interlocks and Permissive Signals (2 pages)

Interlock or permissive input	Hard-wired or PLC	Safety interlock
[Proprietary Information] (TF-Z-662) door closed switch	PLC	N/A
[Proprietary Information] (TF-Z-663) door closed switch	PLC	N/A
Reduction furnace offgas heat exchanger (TF-E-670) outlet high-oxygen concentration	PLC	N/A
Reduction furnace offgas heat exchanger (TF-E-670) outlet high-hydrogen concentration	PLC	N/A
Aqueous waste pencil tank (TF-TK-700) high-level alarm	PLC	N/A
Aqueous waste pencil tank (TF-TK-705) high-level alarm	PLC	N/A
TCE tank (TF-TK-760) high-level switch	PLC	N/A
Target fabrication overflow tank (TF-TK-770) high-high-level switch	PLC	N/A

ADUN = acid-deficient uranyl nitrate.
PLC = programmable logic controller.
TBD = to be determined.
TCE = trichloroethylene.

7.3.2.4 System Performance Analysis and Conclusion

The system performance analysis and conclusion for each process system will be provided in the Operating License Application.

7.3.3 Target Receipt and Disassembly System

The target receipt and disassembly system will include the delivery and receipt of the irradiated target cask, introduction of the irradiated targets into the hot cell, disassembly of the targets, and retrieval and transfer of the irradiated target material for processing. This system will feed the target dissolution system by the transfer of recovered irradiated target material through the dissolver 1 hot cell (DS-EN-100) and dissolver 2 hot cell (DS-EN-200) isolation door interfaces.

Due to the variety of activities performed during target receipt and disassembly, the system description is divided into the following subsystems:

- Cask receipt
- Target receipt
- Target disassembly

7.3.3.1 Design Criteria

Design criteria for the target receipt and disassembly I&C systems are described in Section 7.2.

7.3.3.2 Design Basis and Safety Requirements

The design basis and safety requirements for the target receipt and disassembly I&C systems are described in Section 7.2. The ESFs for this system are listed in Chapter 6.0.

7.3.3.3 System Description

The target receipt and disassembly I&C system will be defined in the Operating License Application. The strategy and associated parameters for the I&C system are provided below. Preliminary process sequences are provided in Chapter 4.0 to communicate the control strategy for normal operations, which sets the requirements for the process monitoring and control equipment, and the associated instrumentation.

Normal operating functions will be performed remotely using the FPC system HMI in the truck bay, cask preparation airlock, and the operating gallery. Redundant control functions will be provided in the control room. In addition, the implementation of IROFS CS-14, CS-15, CS-20, CS-27, and RS-10 interlocks for this system are under development. Details of the control system (e.g., interlocks and permissive signals), nuclear and process instruments, control logic and elements, indication, alarm, and control features will be developed for the Operating License Application.

Prior to the start of disassembly operations, the following process control permissive signals will be required.

- Ventilation inside the hot cell is operable.
- Fission gas capture hood is on and functional.
- Irradiated target material collection container is in position under the target cutting assembly collection bin.
- Waste drum transfer port is open and there is physical space to receive the waste target hardware after disassembly and irradiated target material recovery.

The control parameters and monitoring parameters will be defined during design development for the Operating License Application.

7.3.3.4 System Performance Analysis and Conclusion

The system performance analysis and conclusion for each process system will be provided in the Operating License Application.

7.3.4 Target Dissolution System

The target dissolution system process will receive the LEU target material from the target receipt and disassembly system and dissolve the uranium and molybdenum-99 (^{99}Mo) in the solid irradiated target material in hot nitric acid. The concentrated uranyl nitrate solution will then be transferred to the Mo recovery and purification system for further processing.

The target dissolution process will be operated in a [Proprietary Information] transferred to a collection container. The collection container will move through the pass-through to a dissolver basket positioned over a dissolver, the target material will then be dissolved and the resulting solution transferred to the Mo recovery and purification system.

Target dissolution of irradiated LEU will result in gaseous fission products (iodine [I], krypton [Kr], and xenon [Xe]) with very high radiation fields. A primary function of the process offgas systems will be to control release of these gases both internal and external to the facility. The dissolver offgas treatment system will include the nitrogen oxide (NO_x) treatment and fission gas treatment subsystems.

Due to the variety of process activities performed during target dissolution, the system description is divided into the following subsystems:

- Target dissolution 1 and target dissolution 2
- NO_x treatment 1 or NO_x treatment 2
- Pressure relief
- Primary fission gas treatment
- Secondary fission gas treatment
- Waste collection

7.3.4.1 Design Criteria

Design criteria for the target dissolution I&C systems are described in Section 7.2.

7.3.4.2 Design Basis and Safety Requirements

The design basis and safety requirements for the target dissolution I&C systems are described in Section 7.2. The ESFs for this system are listed in Chapter 6.0.

7.3.4.3 System Description

The target dissolution I&C system will be defined in the Operating License Application. The strategy and associated parameters for the I&C system are provided below. Preliminary process sequences are provided in Chapter 4.0 to communicate the control strategy for normal operations, which sets the requirements for the process monitoring and control equipment, and the associated instrumentation.

Loading of [Proprietary Information] into the dissolver will involve mechanical handling of the transfer containers. Operators using remote in-cell cranes and manipulators will perform these functions. Other normal operating functions will be performed remotely using the FPC system HMI in the operating gallery. Redundant control functions will be provided in the control room. Table 7-7 lists the anticipated control parameters, monitoring parameters, and primary control locations for each subsystem. Details of the control system (e.g., interlocks and permissive signals), control logic, indication, alarm, and control features will be defined in the Operating License Application.

Table 7-7. Target Dissolution System Control and Monitoring Parameters

Subsystem name	Control parameters (automatic/manual)	Monitoring parameters	Primary control location
Target dissolution 1 and 2	• Dissolver agitator actuation (A/M) • Dissolver agitator speed (A) • Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Dissolver agitator speed • Flowrate • Flowrate totalizer • Level • Pressure • Radiation • Temperature • Valve position	Operating gallery
NO_x treatment 1 or 2	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Differential pressure • Flowrate • Flowrate totalizer • Level • Pressure • Radiation • Temperature • Valve position	Operating gallery
Pressure relief	• Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Flowrate • Level • Pressure • Valve position	Operating gallery
Primary fission gas treatment	• Temperature (A) • Valve actuation (A/M)	• Differential pressure • Flowrate • Pressure • Radiation • Temperature • Valve position	Operating gallery
Secondary fission gas treatment	• Valve actuation (A/M)	• Differential pressure • Flowrate • Pressure • Radiation • Temperature • Valve position	Operating gallery
Waste collection	• Pump actuation (A/M) • Pump motor Speed (A) • Temperature (A) • Valve actuation (A/M)	• Differential pressure • Flowrate • Level • Temperature • Pressure • Radiation • Valve position	Operating gallery

NO_x = nitrogen oxide.

Table 7-8 provides a preliminary listing of the target dissolution I&C system interlocks and permissive signals that have been identified. In addition, the implementation of IROFS CS-14, CS-15, CS-20, CS-27, and RS-10 interlocks for this system are under development. These devices will be further developed and detailed information will be provided in the Operating License Application.

Table 7-8. Target Dissolution System Interlocks and Permissive Signals (2 pages)

Interlock or permissive input	Hard-wired or PLC	Safety interlock
Dissolver 1 (DS-D-100) high-liquid level alarm	PLC	N/A
Dissolver 1 (DS-D-100) low-liquid level alarm	PLC	N/A
Dissolver 1 (DS-D-100) high liquid temperature alarm	PLC	N/A
Dissolver 1 Condenser (DS-E-130) high gas temperature alarm	PLC	N/A
Dissolver 2 (DS-D-200) high-liquid level alarm	PLC	N/A
Dissolver 2 (DS-D-200) low-liquid level alarm	PLC	N/A
Dissolver 2 (DS-D-200) high liquid temperature alarm	PLC	N/A
Dissolver 2 condenser (DS-E-230) high gas temperature alarm	PLC	N/A
Primary caustic scrubber 1 (DS-C-310) high-liquid level alarm	PLC	N/A
Caustic scrubber 1 (DS-C-310) high gas temperature	PLC	N/A
NO_x oxidizer 1 (DS-C-340) high-liquid level alarm	PLC	N/A
NOx oxidizer 1 (DS-C-340) high gas temperature	PLC	N/A
NO_x absorber 1 (DS-C-370) high-liquid level alarm	PLC	N/A
NOx absorber 1 (DS-C-370) high gas temperature	PLC	N/A
Primary caustic scrubber 2 (DS-C-410) high-liquid level alarm	PLC	N/A
Caustic scrubber 2 (DS-C-410) high gas temperature	PLC	N/A
NO_x oxidizer 2 (DS-C-440) high-liquid level alarm	PLC	N/A
NOx oxidizer 2 (DS-C-440) high gas temperature	PLC	N/A
NO_x absorber 2 (DS-C-470) high-liquid level alarm	PLC	N/A
NOx absorber 2 (DS-C-470) high gas temperature	PLC	N/A
Pressure relief tank (DS-TK-500) high-pressure alarm	Hard-wired	Opens valve to capture dissolver gases
Pressure relief tank (DS-TK-500) high-liquid level alarm	PLC	N/A
Pressure relief tank (DS-TK-500) low-liquid level alarm	PLC	N/A
Dryer A (DS-E-610A) high gas temperature alarm	PLC	N/A
Primary adsorber A (DS-SB-620A) high gas temperature alarm	PLC	N/A
Filter A (DS-F-630A) high-pressure differential alarm	PLC	N/A
Dryer B (DS-E-610B) high gas temperature alarm	PLC	N/A
Primary adsorber B (DS-SB-620B) high gas temperature alarm	PLC	N/A
Filter B (DS-F-630B) high-pressure differential alarm	PLC	N/A
Dryer C (DS-E-610C) high gas temperature alarm	PLC	N/A
Primary adsorber C (DS-SB-620C) high gas temperature alarm	PLC	N/A
Filter C (DS-F-630C) high-pressure differential alarm	PLC	N/A

Table 7-8. Target Dissolution System Interlocks and Permissive Signals (2 pages)

Interlock or permissive input	Hard-wired or PLC	Safety interlock
Secondary adsorber A (DS-SB-730A) high gas temperature alarm	PLC	N/A
Secondary adsorber B (DS-SB-730B) high gas temperature alarm	PLC	N/A
Secondary adsorber C (DS-SB-730C) high gas temperature alarm	PLC	N/A
Waste collection and sampling tank 1 (DS-TK-800) high-liquid level alarm	PLC	N/A
Waste collection and sampling tank 1 (DS-TK-800) high-liquid temperature alarm	PLC	N/A
Waste collection and sampling tank 2 (DS-TK-820) high-liquid level alarm	PLC	N/A
Waste collection and sampling tank 2 (DS-TK-820) high-liquids temperature alarm	PLC	N/A

N/A = not applicable.
NO_x = nitrogen oxide.
PLC = programmable logic controller.

7.3.4.4 System Performance Analysis and Conclusion

The system performance analysis and conclusion for each process system will be provided in the Operating License Application.

7.3.5 Molybdenum Recovery and Purification System

The Mo recovery and purification system will receive the impure Mo/uranium solution from the target dissolution system into feed tank 1A and feed tank 1B (MR-TK-100 and MR-TK-140) located in the tank hot cell. The Mo/uranium solution will then be transferred to process hot cells and processed through three separate ion exchange unit operations to achieve the desired product criteria. A collection container holding the separated and purified Mo product material will be used for final chemical adjustment and sampling for verification of batch acceptance. The product will be sampled and weighed, placed in stainless steel bottles with lids applied and tightened, loaded into shielded containers, and then shipped in an approved cask.

Due to the variety of activities performed during Mo recovery and purification, the system description is divided into the following subsystems:

- Primary ion exchange
- Secondary ion exchange
- Tertiary ion exchange
- Mo product

7.3.5.1 Design Criteria

Design criteria for the Mo recovery and purification I&C systems are described in Section 7.2.

7.3.5.2 Design Basis and Safety Requirements

The design basis and safety requirements for the Mo recovery and purification I&C systems are described in Section 7.2. The ESFs for this system are listed in Chapter 6.0.

7.3.5.3 System Description

The Mo recovery and purification I&C system will be defined in the Operating License Application. The strategy and associated parameters for the I&C system are provided below. Preliminary process sequences are provided in Chapter 4.0 to communicate the control strategy for normal operations, which sets the requirements for the process monitoring and control equipment, and the associated instrumentation.

Operators using remote in-cell manipulators will perform the product transfer and packaging functions. All other normal operating functions will be performed remotely using the FPC system HMI in the operating gallery. Redundant control functions will be provided in the control room. Table 7-9 lists the anticipated control parameters, monitoring parameters, and primary control locations for each subsystem. In addition, the implementation of IROFS CS-14, CS-15, CS-20, CS-27, and RS-10 interlocks for this system are under development. Details of the control system (e.g., interlocks and permissive signals), nuclear and process instruments, control logic and elements, indication, alarm, and control features will be developed for the Operating License Application.

Table 7-9. Molybdenum Recovery and Purification System Control and Monitoring Parameters

Subsystem name	Control parameters (automatic/manual)	Monitoring parameters	Primary control location
Primary ion exchange	• Temperature (A) • Valve actuation (A/M)	• Density • Flowrate • Level • Temperature • Pressure • Radiation • Valve position	Operating gallery
Secondary ion exchange	• Pumps (M)	• Temperature	Operating gallery
Tertiary ion exchange	• Pumps (M)	• Density • Flowrate • Level • Pressure • Temperature	Operating gallery
Molybdenum product	• Actuate capping unit (M)	• Weight	Operating gallery

Table 7-10 provides a preliminary listing of the Mo recovery and purification system interlocks and permissive signals that have been identified. These devices will be further developed and detailed information will be provided in the Operating License Application.

Table 7-10. Molybdenum Recovery and Purification System Interlocks and Permissive Signals

Interlock or permissive input	Hard-wired or PLC	Safety Interlock
Feed tank 1A (MR-TK-100) high-liquid level alarm	PLC	N/A
Feed tank 1A (MR-TK-100) low-liquid level alarm	PLC	N/A
Feed tank 1A (MR-TK-100) high-temperature alarm	PLC	N/A
Feed tank 1A (MR-TK-100) high-pressure alarm	PLC	N/A
Feed tank 1B (MR-TK-140) high-liquid level alarm	PLC	N/A
Feed tank 1B (MR-TK-140) low-liquid level alarm	PLC	N/A
Feed tank 1B (MR-TK-140) high-temperature alarm	PLC	N/A
Feed tank 1B (MR-TK-140) high-pressure alarm	PLC	N/A
U solution collection tank (MR-TK-180) high-liquid level alarm	PLC	N/A
U solution collection tank (MR-TK-180) low-liquid level alarm	PLC	N/A
U solution collection tank (MR-TK-180) high-pressure alarm	PLC	N/A
Waste collection tank (MR-TK-340) high-liquid level alarm	PLC	N/A
Waste collection tank (MR-TK-340) low-liquid level alarm	PLC	N/A
Waste collection tank (MR-TK-340) high-pressure alarm	PLC	N/A

N/A = not applicable.
PLC = programmable logic controller.
U = uranium.

7.3.5.4 System Performance Analysis and Conclusion

The system performance analysis and conclusion for each process system will be provided in the Operating License Application.

7.3.6 Waste Handling System

The waste handling system will consist of storage tanks for accumulating waste liquids and adjusting the waste composition, and the equipment needed for handling and encapsulating solid waste. Liquid waste will be split into high-dose and low-dose streams by concentration. The high-dose fraction will be further concentrated and adjusted. Liquid waste will then be mixed with an adsorbent material. The solid waste streams will be placed in a waste drum and encapsulated by adding a cement material to fill voids remaining within the drum. All high-dose waste streams will be held for decay and shipped to a disposal facility.

Due to the variety of activities performed during waste handling, the system description is divided into the following subsystems:

- High-dose liquid waste collection
- Low-dose liquid waste collection
- Low-dose waste evaporation
- High-dose liquid waste solidification
- Low-dose liquid waste solidification
- Spent resin dewatering
- Solid waste encapsulation
- High-dose waste decay
- High-dose waste handling

7.3.6.1 Design Criteria

Design criteria for the waste handling I&C systems are described in Section 7.2.

7.3.6.2 Design Basis and Safety Requirements

The design basis and safety requirements for the waste handling I&C systems are described in Section 7.2. The ESFs for this system are listed in Chapter 6.0.

7.3.6.3 System Description

The waste handling I&C system will be defined in the Operating License Application. The strategy and associated parameters for the I&C system are provided below. Preliminary process sequences are provided in Chapter 4.0 to communicate the control strategy for normal operations, which sets the requirements for the process monitoring and control equipment, and the associated instrumentation.

All normal operating functions for low-dose liquid solidification will be controlled locally using HMIs in the low-dose waste room (Room W107). A local HMI display area will be provided in this room for most waste handling operations. All normal operating functions for the high-dose liquid waste solidification, high-dose waste decay, spent resin dewatering, and solid waste handling hot cell operations will be controlled and/or monitored from the low-dose waste room (Room W107). Liquid waste collection and low-dose liquid waste evaporation operations will be controlled from the RPF control room. Table 7-11 lists the anticipated control parameters, monitoring parameters, and primary control locations for each subsystem. In addition, the implementation of IROFS CS-14, CS-15, CS-20, CS-27, and RS-10 interlocks for this system are under development. Details of the control system (e.g., interlocks and permissive signals), nuclear and process instruments, control logic and elements, indication, alarm, and control features will be developed for the Operating License Application.

Table 7-11. Waste Handling System Control and Monitoring Parameters

Subsystem name	Control parameters (automatic/manual)	Monitoring parameters	Primary control location
High-dose liquid waste collection	• Valve position	• Density • Differential pressure • Flowrate • Flowrate totalizer • Level • Temperature • Pressure • Radiation • Valve position	Control room
High-dose liquid waste solidification	• Valve position	• Density • Differential Pressure • Flowrate • Flowrate totalizer • Level • Temperature • Pressure • Radiation • Valve Position	Low dose solidification room
Low-dose liquid waste collection	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Density • Differential pressure • Flowrate • Flowrate totalizer • Level • Temperature • Pressure • Valve position	Control room
Low-dose liquid waste evaporation	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Differential pressure • Flowrate • Level • Temperature • Pressure • Valve position	Control room
Low-dose liquid waste solidification	• Flowrate (A) • Pump actuation (A/M) • Pump motor speed (A) • Temperature (A) • Valve actuation (A/M)	• Density • Differential pressure • Flowrate • Flowrate totalizer • Level • Temperature • Pressure • Valve position	Low dose solidification room
Spent resin dewatering	• Valve actuation (A/M)	• Valve position	Low dose solidification room
Solid waste encapsulation	• Actuate grout mixer (M)	• Pressure	Low dose solidification room
High-dose waste decay	TBD	TBD	Low dose solidification room
High-dose waste handling	TBD	TBD	Low dose solidification room

TBD = to be determined.

Table 7-12 provides a preliminary listing of the waste handling system interlocks and permissive signals that have been identified. These devices will be further developed and detailed information will be provided in the Operating License Application.

Table 7-12. Waste Handling System Interlocks and Permissive Signals

Interlock or permissive input	Hard-wired or PLC	Safety interlock
High-dose waste collection tank (WH-TK-100) high-liquid level alarm	PLC	N/A
High-dose waste collection tank (WH-TK-100) low-liquid level alarm	PLC	N/A
High-dose waste collection tank (WH-TK-100) low-pressure alarm	PLC	N/A
High-dose waste concentrator (WH-Z-200) high-liquid level alarm	PLC	N/A
High-dose waste concentrator (WH-Z-200) low-liquid level alarm	PLC	N/A
High-dose waste concentrator (WH-Z-200) demister high-differential pressure alarm	PLC	N/A
High-dose waste concentrator (WH-Z-200) condenser high-differential pressure alarm	PLC	N/A
High-dose waste concentrator (WH-Z-200) condenser offgas high-temperature alarm	PLC	N/A
Low-dose waste collection tank (WH-TK-240) high-liquid level alarm	PLC	N/A
Low-dose waste collection tank (WH-TK-240) low-liquid level alarm	PLC	N/A
Low-dose waste collection tank (WH-TK-240) low-pressure alarm	PLC	N/A
High-dose waste container offgas filter (WH-F-330) high-pressure differential alarm	PLC	N/A
Condensate collection tank (WH-TK-400) high-liquid level alarm	PLC	N/A
Condensate collection tank (WH-TK-400) low-liquid level alarm	PLC	N/A
Condensate collection tank (WH-TK-400) low-pressure alarm	PLC	N/A
Low-dose waste collection tank (WH-TK-420) high-liquid level alarm	PLC	N/A
Low-dose waste collection tank (WH-TK-420) low-liquid level alarm	PLC	N/A
Low-dose waste collection tank (WH-TK-420) low-pressure alarm	PLC	N/A
Low-dose waste evaporation tank 1 (WH-TK-500) high-liquid level alarm	PLC	N/A
Low-dose waste evaporation tank 1 (WH-TK-500) low-liquid level alarm	PLC	N/A
Low-dose waste evaporation tank 1 (WH-TK-500) low-pressure alarm	PLC	N/A
Low-dose waste evaporation tank 2 (WH-TK-530) high-liquid level alarm	PLC	N/A
Low-dose waste evaporation tank 2 (WH-TK-530) low-liquid level alarm	PLC	N/A
Low-dose waste evaporation tank 2 (WH-TK-530) low-pressure alarm	PLC	N/A
Low-dose waste container offgas filter (WH-F-630) high-pressure differential alarm	PLC	N/A

PLC = programmable logic controller. TBD = to be determined.

7.3.6.4 System Performance Analysis and Conclusion

The system performance analysis and conclusion for each process system will be provided in the Operating License Application.

7.3.7 Criticality Accident Alarm System

The RPF will use a CAAS to monitor for a criticality and provide emergency notifications for evacuation.

7.3.7.1 Design Criteria

Design criteria for the CAAS I&C systems are described in Section 7.2.

7.3.7.2 Design Basis and Safety Requirements

The design basis and safety requirements for the CAAS I&C systems are described in Section 7.2.

7.3.7.3 System Description

The CAAS will be provided as a vendor package with an integrated control system. The CAAS control HMI will be located in the control room and will provide local alarms at the detector locations and at the CAAS HMI. The FPC system will provide alarm and status monitoring in the control room. The facility-wide notification system configuration will be provided in the Operating License Application. The surveillance requirements for the CAAS system are described in Chapter 6.0.

7.3.7.4 System Performance Analysis and Conclusion

The system performance analysis for each process system will be provided in the Operating License Application. The overall I&C system performance analysis is discussed in Section 7.2.

The CAAS will provide for continuous monitoring, indication, and recording of neutron or gamma radiation levels in areas where personnel may be present and wherever an accidental criticality event could result from operational processes. The CAAS will be capable of detecting a criticality accident that produces an absorbed dose in soft tissue of 20 radiation absorbed dose (rad) of combined neutron or gamma radiation at an unshielded distance of 2 meters (m) from the reacting material within 1 minute (min), except for events occurring in areas not normally accessed by personnel and where shielding provides protection against radiation generated from an accidental criticality. Two detectors will cover each area needing CAAS coverage.

The control unit electronics will actuate local and remote alarms. The locations of the detectors will be provided in the Operating License Application.

The CAAS detectors will provide local annunciation and remote annunciation in the control room to alarm when the radiation levels exceed established setpoints. Alarming CAAS monitors will communicate the location of the criticality accident alarm to the FPC system. Diagrams of the CAAS and associated systems will be provided in the Operating License Application.

The uninterruptible power supply (UPS) will provide emergency power to the CAAS during a loss of off-site power. The CAAS will meet the criteria of 10 CFR 20.1501, "General," and use the guidance provided by ANSI/ANS 8.3, *Criticality Accident Alarm System*, and Regulatory Guide 3.71, *Nuclear Criticality Safety Standards for Fuels and Material Facilities*. As a safety-related system, the CAAS will be designed to remain operational during design basis accidents, which are described in Chapter 13.0.

7.4 ENGINEERED SAFETY FEATURES ACTUATION SYSTEMS

7.4.1 System Description

The ESFs are active or passive features designed to mitigate the consequences of accidents and to keep radiological exposures to workers, the public, and environment within acceptable values. Chapter 6.0 provides a description of the ESFs, including the accidents mitigated and SSCs used to provide the ESFs.

The ESF systems will operate independently from the FPC systems as hard-wired controls. However, the ESFs will integrate into the FPC systems and provide a common point of HMI, monitoring, and alarming at the control room and local HMI workstations.

Table 7-13 lists the ESFs that will require actuation by the I&C system. Monitoring systems that are credited in the safety analysis are also included in the table.

Table 7-13. Engineered Safety Feature Actuation or Monitoring Systems (2 pages)

Engineered safety feature	IROFS	Accident(s) mitigated	I&C SSCs providing engineered safety feature
Primary offgas relief system	RS-09	Dissolver offgas failure during dissolution operation	Pressure relief device, pressure relief tank
Active radiation monitoring and isolation of low-dose waste transfer	RS-10	Transfer of high-dose process liquid outside the hot cell shielding boundary	Radiation monitoring and isolation system for low-dose liquid transfers
Cask local ventilation during closure lid removal and docking preparations	RS-13	Target cladding leakage during shipment	Local capture ventilation system over closure lid during lid removal
Cask docking port enabler	RS-15	Cask not engaged in the cask docking port prior to opening the docking port door	Sensor system controlling cask docking port door operation
Process vessel emergency purge system	FS-03	Hydrogen deflagration or detonation	Backup bottled nitrogen gas supply
Active discharge monitoring and isolation	CS-14	Accidental criticality	To be provided in the Operating License Application
Independent active discharge monitoring and isolation	CS-15	Accidental criticality	To be provided in the Operating License Application
Evaporator or concentrator condensate monitoring	CS-20	Prevent nuclear criticality from high-volume transfer to non-geometrically favorable vessels in solutions with normally low fissile component concentrations	Conductivity analyzer and control valve

Table 7-13. Engineered Safety Feature Actuation or Monitoring Systems (2 pages)

Engineered safety feature	IROFS	Accident(s) mitigated	I&C SSCs providing engineered safety feature
Closed heating or cooling loop with monitoring and alarm	CS-27	Accidental criticality	Closed-loop, high-volume heat transfer fluid systems to prevent nuclear criticality or transfer of high-dose material across shielding boundary in the event of a leak into the heat transfer fluid with normally low fissile component concentrations
Dissolver offgas vacuum receiver or vacuum pump	TBD	Potential limiting control for operations; motive force for dissolver offgas	Dissolver offgas vacuum receiver tanks, dissolver offgas vacuum pumps

I&C = instrumentation and control.
IROFS = items relied on for safety.
SSC = structures, systems, and components.
TBD = to be determined.

7.4.2 Annunciation and Display

The actuation of an ESF will be displayed on the FPC system HMI and locally at the affected system with an audible alarm. The alarm annunciator display panel and the alarm or event display will show the triggering event. Once actuated, the ESFs will require manual input from the operator to reset the ESF. Clearing the triggering event will be required.

7.4.3 System Performance Analysis

Section 7.2.4 provides additional details on the analysis of system performance. Potential variables, conditions, or other items that will be probable subjects of technical specifications associated with the FPC system are provided in Chapter 14.0.

7.5 CONTROL CONSOLE AND DISPLAY INSTRUMENTS

7.5.1 Design Criteria

Design criteria for the control room I&C systems are described in Section 7.2.

7.5.2 Design Basis and Safety Requirements

The design basis and safety requirements for the control room I&C systems are described in Section 7.2.

7.5.3 System Description

The control room will provide the majority of interfaces for the facility and process control systems, with overall process controls, monitoring, alarms, and acknowledgement. The control room will consist of a properly sized and shaped control console with two or three operator interface stations or HMIs (one being a dedicated engineering interface), a master PLC or distributed controller, and all related and necessary cabinetry and subcomponents (e.g., input/output boards, gateways, Ethernet switches, power supplies, and UPS). This control system will be supported by a data highway of sensing instrument signals in the facility process areas that will be gathered onto the highway throughout the facility by an Ethernet communication-based interface backbone and brought into the control room and onto the console displays.

Dedicated controllers and human-machine monitoring interfaces or stations for other equipment systems will also be in the control room. This equipment includes the facility crane, closed-circuit television system, CAAS, and radiation monitoring system. A control panel for all facility on-site and off-site (if required) communications (e.g., telephone, intercom) will likely also be located there. The control room door into the facility will be equipped with controlled access.

The BMS will be primarily controlled and monitored from the control room. Utility systems with vendor packages and integrated controls will provide surveillance monitoring to the control room.

The FPC system will operate with a synchronized hot standby redundant system structure for all hot cell processes. Each hot cell process will be an independent subsystem having a local HMI with monitoring and control functions from the control room. Workstations for each system within the control room will be hot standby redundant. The redundant stations will run software on identical PLC systems. The PLC systems will monitor each other. On loss of synchronizing signal from one system, the other system will continue with control and monitoring.

Process systems that will be primarily controlled in the control room include uranium recovery and recycle, target dissolution, and liquid waste handling. The target receipt system will be controlled with local HMIs in the irradiated target basket receipt bay or target cask preparation airlock. Mo production process hot cell systems, including target disassembly and Mo recovery and purification, will be controlled with local HMIs in the hot cell operating gallery. The hot cell processes will have monitoring and redundant control functions from the control room.

The FPC subsystem for target fabrication processes will be controlled with local HMIs in the target fabrication area, with surveillance monitoring in the control room.

Local HMIs will be provided in Room W107, which houses equipment for low-dose waste solidification. Low-dose liquid waste will be piped in from the holding tanks in the utility area above Room W107, and drums of solidified waste will be transported out by pallet jack. This local HMI will be the primary control location for the high-dose liquid waste solidification, high-dose waste decay, spent resin dewatering, and solid waste handling hot cell operations.

7.5.4 System Performance Analysis and Conclusion

The system performance analysis for each process system will be provided in the Operating License Application. The overall I&C system performance analysis and conclusions are provided in Section 7.2.

7.6 RADIATION MONITORING SYSTEMS

The radiation monitoring systems will include CAMs, continuous monitoring at the exhaust stacks, process control instruments, and personnel monitoring and dosimetry. Process control instruments used to analyze for uranium concentrations are described in each respective process system in Section 7.3.

The objective of the radiation monitoring system is to provide the RPF control room personnel with a continuous record and indication of radiation levels at selected locations where radioactive materials may be present, stored, handled, or inadvertently introduced. The system is also designed to ensure that there is accurate and reliable information concerning radiation safety as related to personnel safety. The design considerations for the radiation monitoring system include the following:

- Provision of information to RPF operators so that in the event of an accident resulting in a release of radioactive material, decisions on deployment of personnel can be properly made.
- Indication and recording in the control room of the gamma and airborne radiation levels in selected areas as a function of time, and, if necessary, alarming to indicate any abnormal radiation condition. These indicators aid in maintaining plant contamination levels as low as reasonably achievable (ALARA) and in minimizing personnel exposure to radiation.
- Provision of local alarms and/or indicators positioned at key points throughout the RPF where a substantial increase in radiation levels might be of immediate importance to personnel frequenting or working in the area.

Radiation Monitoring Locations

RAMs will be located in areas where personnel may be present and where radiation levels could become significant based on the following considerations:

- Occupancy status of the area, including time requirements of personnel in the area, the proximity to primary and secondary radioactive sources, and shielding
- Potential for increase in the background radioactivity level
- Desirability of surveillance of infrequently visited areas

CAMs will be located in work areas where there is a potential for airborne radioactivity. The CAMs will have the capability to detect derived air concentrations within a specified time.

7.6.1 Design Criteria

Design criteria for the radiation monitoring I&C systems are described in Section 7.2.

7.6.2 Design Basis and Safety Requirements

The design basis and safety requirements for the radiation monitoring I&C systems are described in Section 7.2. The ESFs for this system are listed in Chapter 6.0.

7.6.3 System Description

The radiation safety monitoring system will include CAMs, continuous monitors at the exhaust stacks, and personnel monitoring and dosimetry.

Three basic types of personnel monitoring equipment will be used at the facility: count rate meters (friskers), hand/foot monitors, and portal monitors. All personnel whose duties require entry to restricted areas will wear individual external dosimetry devices (e.g., passive dosimeters such as thermoluminescent dosimeters that are sensitive to beta, gamma, and neutron radiation) from a National Voluntary Laboratory Accreditation (NAVLAP)-certified vendor. Personnel monitoring and dosimetry is described in Chapter 11.0, "Radiation Program and Waste Management."

7.6.3.1 Air Monitoring

Continuous air monitors – CAM units will consist of a particulate measuring channel with a filter to capture particulate. Air will be drawn through the system by a pump assembly. The sample will be withdrawn from inside the appropriate area, room, or cell through an isokinetic nozzle with the sampling volume flow at a known fixed rate, so that the accumulation of radioactive particles can be interpreted as a quantitative sample. After passing through the nozzle, the sample will be drawn through tubing and through a fixed or moving filter tape before being discharged to the atmosphere. The samplers also have a purging system for flushing the volume cell surrounding the gas sample chamber with clean air for purposes of calibration and the removal of crust activity. Replaceable liners will be changed out periodically when contamination becomes excessive. Flow regulating will ensure that flow through the filters remains constant.

Each instrument channel will include a detector, preamplifier, count rate meter, and power supply. The detector may be a scintillation counter or similar device having a gamma sensitive crystal, and a photo multiplier whose output pulses are counted by the rate meter. Each readout module will be equipped with a light that illuminates when the radiation level exceeds preset limits. The setpoint will be adjustable over the entire detection range. Pressing a button will cause the meter to indicate the alarm setpoint. Visible alarms will be accompanied by a simultaneous local audible alarm with an alarm light in the control room. A normally energized light will deenergize when there is a detector signal failure, circuit failure, power failure, or failure due to a disconnected cable. Power for the monitors that initiates a safety signal will be provided from the UPS. Loss of power and signal failure will be monitored for each detector.

CAMs will be provided with a check source. This check source will simulate a radiation field and will be used as a convenient operational and gross calibration check of the detectors and readout equipment. CAM calibration will include, where practical, exposures to the specific isotopes that the particular system monitors in the field. Instrument calibrations will be performed at prescribed frequencies. An electronic test signal and/or radioactive check source drift indication may also require CAM recalibration.

Radiation area monitors – The RAM detector unit will be housed in an environmentally suitable container that is mounted in a duct, on a wall, or other suitable surface. The sensitivity of each detector will be sufficient to have the alarm setpoint an order of magnitude higher than the detection threshold.

The detectors are designed to be operational over a wide range of temperatures. The design of the detectors will meet expected normal and abnormal environmental design conditions, as appropriate. Saturation will not be expected to adversely affect operation of the detector within its calibrated range.

Sensors will be mounted as close as practical to the most probable radiation sources with no objects, persons, pillars, and piping serving as shielding. The sensors will also be mounted so as to minimize inaccuracies due to any directionality of the detector.

Audible and visual alarm devices – When the radiation exceeds predetermined levels, alarms will actuate in the control room and at selected detector locations.

The alarms will consist of the following capabilities:

- "Alert light" will illuminate when the radiation level exceeds preset limits with an adjustable setpoint
- "High alarm red light" will illuminate when radiation levels exceed a predetermined alarm setpoint
- "Failure alarm" will sound when either the power or the channel's electronics fail

The visual alarms will be accompanied by a simultaneous audible alarm annunciator at the selected detector locations and in the control room. The annunciator windows for the monitors will be located in the control room. The alarm can be manually reset when the alarm conditions are corrected. The local alarm horns and warning lights will remain on until the radiation level is below the present level.

Additional CAM requirements and locations are described in Chapter 11.0.

7.6.3.2 Stack Release Monitoring

The exhaust stacks will be provided with continuous monitors for noble gases, particulate, and iodine. The stack monitoring system design basis is to continuously monitor the radioactive stack releases. Additional information will be provided in the Operating License Application. Airborne exposure pathway monitoring is described in Chapter 11.0.

7.6.4 System Performance Analysis and Conclusions

The system performance analysis and conclusions for each process system will be provided in the Operating License Application. The overall I&C system performance analysis is provided in Section 7.2.

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Chapter 8.0 – Electrical Power Systems

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 3
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Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, OR 97330

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Chapter 8.0 – Electrical Power Systems

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FIGURES

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TERMS

Acronyms and Abbreviations

AEC	active engineering control
ATS	automatic transfer switch
CAAS	criticality accident alarm system
HVAC	heating, ventilation, and air conditioning
IEEE	Institute of Electrical and Electronics Engineers
IROFS	item relied on for safety
MCC	motor control center
NEP	normal electrical power
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NWMI	Northwest Medical Isotopes, LLC
RPF	Radioisotope Production Facility
SEP	standby electrical power
UPS	uninterruptable power supply

Units

gal	gallon
hp	horsepower
hr	hour
Hz	hertz
km	kilometer
kV	kilovolt
kW	kilowatt
L	liter
mi	mile
min	minute
sec	second
V	volt

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8.0 ELECTRICAL POWER SYSTEMS

This chapter provides a description of the normal electrical power (NEP) and emergency electrical power systems within the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF). The RPF design uses high-quality, commercially available components and wiring in accordance with applicable code. Electrical power circuits will be isolated sufficiently to avoid electromagnetic interference with safety-related instrumentation and control functions. The facility is designed for passive, safe shutdown and to prevent uncontrolled release of radioactive material if NEP is interrupted or lost. Uninterruptable power supplies (UPS) automatically provide power to systems that support the safety functions protecting workers and the public.

The NEP system is designed to provide reasonable assurance that use or malfunction of electrical power systems will not damage the RPF or prevent safe RPF shutdown. In addition, the RPF has a non-safety standby electrical power (SEP) system to reduce or eliminate process downtime due to electrical outages. A combination of UPSs and the SEP system will provide emergency electrical power (defined in Section 8.2) to the RPF.

Table 8-1 lists the RPF electrical loads, including the NEP system peak loads, which systems have UPSs, and the loads for those systems supported by the SEP system.

Table 8-1. Summary of Radioisotope Production Facility and Ancillary Facilities Electrical Loads (2 pages)

Demand	Normal electrical peak power load		Uninterruptable power	Standby electrical peak power load	
	kW	hp		kW	hp
Target fabrication system	125	168	No	0	0
Target receipt and disassembly system	30	40	No	0	0
Target dissolution system	40	54	No	40	54
Molybdenum recovery and purification system	30	40	No	25	34
Uranium recovery and recycle system	10	13	No	10	13
Waste handling system	25	34	No	5	7
Radiation monitoring and CAAS systems	5	7	Yes[a]	5	7
Standby electrical power system	N/A		No	N/A	N/A
General facility electrical power	173	232	Yes[a]	101	135
Process vessel ventilation system	40	54	No	40	54
Facility ventilation system					
Ventilation Zone I	67	90	No	67	90
Ventilation Zone II/III	215	288	No	215	288
Ventilation Zone IV	295	396	No	295	396
Laboratory ventilation	38	51	No	10	13
Supply air	49	66	No	49	66
Fire protection system	0.8	1	Yes[a]	0[b]	0[b]
Plant and instrument air system	60	83	No	60	83
Gas supply system	0.8	1	No	0.8	1
Process chilled water system	280	375	No	140	188

Table 8-1. Summary of Radioisotope Production Facility and Ancillary Facilities Electrical Loads (2 pages)

Demand	Normal electrical peak power load		Uninterruptable power	Standby electrical peak power load	
	kW	hp		kW	hp
Facility chilled water system	1,300	1,743	No	0	0
Facility heated water system	47	63	No	0	0
Process stream system	0.8	1	No	0.8	1
Demineralized water system	0.8	1	No	0	0
Supply air system					
Chemical supply system	49	66	No	49	66
Facility process control and communications systems	5	7	Yes	5	7
Energy recovery	5	7	No	0	0
Safeguards and security	40	54	Yes	40	54
Administrative building	90	121	No	18	24
Waste management building	11	15	No	3	4

[a] Only parts of the system are provided with uninterruptable power supplies.

[b] The fire detection and fire alarm subsystems will be provided by an uninterruptable power supply with a 24-hr capacity. Chapter 9.0 provides additional detail.

CAAS = criticality accident alarm system N/A = not applicable.

8.1 NORMAL ELECTRICAL POWER SYSTEMS

The NEP system will connect to electric utility power from the off-site utility transmission and distribution system at a point of common coupling. This point of common coupling will be located near the property line on the NWMI site. The NEP distribution system will operate in a redundant electrical system topology from the utility transmission and distribution system to the 480 volt (V) service entrance switchgear that services the RPF electrical distribution system and the devices and equipment within the facility. The RPF electrical distribution system is designed to support the safety functions protecting workers, the public, special nuclear material activities, and radioisotope production operation processes, as described in Chapter 4.0, "Radioisotope Production Facility Description," and to minimize the number of points where a failure in the RPF is a single point of power conveyance.

Figure 8-1 provides a preliminary electrical one-line diagrams for the electrical distribution topology. The electrical one-line diagrams will be updated after completion of the RPF final design and included in the Operating License Application.

Power will be provided to the NWMI site from an underground utility feed 1 to the pad-mounted switchgear located outside of the RPF building. Power will then be routed underground from the switchgear to the Administrative Building 2 and the RPF 3.

The underground feeders 3 to the RPF will comprise two redundant full-capacity service laterals to the RPF. Each service lateral will support redundant full-capacity service transformers 4 that will normally carry half the RPF load. Either of the RPF feeders can be opened and the tie breaker closed, as needed, allowing the other feeder to carry the entire RPF load.

Any RPF loads requiring SEP will be provided power from the diesel generator when required 5.

[Proprietary Information]

Figure 8-1. Radioisotope Production Facility Electrical One Line Diagram

The two underground feeders will be located on each side of the switchgear and will normally carry approximately half of the electrical load. However, each underground feeder will be capable of carrying the entire load of the facility. The designed NEP topology will provide the RPF with redundancy. In addition, each underground feeder can be maintained and inspected independently, due to redundancy, while the RPF and associated safety functions are serviced with electrical power.

The 480 V service entrance equipment will have a main-tie-main arrangement on the service entrance electrical bus, with a service main on either end of a common bus. The common bus will be segregated by a tie-breaker. In normal mode operation, the two main breakers will be closed and the tie-breaker open. In the event one feeder is unavailable, the other feeder will carry the entire RPF load by opening the unavailable feeder main breaker and closing the tie breaker.

Electrical distribution on the load side of the 480 V service entrance switchgear and the heating, ventilation, and air conditioning (HVAC) redundant loads will be serviced from opposite sides of the switchgear through electrical equipment and feeders, including motor control centers (MCC), switchboards, and distribution panel boards. Equipment, systems, and devices designed with redundant or N+1 capability will be fed from opposite sides of the service entrance switchgear. The planned loads on the MCC will be evaluated in the RPF final design to ensure the equipment is appropriately balanced. These loads will be provided in the Operating License Application.

Systems requiring emergency electrical power in the event of the loss of NEP will be serviced by an on-site diesel generator through the SEP system. Section 8.2 provides additional information on the SEP system.

UPSs will be provided for selected systems for the RPF, as identified in Table 8-1. UPS systems include unit device, rack-mounted, and/or larger capacity cabinet units (a large battery room as part of the UPS system is not planned). These UPS systems will service loads requiring uninterruptable power on a short-term basis. The UPS systems will be backed up by the on-site diesel generator to extend the duration of power available to connected loads. The UPS systems locations on the electrical one-line diagram will be defined in the RPF final design and provided in the Operating License Application.

Internal to the RPF and Administration Building, the NEP distribution system will service end user equipment and devices. Feeders, busing, overcurrent protection, devices, and equipment will provide the conveyance and conductor protection throughout the building. Design of the electrical distribution system includes recommended practices from the Institute of Electrical and Electronics Engineers (IEEE) 493, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems*, and IEEE 379, *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems*. The electrical distribution system topology will employ a redundant power conveyance system.

The distribution system will include overcurrent protective devices, surge arresters, fusing, relays, and similar safety-related protective devices. These safety devices will conform to the requirements of the National Fire Protection Association (NFPA) 70, *National Electric Code*, relevant IEEE standards and recommendations, and local codes and standards.

8.1.1 Design Basis of the Normal Electric Power System

The NEP system design basis will provide sufficient and reliable electrical power to the RPF systems and components requiring electrical power for normal operations, including the electrical requirements of the system, equipment, instrumentation, control, communication, and devices related to the safety functions and devices.

There are no items relied on for safety (IROFS) applicable to the NEP, per Chapter 13.0, "Accident Analysis," Section 13.2.5 (loss of power accident analysis scenario). The NEP will provide power to the active engineered control (AEC) systems through the instrumentation, monitoring, alarm, and related control systems. The design basis is provided in Chapter 3.0, "Design of Structures, Systems, and Components."

8.1.2 Design for Safe Shutdown

In the event of the loss of NEP, UPSs automatically provide power to the RPF systems and components that support the safety functions protecting workers and the public. The following systems and components are supported with UPSs:

- Process and facility monitoring and control systems
- Facility communication and security systems
- Emergency lighting
- Fire alarms
- Radiation protection and criticality accident alarm system (CAAS)

The UPSs will be designed to operate for a period of up to 120 minutes (min) or longer if identified as needed beyond 120 min in the final safety analysis. The fire protection system will have a UPS that provides 24 hours (hr) of uninterrupted power. If NEP service is reestablished within a determined timeframe (to be provided in the Operating License Application), the RPF will resume normal operation. Upon loss of normal power:

- Inlet bubble-tight isolation dampers within the Zone I ventilation system will close, and the HVAC system will automatically be placed into the passive ventilation mode of operation
- The process vessel vent system will automatically be placed into the passive ventilation mode of operation, and all electrical heaters will cease operation as part of the passive operation mode
- Pressure-relief confinement system for the target dissolver offgas system will be activated on reaching the system relief setpoint, and dissolver offgas will be confined in the offgas piping, vessels, and pressure-relief tank
- Process vessel emergency purge system will be activated for hydrogen concentration control in tank vapor spaces
- Uranium concentrator condensate transfer line valves will be automatically configured to return condensate to the feed tank due to residual heating or cooling potential for transfer of process fluids to waste tanks
- Equipment providing a motive force for process activities will cease, including:
  - Pumps performing liquid transfers of process solutions
  - Pumps supporting operation of the steam and cooling utility heat transfer fluids
  - Equipment supporting physical transfer of items (primarily cranes)

8.1.3 Ranges of Electrical Power Required

The RPF power service will be 480 V, 3-phase, 120 amp, 60 hertz (Hz). The total power required for the facility will be approximately 2,998 kilowatt (kW) (4,020 horsepower [hp]). Table 8-1 lists the loads for different locations and processes within the RPF.

8.1.4 Use of Substations Devoted Exclusively to the Radioisotope Production Facility

The RPF will receive power from Columbia Water and Light through the Grindstone Substation. This substation is approximately 2.4 kilometer (km) (1.5 miles [mi]) to the northwest of the RPF. The substation is 169 kilovolt (kV) that converts the current to 13,000 – 800 V for public distribution. The use of a shared substation will not affect the safe shutdown of the RPF.

8.1.5 Special Processing of Electrical Service

Details on special processing of the electrical service, such as isolation, transformers, noise limiters, lightning arresters, or constant voltage transformers, will be provided in the Operating License Application.

8.1.6 Design and Performance Specification

Design and performance specifications of principal and non-standard components will be provided in the Operating License Application.

8.1.7 Special Routing or Isolation

Special routing and isolation of wiring and circuits will be provided in the Operating License Application.

8.1.8 Deviations from National Codes

The RPF electrical system will be designed to meet all required national codes and standards, as described in Chapter 3.0.

8.1.9 Technical Specifications

As evaluated in Chapter 13.0, the RPF is designed to safely shut down without NEP for occupational safety and for protection of the public and environment. The NEP system will not require a technical specification per the guidelines in Chapter 14.0, "Technical Specifications."

8.2 EMERGENCY ELECTRICAL POWER SYSTEMS

Emergency electrical power is defined by NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, as any temporary substitute for normal electrical service. A combination of UPSs and the SEP system will provide emergency electrical power to the RPF, although only selected UPS systems will have a safety function. A 1,000 kW (1,341 hp) diesel generator will provide SEP.

Figure 8-1 also provides the electrical distribution topology for the SEP system. Power from this generator will service the RPF through an automatic transfer switch (ATS). The normal power side of the ATS will be connected to the RPF service entrance switchgear, with the load side of the ATS to be connected to the standby switchboard. The SEP system is designed to support the safety functions during RPF operations to protect workers, the public, and environment.

The SEP system design includes recommended practices from IEEE 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*, NFPA 110, *Standard for Emergency and Standby Power Systems*, IEEE 379, and IEEE 493.

The SEP system will include overcurrent protective devices, surge arresters, fusing, relays, and similar safety-related protective devices. These safety devices will conform to the requirements of NFPA 70, relevant IEEE standards and recommendations, and local codes and standards.

SEP will be available to the exhaust system through a redundant electrical distribution topology. Approximately half of the exhaust electrical load requiring standby will be connected to an MCC, with the other half connected to a redundant MCC.

The standby switchboard will service equipment and devices in the hot cell, control room, exhaust system ventilation system, and other loads requiring standby power. During switchover to the SEP, the loads will be sequenced to protect the generator and electrical equipment. Feeders, busing, overcurrent protection, devices, and equipment will provide the conveyance and conductor protection throughout the building.

During normal operations, loads connected to the standby switchboard will be serviced through the ATS with normal and facility electric power. In this way, any malfunctions of the SEP system during RPF operation with NEP will not interfere with normal RPF operations or prevent safe facility shutdown. When the ATS senses a loss of normal power, the switch will signal the on-site diesel generator to start up. When the diesel generator voltage and frequency are within acceptable limits, the ATS will switch from the normal power source to the diesel generator power source. Loads connected to the standby switchboard will continue to be serviced by the diesel generator until the normal power source returns. The ATS will sense the normal power source voltage and frequency. Once the voltage and frequency are within acceptable limits and after a prescribed delay, the ATS will switch from the diesel generator power source to the normal power source.

UPSs will be provided, as required. The function of the UPSs is to provide power to select loads while the diesel generator starts. The UPS systems will include unit devices, rack-mounted, and/or larger capacity cabinet units. The RPF loads requiring uninterruptable power on a short-term basis will be backed up by the on-site diesel generator to extend the duration of UPS power available to connected loads.

The 1,000 kW (1,341 hp) diesel generator will be serviced with a 3,785 liter (L) (1,000-gallon [gal]) diesel tank. This capacity will enable the generator to operate for 11–14 hr, depending on actual loads, without requiring additional fuel.

8.2.1 Design Basis of the Emergency Electric Power System

The emergency electrical power system design basis is to provide uninterrupted power to instrumentation, control, communication systems, and devices required to support the safety functions protecting workers and the public, and to provide sufficient electrical power to the RPF to ensure safe shutdown in the event of loss of NEP. The system design basis also provides SEP to operate select process-related equipment to limit the impacts of loss of NEP on RPF production operations. Additional information on the design basis is provided in Chapter 3.0.

8.2.2 Ranges of Emergency Electrical Power Required

The RPF power service is 480 V, 3-phase, 42 amp, 60 Hz. The total peak SEP for the RPF is 1,178.6 kW (1,585 hp). Table 8-1 lists the backup peak electrical power loads for different locations and processes within the RPF.

8.2.3 Power for Safety-Related Instruments

Safety-related instrumentation will be provided with UPSs. The UPSs will provide power to safety-related instruments while the diesel generator starts and will provide service loads requiring uninterruptable power on a short-term basis. The diesel generator will maintain power until the normal power system is operating within acceptable limits.

8.2.4 Power for Effluent, Process, and Area Radiation Monitors

Effluent, process, and area radiation monitors will be provided with the UPSs. The UPSs will provide service loads requiring uninterruptable power for up to 120 min, while the diesel generator will maintain power until the normal power system is operating within acceptable limits.

8.2.5 Power for Physical Security Control, Information, and Communication Systems

Physical security control, information, and communication systems will be provided with a UPS. The UPS provides service loads requiring uninterruptable power for up to 120 min, while the diesel generator will maintain power until the normal power system is operating within acceptable limits.

8.2.6 Power to Maintain Experimental Equipment in Safe Condition

There are no experimental equipment or facilities in the RPF.

8.2.7 Power for Active Confinement/Containment Engineered Safety Feature Equipment and Control Systems

Based on the analysis in Chapter 13.0, the Zone I exhaust ventilation subsystems operations, equipment, and components ensures the confinement of hazardous materials during normal and abnormal conditions, including natural phenomena, fires, and explosions. After a loss of NEP, the Zone I exhaust ventilation subsystem will automatically place itself into the passive mode, including inlet bubble-tight isolation dampers that close to provide passive confinement.

The system will remain in this configuration until the voltage and frequency of power from the diesel generator are within acceptable limits. At that point, the system can be manually started and operated in a reduced ventilation mode with one operating group of HVAC fans and components. The Zone I exhaust ventilation subsystems are designed to function in a manner, whether operational or not, consistent with occupational safety and protection of workers, the public, and environment. Therefore, this system is not considered an IROFS.

8.2.8 Power for Coolant Pumps or Systems

Based on the analysis provided in Chapter 5.0, "Coolant Systems," the coolant system is designed to function in a manner, whether operational or not, consistent with occupational safety and protection of the public and the environment. Therefore, power to coolant systems is not considered an IROFS.

8.2.9 Power for Emergency Cooling

Based on the analysis provided in Chapter 5.0, an emergency cooling water system is not required.

8.2.10 Power for Engineered Safety Feature Equipment

Engineered safety features requiring power will be provided with UPSs. The UPSs will provide service loads requiring uninterruptable power for up to 120 min. The diesel generator will maintain power until the normal power system is operating within acceptable limits. Additional information will be provided in the Operating License Application.

8.2.11 Power for Emergency Lighting

Power required for emergency lighting will be provided by UPSs. The UPSs will provide service loads requiring uninterruptable power for up to 120 min, while the diesel generator will maintain power until the normal power system is operating within acceptable limits. Additional information will be provided in the Operating License Application.

8.2.12 Power for Instrumentation and Control Systems to Monitor Shutdown

Power for instrumentation and control systems used to monitor safe shutdown will be provided with UPSs. The UPSs will provide service loads requiring uninterruptable power for up to 120 min, while the diesel generator will maintain power until the normal power system is operating within acceptable limits. Additional information will be provided in the Operating License Application.

8.2.13 Technical Specifications

As evaluated in Chapter 13.0, the RPF is designed to safely shut down without SEP consistent with occupational safety and protection of the public and the environment. The UPS systems, as required, are anticipated to be part of the technical specification for the system being supported. The SEP system will not require a technical specification per the guidelines in Chapter 14.0.

8.3 REFERENCES

IEEE 379, *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems*, Institute of Electrical and Electronics Engineers, Piscataway, New Jersey, 2014.

IEEE 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*, Institute of Electrical and Electronics Engineers, Piscataway, New Jersey, 2014.

IEEE 493, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)*, Institute of Electrical and Electronics Engineers, Piscataway, New Jersey, 2007.

NFPA 70, *National Electrical Code (NEC)*, National Fire Protection Association, Quincy, Massachusetts, 2014.

NFPA 110, *Standard for Emergency and Standby Power Systems*, Institute of Electrical and Electronics Engineers, Piscataway, New Jersey, 2014.

NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, Part 1, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C., February 1996.

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Chapter 9.0 – Auxiliary Systems

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 3
September 2017

Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, OR 97330

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Chapter 9.0 – Auxiliary Systems

Construction Permit Application for Radioisotope Production Facility

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REVISION HISTORY

Rev	Date	Reason for Revision	Revised By
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1	6/26/2017	Incorporate changes based on responses to NRC Requests for Additional Information	C. Haass
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3	9/5/2017	Incorporate final comments from NRC Staff and ACRS; full document revision	C. Haass

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FIGURES

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TERMS

Acronyms and Abbreviations

^{89}Sr	strontium-89
^{90}Sr	strontium-90
^{99}Mo	molybdenum-99
^{230}Th	thorium-230
^{231}Pa	protactinium-231
^{233}Pa	protactinium-233
^{233}U	uranium-233
^{235}U	uranium-235
^{237}Np	neptunium-237
^{238}Pu	plutonium-238
^{238}U	uranium-238
^{239}Pu	plutonium-239
^{240}Pu	plutonium-240
^{241}Am	americium-241
ALARA	as low as reasonably achievable
CFR	Code of Federal Regulations
DBF	design basis fire
DOT	U.S. Department of Transportation
H_2	hydrogen gas
HEGA	high-efficiency gas adsorption
HEPA	high-efficiency particulate air
HIC	high-integrity container
HNO_3	nitric acid
HVAC	heating, ventilation, and air conditioning
IBC	International Building Code
ICP-MS	inductively coupled plasma mass spectrometry
IROFS	item relied on for safety
IRU	iodine removal unit
IX	ion exchange
Kr	krypton
LAN	local area network
LEU	low-enriched uranium
Mo	molybdenum
MURR	University of Missouri Research Reactor
NaOH	sodium hydroxide
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NO_x	nitrogen oxide
NRC	U.S. Nuclear Regulatory Commission
NWMI	Northwest Medical Isotopes, LLC
OSTR	Oregon State University TRIGA Reactor
OSU	Oregon State University
PFHA	preliminary fire hazards analysis
RCA	radiologically controlled area
RPF	Radioisotope Production Facility
SNM	special nuclear material
TiO_2	titanium dioxide
U	uranium

U.S.	United States
U.S.C.	United States Code
VoIP	Voice over Internet Protocol
Xe	xenon

Units

°C	degrees Celsius
°F	degrees Fahrenheit
μ	micron
cm	centimeter
cm^2	square centimeter
ft	feet
ft^2	square feet
ft^3	cubic feet
gal	gallon
gmol	gram-mol
hr	hour
in.	inch
in.^{2}	square inch
kg	kilogram
L	liter
lb	pound
m	meter
M	molar
m^2	square meter
m^3	cubic meter
min	minute
mm	millimeter
W	watt
wt%	weight percent

9.0 RADIOISOTOPE PRODUCTION FACILITY AUXILIARY SYSTEMS

This chapter provides the descriptions of the auxiliary systems for the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF) that have not been addressed in previous chapters. These auxiliary systems are important to the safe operation of the RPF and to protect the health and safety of workers, the public, and environment. The chapter is organized in accordance with NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, as augmented by the *Final Interim Staff Guidance Augmenting NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Parts 1 and 2, for Licensing Radioisotope Production Facilities and Aqueous Homogeneous Reactors* (NRC, 2012).

The RPF auxiliary systems include the following:

- Heating and ventilation, and air conditioning (HVAC) systems
- Fire protection systems
- Communication systems
- Possession and use of byproduct, source, and special nuclear material
- Cover gas control in the closed primary coolant system
- Other auxiliary systems, including utility systems, control and storage of radioactive waste, analytical laboratory, and chemical supply

For each auxiliary system, a description is provided of the system's capability to function as designed without compromising RPF operations and to shut down the RPF during normal operations or under RPF accident conditions. Each auxiliary system description includes:

- Design basis
- System description
- Operational analysis and safety function
- Instrumentation and control requirements
- Required technical specifications and their bases, including testing and surveillance

9.1 HEATING VENTILATION AND AIR CONDITIONING SYSTEMS

The RPF HVAC system, also referred to as the facility ventilation system, is designed to ensure that temperature, relative humidity, and air exchange rates are within the design-basis limits for personnel and equipment and to ensure that all normal sources of airborne radioactive material are controlled so that occupational doses do not exceed the requirements of Title 10, *Code of Federal Regulations*, Part 20, "Standards for Protection Against Radiation" (10 CFR 20). The system design is consistent with NWMI's as low as reasonably achievable (ALARA) program.

The RPF design features ensure that airflow and relative pressure will prevent inadvertent diffusion or other uncontrolled release of airborne radioactive material from the RPF. The facility is also designed and operated to ensure that no uncontrolled release of airborne radioactive material to the unrestricted environment can occur.

The analyses of system operations show that planned releases of airborne radioactive material to the unrestricted environment will not expose the public to doses that exceed the limits of 10 CFR 20 and the NWMI ALARA program. NWMI's ALARA program is discussed in Chapter 11.0, "Radiation Protection Program and Waste Management," and a detailed airborne exposure analysis is provided in Chapter 11, Section 11.1.1.1.2.

9.1.1 Design Basis

The facility ventilation system is designed to provide confinement of hazardous chemical fumes and airborne radiological materials and conditioning of the RPF environment for facility personnel and equipment. The design basis of the facility ventilation system and the process vessel ventilation system is provided in Chapter 3.0, "Design of Structures, Systems, and Components," Section 3.5.7.2; and the safety functions are provided in Chapter 6.0, "Engineered Safety Features," Section 6.2.1.1.

9.1.2 System Description

The facility ventilation system will maintain a series of cascading pressure zones to draw air from the cleanest areas of the facility to the most contaminated areas. Zone IV will be a clean zone that is independent of the other ventilation zones. Zone IV will be slightly positively pressurized with respect to the atmosphere. Zone III will be the cleanest of the potentially contaminated areas, with each subsequent zone being more contaminated and having lower pressures.

A common supply air system will provide 100 percent outdoor air to all Zone III areas and some Zone II areas that require makeup air in addition to that cascaded from Zone III. Three separate exhaust systems will maintain zone pressure differentials and containment: (1) the Zone I exhaust system will service the hot cell, waste loading areas, target fabrication enclosures, and process vessel ventilation subsystems in Zone I; (2) the Zone II/III exhaust system will service exhaust flow needs from Zone II and Zone III in excess of flow cascaded to interior zones; and (3) a laboratory exhaust system will service fume hoods in the laboratory area.

Supply air will be conditioned using filters, heater coils, and cooling coils to meet the requirements of each space. Abatement technologies, primarily high-efficiency particulate air (HEPA) filtration and activated carbon, will be used to ensure that air exhausted to the atmosphere meets 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants" (NESHAP), and applicable State law.

A stack monitoring and sampling system will be employed to demonstrate compliance with the stated regulatory requirements for exhaust.

The RPF ventilation system will include the air supply, process ventilation, and exhaust air systems and associated filters, fans, dampers, ducts, and control instrumentation. The supply air system will draw in and condition fresh air and distribute it throughout the facility. A portion of the supply air will enter the process ventilation system through fume hoods, open-front enclosures, gloveboxes, and hot cells, and will be removed with other exhaust air systems through the stacks to the environment after being treated.

The safety functions of the ventilation systems will serve to protect workers, the public, and environment by maintaining confinement barriers in a multiple confinement barrier system.

The RPF will typically be ventilated such that airflows travel from areas of lower potential for contamination to areas of higher potential. The ventilation system functions will include temperature and air quality control to meet production and worker needs.

The RPF building ventilation system will have four confinement zone designations, with airflow directed from lowest to highest potential for contamination: Zone I, Zone II, Zone III, and Zone IV. Figure 9-1 through Figure 9-3 show the facility confinement boundaries on the ground level (first level), upper level (second level), and lower level (basement), respectively. Table 9-1 defines the confinement zone applicable to major spaces. The zones are defined as follows:

- **Zone I**, shown in pink, is the initial confinement barrier and includes gloveboxes, vessels, tanks, piping, hot cells, and the Zone I exhaust subsystem.
- **Zone II**, shown in orange, is the secondary confinement subsystem and includes the walls, floors, ceilings, and doors of the laboratories with the gloveboxes, HEPA filter rooms, and the Zone II ventilation exhaust subsystem. Laboratory gloveboxes and fume hoods are also Zone II.
- **Zone III**, shown in green, is the tertiary confinement barrier and includes the walls floor, ceilings, and doors of the corridor that surround the operating galleries, and the mechanical mezzanine.
- **Zone IV**, shown in blue, is the non-confinement ventilation zone – the positively pressurized areas served by unitary, non-safety, and commercial-grade equipment. These areas will include the administration support area, truck bays, and maintenance utility areas.

Table 9-1. Facility Areas and Respective Confinement Zones

Area	Zone
Hot cells (production)	I
Tank hot cell	I
Solid waste treatment hot cell	I
High dose waste solidification hot cell	I
Uranium decay and accountability hot cell	I
HIC vault	I
Analytical laboratory gloveboxes	I
R&D hot cell laboratory hot cells	I
Target fabrication room and enclosures	II
Utility room	II
Analytical laboratory room and hoods	II
R&D hot cell laboratory room and hoods	II
Waste loading hot cell	II
Maintenance gallery	II
Manipulator maintenance room	II
Exhaust filter room	II
Airlocks[a]	II, III
Irradiated target basket receipt bay	III
Waste loading truck bay	III
Operating gallery and corridor	III
Electrical/mechanical supply room	III
Chemical supply room	III
Corridors	III
Decontamination room	III
Loading docks	IV
Waste management loading bay	IV
Irradiated target receipt truck bay	IV
Maintenance room	IV
Support staff areas	IV

[a] Confinement zone of airlocks will be dependent on the two adjacent zones being connected.
HIC = high integrity container.
R&D = research and development.

[Proprietary Information]

Figure 9-1. Ground Level Confinement

[Proprietary Information]

Figure 9-2. Upper Level Confinement

[Proprietary Information]

Figure 9-3. Lower Level Confinement

9.1.2.1 Confinement

Confinement is an engineered safety feature of the HVAC system. Confinement is the term used to describe the boundary that surrounds radioactive materials and the associated ventilation system. Confinement systems are designed to localize any release of radioactive material to controlled areas in normal operational states and to mitigate the consequences of design basis accidents. Radiation protection control features (e.g., adequate shielding and confinement ventilation systems) minimize hazards associated with radioactive materials. The principal design and safety objective of the confinement system is to protect on-site personnel and the off-site public. The second design objective is to minimize the reliance on administrative or complex active engineering controls to provide a confinement system as simple and fail-safe as reasonably possible.

The process vessel ventilation system will serve as the primary confinement pressure boundary and is safety-related. The Zone I exhaust subsystem is an engineered safety feature that (along with shielding) will create a secondary confinement boundary; enclosing the vessels and process offgas within the hot cells. Confinement of the hot cells will be achieved through both the confinement ventilation system and the shielding provided by the steel and concrete structures comprising the walls, roofs, penetrations, and covers of the cells.

Secondary confinement will be accomplished by the zone boundaries, associated ventilation systems, and HEPA filter plenums to filter exhaust air prior to discharge at the facility ventilation stacks. Secondary confinement will also be accomplished through the use of bubble-tight isolation dampers. These dampers will isolate the ducts at the zone boundary under certain scenarios to ensure that all potential releases have been HEPA-filtered prior to exiting the facility (i.e., release to atmosphere). The safety aspects of the confinement system are discussed in Chapter 6.0, "Engineered Safety Features," Section 6.1, including the design response to off-normal conditions (e.g., loss of power).

9.1.2.2 Supply Air System

The RPF supply air system will provide conditioned air for facility workers and equipment and supply makeup air for RPF exhaust air systems. The supply air system will provide filtered and conditioned air to all Zone III spaces and some Zone II spaces at a ventilation rate of 100 percent outside air. The three air supply handling units will be sized at 50 percent capacity each, for redundancy. Two of the three units will be operating, while the third is on standby. If a single unit fails, the standby unit will start automatically. Each unit will consist of an outdoor air louver, filters, cooling coil, heating coil, heat recovery coil, isolation dampers, and a fan.

Variable-speed fans will be modulated to control the pressure in the common air plenum. The heating and cooling coils in each air-handling unit will be controlled based on a common supply air temperature sensor. Reheat coils will be provided in the supply ducts to each space, as required, to further condition the supply air, based on space temperature thermostats.

Outside air will be drawn into the RPF air supply system through air-handling units (Figure 9-4). The units will normally supply a constant volume of conditioned air to the Zone II and Zone III areas of the RPF.

Zone III air will be cascaded into Zone II areas through engineered leakage pathways by a negative pressure differential, maintaining the desired pressure drop between the zones (Figure 9-4). Terminal unit components in the supply duct system will include airflow control valves and reheat coils. The terminal reheat coils will provide final tempering of the supply air to maintain the Zone II space temperature setpoint. Zone II supply airflow control valves will operate in conjunction with exhaust valves to control the pressure differential in each zone by maintaining a fixed difference between the total supply and exhaust air flows for each Zone II space. Exhaust from Zone II will be expelled through the 23 meter (m) (75-foot [ft]) high Zone II exhaust stack. Additional detailed information on the Zone II stack design will be developed for the Operating License Application.

The isolation dampers and backdraft dampers in the supply duct system at the zone boundary (Figure 9-5) will close when required to provide confinement at the zone boundary. The supply air system HVAC controls will operate through the building management system.

[Proprietary Information]

Figure 9-4. Facility Ventilation System Diagram 1

[Proprietary Information]

Figure 9-5. Facility Ventilation System Diagram 2

9.1.2.3 Exhaust Air System

The RPF will have four exhaust air subsystems: Zone I exhaust, Zone II/III exhaust, laboratory exhaust, and process vessel ventilation exhaust. Each exhaust system will be provided with two 100 percent capacity exhaust fans and filter trains for complete redundancy on all exhaust subsystems. This redundancy is important to ensure confinement ventilation pressure differentials are maintained at all times. [Proprietary Information]. Exhaust ducts upstream of the filter trains will be round to minimize areas where contamination can accumulate, and are sized to minimize particulate settling in the duct. Each exhaust system will have a separate stack, with the exception of the process vessel ventilation subsystem, which will merge with the Zone I exhaust stream. A stack monitoring and sampling system will be provided on each stack to demonstrate compliance with applicable State law.

9.1.2.3.1 Zone I Exhaust System

The Zone I exhaust system will serve the hot cell, high-integrity container (HIC) loading area, and solid waste loading area. This exhaust system will maintain Zone I spaces at negative pressure with respect to atmosphere. The disassembly hot cell station will be maintained at a slightly lower pressure due to the increased likelihood of contamination in that area. All makeup air to Zone I spaces will be cascaded from Zone II spaces. Space temperature control will not be provided for Zone I spaces unless thermal loads are expected to cause temperatures to exceed equipment operating ranges without additional cooling. HEPA filters will be included on both the inlet and outlet ducts to Zone I. The outlet HEPA filters will minimize the spread of contamination from the hot cell into the ductwork leading to the exhaust filter train. The inlet HEPA filters will prevent contamination spread in case of an upset condition that results in positive pressurization of Zone I spaces with respect to Zone II spaces. The process vessel ventilation subsystem will enter the Zone I exhaust subsystem just upstream of the filter train.

The Zone I exhaust system will expel air from the hot cells and glovebox enclosures located within the RPF. The system will also capture exhaust from the process vessel ventilation system. The Zone I hot cell and glovebox enclosure will draw ventilation air from the surrounding Zone II spaces through HEPA filters. The exhaust air from each cell will pass through local HEPA filters.

Negative space pressure in Zone I will be controlled through local exhaust airflow control valves for each cell. The exhaust from the cells will collect in a Zone I system duct header and then be drawn through final, testable, HEPA filters and carbon adsorbers prior to discharge into the exhaust stack. The speed of the Zone I exhaust fans will be controlled to maintain a negative pressure setpoint in the Zone I exhaust duct header. The exhaust fans will be fully redundant. If the operating fan fails, the standby fan will start automatically. Exhaust from Zone I will be expelled through the 23 m (75-ft) high Zone I exhaust stack. Detailed information on the Zone I stack design will be developed for the Operating License Application.

9.1.2.3.2 Zone II/III Exhaust System

The Zone II/III exhaust system will serve the Zone II spaces and those Zone III spaces that do not provide cascaded air flow into Zone II. This exhaust system will maintain Zone II spaces at negative pressure and Zone III spaces at a less negative pressure with respect to atmosphere. Makeup air to Zone II spaces will either be cascaded from Zone III spaces or supplied from the supply air subsystem to meet additional space conditioning needs. All makeup air to Zone III spaces will be provided from the supply air subsystem.

The RPF Zone II exhaust system will expel air from the operating areas, workrooms, and fume hoods to maintain confinement. This confinement is important to safety to protect facility workers from radiological and hazardous chemical releases. The exhaust air from these spaces will collect in a Zone II exhaust header and will then be drawn through final, testable, HEPA filters and carbon adsorbers prior to discharge into the exhaust stack (Figure 9-4). The exhaust fan speed will be controlled to maintain the desired negative pressure in the RPF Zone II exhaust header. The exhaust fans will be fully redundant. If the operating fan fails, the standby fan will start automatically.

Air flow control valves in the Zone II room exhaust duct system will operate in conjunction with the zone supply valves to produce an offset between the exhaust and supply flow rates. The flow offset will enable a negative space pressure. Flow control valves in the fume hood exhaust ducts will maintain a constant volume through each fume hood. The control valves will automatically modulate to compensate for a drop in air pressure due to loading of local filters.

9.1.2.3.3 Laboratory Exhaust System

The laboratory exhaust system will provide fume hood and glovebox exhaust capability. This essentially is a Zone I system, but is separate from the main Zone I exhaust system to accommodate the large flow fluctuations from changing fume hood positions. These highly variable flow conditions will be controlled better through a separate exhaust system. This exhaust system will minimize the potential pressure perturbations and control difficulties that could result from including the fume hoods on the main Zone I exhaust system. Makeup air for increased fume hood exhaust flow will be supplied from the common supply air system.

9.1.2.3.4 Process Vessel Ventilation Treatment System

Due to the relatively short timeframe from neutron fission operations at a reactor to target dissolution and processing in the RPF, there will be an amount of short-lived tellurium isotopes in some process streams. The decay of these tellurium isotopes will create iodine isotopes. While most of these process streams will not likely evolve any iodine species into the offgas, this event cannot be precluded. To ensure the safety of the facility, the offgas from these special process streams will be collected and routed to an iodine removal system. Figure 9-6 provides a flow diagram for the process vessel vent subsystems that flow to the process vessel vent iodine removal unit (IRU).

The locations that are routed to the iodine removal subsystem include the following:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]

[Proprietary Information]

Figure 9-6. Process Flow Diagram for Process Vessel Ventilation Treatment

Iodine removal unit for target dissolution offgas system – This system in the tank hot cell will include offgas from the target disassembly and the target dissolution offgas systems.

- **Target disassembly** – [Proprietary Information].
- **Target dissolution** – [Proprietary Information].

After the offgas filter will be the dissolver offgas system's vacuum pumps and tanks, then the stream will flow through the secondary fission gas adsorbers and into the process vessel vent header.

Iodine removal unit for uranium, molybdenum, and waste accumulation tanks –Some of the liquids in the hot cell will contain tellurium isotopes that generate iodine isotopes during decay. A portion of the iodine will remain in the dissolver solution. Although it is not likely that much of the iodine will evolve into the offgas, these streams will be passed through an IRU before the process vessel vent header.

The expected offgas streams that feed this IRU will be from tank hot cell vessels, including the Mo feed tanks, impure U collection and lag storage tanks, U recovery waste tanks, and the liquid waste handling tanks. [Proprietary Information]. This offgas stream will flow into the process vessel vent header.

General vessel vent system – This header system will service the remaining vessels in the tank hot cell, including the pure U lag storage tanks (14), recycled U collection tank, and tanks attributed to the U concentrators. This offgas stream will flow into the process vessel vent header without additional treatment.

High volume evaporative vent from waste handling – This system will service the three waste solidification unit operations (low-dose liquid waste, high-dose liquid waste, and solid waste) and the low-dose evaporation tanks.

The low-dose evaporation tanks will have high flowrate and elevated temperatures to allow water to evaporate. The header will collect these humid air sweeps and dilute with additional air bleed to ensure that the evaporated water does not condense in the ducting or pipes. This offgas stream will flow into the process vessel vent header.

Target fabrication vent – The target fabrication area ventilation is required for confining: (1) offgas from the dissolver and other process vessel, and (2) offgas from the calcination or reduction furnace systems, where hydrogen will be diluted with air to less than the lower flammability limit. This offgas stream will flow into the process vessel vent header.

Process vessel vent iodine removal unit – The process vessel vent IRU (VV-SB-520) system will consist of a sorbent bed of charcoal or activated carbon to remove iodine from the vessel vent gases. The process vessel vent IRU is part of an item relied on for safety (IROFS) RS-03, "Hot Cell Secondary Confinement Boundary." Chapter 6.0, Section 6.2.1, and Chapter 13.0, "Accident Analysis," Section 13.2.2.8, provide additional detail on the safety function.

Process vessel vent filter – This treatment operation will consist of HEPA filtration and the exhaust fan and will flow to the Zone I exhaust system.

9.1.2.4 Cleanroom Subsystem

The Mo purification hot cell cleanroom subsystem is designed to provide filtered and conditioned air at an exchange rate to meet the standards of an ISO 14644-1, "Cleanrooms and Associated Controlled Environments—Part 1: Classification of Air Cleanliness," Class 8 cleanroom. The cleanroom will be maintained at a slightly positive pressure relative to its surroundings to ensure that unfiltered air does not infiltrate the cleanroom. Air inside the cleanroom will be continually recirculated through a dedicated filtration system to remove internally generated contaminants. Air will be 100 percent recirculated, with the only air exchange with the surroundings of the cleanroom occurring through exfiltration and makeup air entering on the suction side of the fan. The cleanroom air handling unit and filters will be located inside the hot cell and, therefore, must be remotely maintainable. Periodic cleanroom certification testing will also need to be performed remotely with permanently installed instrumentation.

9.1.2.5 Physical Layout and Location

All supply air handling units, supply fans, exhaust fans, and associated heat recovery coils will be located in the mechanical/electrical area (supply air handler room) located on the second floor. This area will house the Zone II and Zone III subsystem air-handling units and fans. The exhaust HEPA filter plenums and exhaust fans will be located in the mechanical area on the second floor.

9.1.2.6 Principles of Operation

The RPF ventilation system will maintain the facility at the desired temperatures and negative pressurization during normal operations. Supply air temperature from the air-handling units will be held constant through the use of heating and cooling coils. Reheat coils will be provided to further temper supply air to occupied areas based on local thermostat demand. The systems also have design features to maintain constant overall building pressures, the Zone I header pressure, and Zone II exhaust header pressures during normal operations. Local room pressurization will be obtained by the airflow offset between supply and exhaust.

Supply airflows will be held constant through the use of supply fan variable-frequency drives and flow measuring stations. Exhaust airflow will be controlled based on building pressure and exhaust header pressure demands and to ensure that the HEPA filter plenum rated airflows are not exceeded. Variable-frequency drives on the exhaust fans will be provided to maintain required exhaust flows when flow resistance resulting from exhaust filter dirt loading increases.

Makeup air to maintain a constant air pressure differential between the Zone II and Zone III areas will be provided by the Zone III supply air. Zone III will provide overall building pressure control during normal operations by modulation of the exhaust/return airflow path, while the supply air remains fixed.

Pressure and flow conditions for the process enclosures and laboratory ventilation will be manually controlled using volume dampers and valves. Airflow control valves will be installed in each room's main supply and exhaust ducts to maintain laboratory design space pressure. These valves will be located outside of the laboratory modules.

The Zone I exhaust system for each module will be adjusted manually using a valve located in the room duct header near the air inlet end to maintain minimum vacuum pressure. A static pressure tap will be located near the air inlet end of the header and will be attached to a magnehelic gauge to monitor the header pressure relative to the laboratory module space pressure (on the radiologically controlled area [RCA]-designed portion of the system). The system is designed to maintain the Zone I process enclosures at their design pressure during normal operations and have the capacity to draw the required inflow of air in the event of a design breach of an enclosure.

The Zone II exhaust system is designed to maintain the Zone II enclosures at their required pressure. A balancing valve located in the exhaust duct of each enclosure will initially be partially closed. As the local filter of the enclosure loads up and a drop in pressure increases across the filter, the valve will be adjusted to reestablish flow in the design range. Differential pressure gauges will be provided at each enclosure to monitor the filter pressure drop and measure the pressure drop across only the enclosure. The enclosure's pressure drop reading will be calibrated to its acceptable face velocity range to monitor enclosure performance.

The Zone II supply air system is designed to provide the supply air volume rate required for each space. The system will supply makeup air as required for the Zone I and II process enclosures, general exhaust, and to maintain the design temperatures in the laboratories. [Proprietary Information] to prevent the entrainment of potentially contaminated air back out of the process enclosures.

9.1.3 Operational Analysis and Safety Function

Chapter 11.0 and Chapter 13.0 provide an analysis of normal and off-normal operation of the RPF HVAC system. Chapter 11.0, Section 11.1.1.1 presents that normal release analysis. Chapter 13.0, Section 13.2 evaluates various accident sequences that involve failure of the ventilation components, radiological spills, and the release of high-dose solutions, vapors, or gases from within the hot cell liquid confinement, secondary confinement, or shielding boundary.

Defense-in-depth – Failure of the air balance system is not in itself an accident, but represents the failure of a system designed to mitigate other accidents that lead to an airborne release of radionuclides in the form of particulates or gases. Systems that will mitigate these releases include the primary confinement and primary offgas treatment system, which will capture particulates, absorb iodine, and absorb Xe and Kr and other gaseous radionuclides, to slow the release following decay to more stable isotopes. In the target fabrication processes, uranium will be handled in physical forms that do not contribute to a high-dose rate factor in airborne releases. Uranium solutions will also be processed in closed systems with filtered process ventilation systems to remove the small amounts of activity normally released.

Item relied on for safety – Based on the Chapter 13.0 analysis, the hot cell secondary confinement (Zone I exhaust ventilation subsystem) has been designated as an IROFS (RS-03, "Hot Cell Secondary Confinement Boundary"). The operations, equipment, and components of this system will ensure the confinement of hazardous materials during normal and abnormal conditions, including natural phenomena, fires, and explosions. Components of the dissolver offgas subsystem and the process vessel ventilation system have also been designated as IROFS. The safety functions of the confinement system are discussed in more detail in Chapter 6.0, Section 6.1.

Chapter 13.0 evaluates a fire that could cause the carbon retention beds to ignite, leading to the release of radionuclides into the RPF exhaust stack. Based on analysis of this accident, the exhaust stack height was identified as an IROFS (FS-05, "Exhaust Stack Height"). This analysis is discussed in more detail in Chapter 13.0. This passive engineered control is designed and fabricated with a fixed height for safe release of gaseous effluents.

9.1.4 Instrumentation and Control Requirements

Section 9.1.2.6 provides a general description of the operation of the RPF ventilation system. Ventilation system control and monitoring is discussed in Chapter 7.0, "Instrumentation and Control Systems." Table 9-2 summarizes the system parameters (in general) and whether they are monitored or alarmed. The system sequence of operation will be developed and provided in the Operating License Application.

Table 9-2. Indications for Facility Ventilation System Parameters

Parameter	Alarm	Monitor
Equipment operating status	✓	✓
Damper position status		✓
Exhaust header pressure	✓	✓
Fan speed	✓	✓
Filter differential pressures	✓	✓
Equipment bearing vibration	✓	✓
Equipment bearing temperatures	✓	✓
HEPA filter unit air inlet temperature	✓	✓
HEPA filter unit airflow rate	✓	✓
First-stage HEPA inlet temperature	✓	✓
Fan motor amperage	✓	✓
Fan thermal overload	✓	
Zone I header pressure	✓	✓
Zone II header pressure	✓	✓
Confinement zone pressure differentials	✓	✓

HEPA = high-efficiency particulate air.

9.1.5 Required Technical Specifications

The technical specifications associated with the ventilation system, if applicable, will be discussed in Chapter 14.0, "Technical Specifications, as part of the Operating License Application.

9.2 MATERIAL HANDLING

The RPF does not handle or store reactor fuel. Material handling activities are discussed in Chapter 4.0, "Radioisotope Production Facility Description," Sections 4.3 and 4.4, and are analyzed in Chapter 13.0.

9.3 FIRE PROTECTION SYSTEMS AND PROGRAMS

The fire protection system is designed to provide varying levels of notification of a fire event, suppress small fires, and prevent small fires from becoming large fires. Notification of personnel will be achieved through detection of a fire by automatic detection devices, manual pull stations, automatic sprinklers, and the use of alarm devices that broadcast within the building and transmit signals to the central alarm station and RPF control room. Suppression of fires will be accomplished through the use of automatic sprinklers where appropriate. The suppression system will include all piping, valves, and fittings from the water supply (i.e., water storage tanks or municipal hydrants) to the automatic sprinklers and standpipes in the building.

9.3.1 Design Basis

The fire protection system design provides detection and suppression of fires in the RPF. The fire protection system design basis includes:

- Providing varying levels of notification of a fire event and transmitting the notification to the site central alarm station and RPF control room
- Suppressing small fires
- Preventing small fires from becoming large fires

Additional information on the design basis is provided in Chapter 3.0, Section 3.5.2.7.

9.3.2 System Description

The fire protection system will provide detection and suppression of fires within the RPF, generation of alarm signals indicating the presence and location of fires, and execution of commands appropriate for the particular location of the fire.

A complete addressable fire alarm system, with both automatic and manual initiation, will be provided throughout the RPF. Detection devices will report to a local alarm panel. All alarms (fire, supervisory and trouble) will transmitted to the site central alarm station and RPF control room. Fire protection system components will have fail-safe features and audible/visual alarms for operability and trouble indication.

The fire detection and alarm subsystem will include smoke detectors, heat detectors, water flow and tamper switches, manual pull stations, horns and strobes, and a notification system. The building fire suppression subsystem will include automatic sprinkler, HEPA filter plenum deluge water sprays, and portable fire extinguishers. Water will be supplied from the exterior fire hydrant supply via connections to the domestic water system. Firewater booster pumps will increase the system pressure in the fire suppression subsystem piping.

Space has been reserved so that if required, the fire protection system can have a dedicated water storage facility onsite. The need for dedicated storage will be dependent on the reliability and flow rate of the city water supply. The storage tank capacity is anticipated to be [Proprietary Information], and will be determined for the Operating License Application. If an on-site water storage system is found to be necessary, an electric motor-driven fire pump will serve as the primary pressure source, and a redundant diesel engine-driven fire pump will provide backup.

Fire protection water will be distributed throughout the building via a gridded water system. Vertical risers will supply various systems, with redundant risers also provided. From the vertical risers, the automatic sprinkler part of the system will feed a series of sprinkler heads that have temperature-sensitive links. When a set temperature is reached at the sprinkler head, the links will melt or break (depending on type) and release water in an umbrella-shaped spray pattern.

The fire protection system is designed to provide a constant flow of water to an area experiencing a fire for a minimum of 120 min. The size of that area will be determined using guidelines from the International Fire Code (IFC, 2012). For sprinkler systems, the International Fire Code uses a design based on the National Fire Protection Association (NFPA) 13, *Standard for the Installation of Sprinkler Systems*. Fire hose stations will also provide flow for use in fighting fires.

Because water from the sprinklers may become contaminated with materials it contacts, areas where hazardous materials are present are designed to hold firewater runoff for sampling prior to release to the environment. Additional detailed information on the firewater runoff storage will be developed for the Operating License Application.

The fire protection system is divided into two major subsystems. The subsystems and components are categorized as follows:

- Fire suppression subsystem consisting of automatic sprinklers, a HEPA filter plenum deluge, glovebox fire suppression, and fire hydrants
- Fire detection and alarm subsystem consisting of:
  - Controls (e.g., fire alarm control panel, subpanels, or devices used for control of devices)
  - General area detection (e.g., room smoke and heat detectors, manual pull stations)
  - Duct smoke detection for non-nuclear ventilation systems, glovebox heat detection
  - HEPA filter plenum heat detection
  - Fire suppression subsystem monitoring devices (e.g., waterflow switches, tamper switches, fire pump, and water storage monitoring devices)
  - Occupant notification
  - Alarm transmission to the central alarm station and RPF control room

9.3.2.1 Fire Suppression Subsystem

The fire suppression subsystem will include automatic sprinklers, HEPA filter plenum deluge, and fire hydrants. The need for fire suppression in gloveboxes will be evaluated and additional information will be provided in the Operating License Application. In addition to the automatic features of the fire suppression subsystem, manual response capabilities will be provided by fire extinguishers with an appropriate classification (discussed further in Section 9.3.2.3).

A 20.3 centimeter (cm) (8-inch [in.]) network of main piping (commonly called a grid) will be provided. Vertical piping, referred to as risers and sized at 15.2 cm (6 in.), will be provided to support the fire suppression subsystem components (sprinklers, HEPA filter plenum deluge, and hydrants). The RPF will also be provided with redundant sprinkler risers. The connection between the risers and sprinkler piping will be provided with control valves, check valves, waterflow switches, and a test/drain assembly for detection of waterflow and system maintenance. Piping from the risers will support automatic sprinklers located throughout the facility. The automatic sprinkler system is designed in accordance with NFPA 13.

The HEPA filter plenum deluge will be also supplied by the 20.3 cm (8-in.) piping network and will be part of a larger filter plenum fire safety design that includes fire screens, demisters, plenum drains, and plenum dampers. The automatic feature will include a deluge valve that is activated via heat detectors in the ducts serving the plenum. When high temperatures are sensed in the air stream, the heat detector will send a signal to the fire alarm control panel, which in turn will send a signal to the deluge valve to operate. Water will flow through the deluge valve into the leading portion of the plenum to cool the air before it reaches the HEPA filters. The heat detectors and deluge valve for a particular plenum will be paired such that only plenums that are experiencing high temperatures will react. A manual bypass feature will be also provided to allow waterflow if the deluge valve fails to open.

A separate, manually activated feature is designed to spray directly on the HEPA filters and is intended to only be used if the HEPA filter ignites. The manual feature will include a control valve connected via piping to a spray nozzle directed at the HEPA filters.

The fire hydrants, located on the exterior of the building, will be supported by the 30.5 cm (12-in.) municipal water supply line provided for the RPF. Two 8-in. connections will support the 20.3 cm (8-in.) loop that surrounds the building. Four fire hydrants, one at each corner of the building, will be provided. The fire hydrants are not designed for natural phenomenon hazards and cannot be relied on for seismic accidents. The fire hydrant subsystem is designed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, and the International Fire Code (IFC, 2012). The subsystem is designed to support fire flows of 5,680 L/min (1,500 gal/min) overall and at least 1,893 L/min (500 gal/min) at each fire hydrant.

9.3.2.2 Fire Detection and Alarm Subsystem

The fire detection and alarm subsystem will provide a range of fire detection capabilities and notification methods. The primary means of detection will be by monitoring the fire suppression system devices, including flow switches that indicate release of water from automatic sprinklers or deluge valves, and tamper switches that supervise valve position. Smoke and heat detection will be provided in specific locations to provide detection of fires in spaces where water damage concerns warrant improved manual intervention (e.g., computer server rooms), areas deserving additional life safety (e.g., egress locations), or other safety-driven functions. As required by NFPA 101, *Life Safety Code*, and NFPA 72, *National Fire Alarm Code*, smoke detection will be provided above the main fire alarm control panel and any subpanels necessary to perform control functions for the system.

For ventilation units, smoke and heat detection will be provided in support of several safety aspects. Smoke detectors will be provided in:

- Non-nuclear ventilation systems, in accordance with NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, and the International Fire Code (IFC, 2012)
- Air intakes, to address smoke infiltration from wild land fires and fires in other facilities that might spread smoke to the surrounding area
- Nuclear ventilation systems, to support shutdown and minimize the spread of contaminated smoke to other areas of the RPF

Heat detectors will be provided in the Zone I and II ventilation system exhausts for both notification of high temperatures and release of the automatic portion of the HEPA filter plenum deluge capability. Control modules and relays will be integrated into the fire detection and alarm subsystem. Control modules will provide signals for releasing the deluge valves for the HEPA filter plenum deluge capability, and control methods will be integrated for shutdown of non-safety HVAC systems.

Alarms received by the fire alarm control panel will be transmitted via a copper cable or fiber optic cable network to monitoring stations in the RPF. The fire alarm control panel will also provide notification through the facility-wide infrastructure to the central alarm station. The central alarm station will provide data to the Columbia Fire Department for response.

The fire detection and alarm subsystem will receive its primary power supply from a dedicated circuit off of the normal building power. Internal batteries will provide a secondary power source, with connection to the standby generator. The batteries will be sized to provide 24 hours (hr) of backup power, plus 10 min of alarm power, as required by NFPA standards.

9.3.2.3 Fire Extinguishers

In addition to the automatic features of the fire suppression subsystem, manual response capabilities will be provided via fire extinguishers with an appropriate classification. Fire extinguishers will be located throughout the building, as required by NFPA 10, *Standard for Portable Fire Extinguishers*. Specific extinguisher types, such as those for metal fires or particular chemicals, will be specified depending on the hazard.

9.3.3 Operational Analysis and Safety Function

Chapter 13.0 identifies fire hazards and evaluates adverse events and accident sequences. The criticality safety evaluations discussed in Chapter 6.0 include the impact of fire suppression water in its analysis. Chapter 13.0 provides an evaluation of the accident sequences that involve either combustible solids or liquids, or explosive gases, in close proximity to the high uranium process streams or the high-dose process streams. As part of this analysis, an emergency purge gas system was identified to prevent flammable concentration in process vessel headspaces. IROFS FS-03, "Process Vessel Emergency Purge System," is discussed in Chapter 13.0, Section 13.2.7, and in Chapter 6.0.

The following summarizes NWMI-2013-039, *Preliminary Fire Hazards Analysis* (PFHA), which was prepared to demonstrate that the RPF will maintain the ability to perform safe-shutdown functions and minimize radioactive material releases to the environment in the event of a fire. The PFHA objectives were to:

- Consider potential in situ and transient fire hazards
- Determine the effects of a fire in any location in the RPF and the ability to safely shut down the facility and/or minimize and control the release of radioactivity to the environment
- Specify measures for fire prevention, detection, suppression, and containment for each fire area housing structures, systems, and components that are important to safety, in accordance with U.S. Nuclear Regulatory Commission (NRC) guidelines and regulations

The PFHA assessed the fire hazards at the RPF, support facilities, and surrounding project site. The analysis also assessed the fire safety criteria identified in NRC Regulatory Guide 1.189, *Fire Protection for Nuclear Power Plants*. The PFHA provided a consequence evaluation of a design basis fire (DBF) scenario within each fire area, assuming the loss of automatic and manual fire suppression. The PFHA also identified facility design features and fire hazard mitigating features for personnel safety and property protection commensurate with the NRC criteria.

9.3.3.1 Radioisotope Production Facility Fire Areas

The fire hazards, life safety considerations, fire protection features, and DBF for designated fire areas within the RPF are discussed below.

The RPF will be subdivided into separate fire areas for the purposes of limiting the spread of fire, protecting personnel, and limiting the consequential damage to the facility. Figure 9-7 and Figure 9-8 provide the delineation of fire areas on the first floor and second floor of the RPF, respectively. The determination of fire area boundaries was based on consideration of the following:

- Types, quantities, density, and location of combustible materials
- Location and configuration of equipment
- Consequences of inoperable equipment
- Location of fire detection and suppression systems
- Personnel safety and exit requirements

Fire areas will typically be bounded by 2-hr fire-rated barriers to separate:

- Processing areas and radioactive material storage areas from each other and adjacent areas
- Rooms with major concentrations of electrical and mechanical equipment from adjacent areas
- Computer and control rooms from adjacent areas
- Maintenance shops from adjacent areas
- Combustible storage areas from adjacent areas
- Fan rooms and plenum chambers from adjacent areas
- Office areas from moderate and high fire hazard areas

In one case, two fire areas will be separated by 3-hr fire-rated barrier walls. The fire-rated barrier design and construction are in accordance with the International Building Code (IBC) (ICC, 2012) and NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*.

Where fire-rated assemblies are partially or fully penetrated by pipes, ducts, conduits, raceways, or other devices, fire-rated barrier material will be placed in and around the penetrations to maintain the fire-resistance rating of the assembly. All openings in the fire barriers will be protected, consistent with the designated fire-resistance rating of the barrier. Fire doors will be rated commensurate with the fire-rated barrier in which they are installed, and comply with the requirements of NFPA 80, *Standard for Fire Doors and Other Opening Protectives*.

[Proprietary Information]

Figure 9-7. Life Safety Plan (First Floor)

[Proprietary Information]

Figure 9-8. Life Safety Plan (Second Floor)

9.3.3.1.1 Hot Cell, Waste Handling, and Shipping Areas

As the most consequential fire area within the RPF, the hot cell area will be a single-story, non-combustible, high bay structure. The footprint of this area will be [Proprietary Information]. The hot cell area will include parts of the irradiated target receipt bay and waste management areas, Mo recovery and purification process, U recovery and recycle process, high bay above the hot cell area, and operating and maintenance galleries. An overhead crane system will be used to transfer radioactive materials between the different operations.

Life Safety Considerations

The hot cell area is anticipated to handle hazardous materials that exceed the maximum allowable quantity limits established in the IBC (ICC, 2012). Therefore, the hot cell area will be designed as High Hazard H-3 and/or H-4 occupancy in accordance with the IBC and will be provided with emergency lighting, illuminated exit signs, automatic sprinklers, and an automatic and manually actuated fire alarm system with audible and visual indicating devices as necessary.

The common path of egress travel for an H-3 occupancy equipped throughout with an automatic sprinkler system will be 7.6 m (25 ft), in accordance with the IBC Section 1014.3. The exit access travel distance for a fully sprinklered H-3 occupancy will be limited to 45.7 m (150 ft), in accordance with the IBC. Dead-ends in corridors should not exceed 6.1 m (20 ft), in accordance with IBC Section 1018.4.

Access to the crane platforms will be limited to maintenance and service personnel only. IBC Section 505.3 defines equipment platforms as not being habitable and are considered to not be occupiable space. Because the crane platforms will normally be unoccupied with limited access, these crane platforms will not be required to meet IBC means of egress requirements.

Exposure Fire Potential/Potential for Fire Spread between Fire Areas

The hot cell, waste, handling and shipping areas will be separated from other fire areas of the building by 2-hr fire-rated barrier walls, with the exception of the wall between the production area and the administrative area, which will have a 3-hr fire-rated barrier wall. Penetrations in the fire-rated barrier walls will be protected with penetration seals, providing a fire rating equivalent to the barriers.

The hot cell area could be exposed to a fire in an adjacent fire area when the large access doors are opened during radiological material transfer activities. The primary areas of concern include the interface (open doors) between the unloading and waste truck bays with the production area. To prevent a fire from spreading between these areas, administrative controls will be implemented that dictate personnel procedures and limit combustibles around interface access doors. Fire spread between areas will be therefore mitigated by personnel actions, limited combustibles, and fire-rated boundaries.

Fire Protection Features

The hot cell area requires the following fire protection features to provide a defense-in-depth approach to fire protection. This approach will result in a fire being quickly detected and suppressed, which will mitigate fire-induced damage.

- **Automatic** – Automatic sprinkler systems will be installed throughout the production area, with the exception of the hot cell enclosure. Self-contained fire suppression systems may be located on equipment such as cranes and forklifts. An automatic fire detection and alarm system will be installed throughout the production area. Analysis of the need for sprinklers in the hot cell area and additional detailed information on these systems will be developed for the Operating License Application.
- **Manual** – Manual fire suppression will consist of portable fire extinguishers and Class I standpipe system hose valves that will be provided within the production area. Manual fire alarm pull stations will be provided at exits from the production area.
- **Passive** – Passive fire protection will be provided in the form of fire-rated construction to protect the means of egress from the facility and separation between fire areas. Fuel traps will be provided where the diesel-powered vehicles interface with the production area. Underhung collection pans will be provided under the crane gearboxes.

Fire Hazards, Ignition Sources, and Design Basis Fire Scenarios

The following fire hazards and ignition sources were considered for evaluation of a DBF scenario within the production area.

- **Scenario 1** – A fire starts within the irradiated target shipping cask that is caused by agitation and spontaneous ignition of the pyrophoric uranium dust or particulate.
- **Scenario 2** – A fire or explosion starts within a tank or exhaust system that is caused by the uncontrolled accumulation of hydrogen gas. Hydrogen generation represents a fire hazard, where the accident sequence is initiated by failure of the sweep gas subsystem.

- **Scenario 3** – A fire starts within the exhaust stack system that is caused by the ignition of the carbon retention bed and/or HEPA filters.
- **Scenario 4** – A fire starts adjacent to a semi-tractor trailer that is caused by the rupture of the fuel tank and ignition of the unconfined (static) diesel spill.
- **Scenario 5** – A fire starts on a diesel-driven forklift that is caused by the rupture of the fuel tank and ignition of the unconfined (static) diesel spill.
- **Scenario 6** – A fire starts in a crane collection pan that is caused by the rupture of the gearbox and ignition of the confined (static) silicone oil pool.

The DBF scenario for the production area consists of a diesel fuel spill and ignition from an unknown source caused by the operation of a semi-tractor trailer or forklift. The semi-tractor trailer is assumed to have two 284 L (75-gal) diesel fuel tanks (568 L [150 gal total]), along with rubber tires, a battery, and small amounts of other combustible material. A small amount of permanent combustibles, including electrical cables, polyethylene tarps, isopropyl alcohol, vinyl, and trash bins, may also be present. These combustibles will be limited by administrative controls.

The DBF scenario postulates that the entire contents of the fuel tanks will spill, forming an approximately 15.5 m (50-ft) diameter pool with a 3 millimeter (mm) (0.12-in.) depth, and will then ignite. The DBF postulates that any combustibles located within the fuel spill diameter will also ignite and be completely consumed (NWMI-2013-039).

Consequences of an Automatic Fire Suppression Failure

Failure of the automatic fire suppression system will cause a delay in responding to a fire, resulting in the combustibles being completely consumed during the DBF. The adoption of administrative controls will limit combustibles and minimize the spread of fire. However, smoke and hot gases could damage equipment located within the production area.

The Columbia Fire Department will be notified of a fire by either actuation of a manual fire alarm pull box station or the automatic smoke or temperature detection systems. The DBF would be contained within the irradiated target receipt bay and operating gallery by the 2-hr rated fire walls. If the automatic fire suppression system fails to operate, the fire department is expected to arrive well before the 2-hr fire walls have failed and extinguish the fire using portable extinguishers or the hose stream supported by the Class I standpipe system. The required response time of the fire department will be determined for the Operating License Application.

Conclusion

While the DBF for this area is unlikely to result in a radiological release with the radioactive material being contained in a U.S. Department of Transportation (DOT) Type B cask, the potential exists for a release in some of the other scenarios described. Additional information, and a determination if the fire protection systems in this fire area will be considered IROFS, will be provided in the Operating License Application.

9.3.3.1.2 Target Fabrication Area

The target fabrication area will be located adjacent to the production area on the east side of the RPF and will be a noncombustible structure with an industrial F-1 occupancy. Two-hour fire-rated barrier walls will separate the target fabrication area from other fire areas of the building. Penetrations in the fire-rated barrier walls will be protected with penetration seals, providing a fire rating equivalent to the barriers.

The footprint of the target fabrication area will be [Proprietary Information] over most of the area. This area will be dedicated to the production of low-enriched uranium (LEU) targets.

Life Safety Considerations

The target fabrication area is required to meet IBC life safety criteria (ICC, 2012) and will be provided with emergency lighting, illuminated exit signs, automatic sprinklers, and an automatic and manually actuated fire alarm system with audible and visual indicating devices as necessary.

An accessible means of egress will be provided in accordance with the IBC. Exit access will be provided to the target fabrication area, with direct exit discharge from the RPF. The maximum distances to the exit access in the target fabrication area will be within the following parameters for a High Hazard H-3 occupancy. The common path of egress travel for an H-3 occupancy equipped throughout with an automatic sprinkler system will be 30.5 m (100 ft), in accordance with IBC Section 1014.3. The exit access travel distance for a fully sprinklered F-1 occupancy will be limited to 76.2 m (250 ft), in accordance with IBC Table 1016.2. Dead-ends in corridors will not exceed 15.2 m (50 ft), in accordance with IBC Section 1018.4, Exception 2. No deviations from the IBC life safety criteria have been identified.

Exposure Fire Potential/Potential for Fire Spread between Fire Areas

The target fabrication area could be exposed to a fire in an adjacent area when the large access doors are opened during target transfer or waste shipping activities. The primary area of concern is an open doorway to the production area.

To prevent a fire from spreading between these areas, administrative controls will be implemented that dictate personnel procedures and limit combustibles around interface access doors. Additional information on these controls will be provided in the Operating License Application. Fire spread between areas will therefore be mitigated by personnel actions, limited combustibles, and 2-hr fire-rated boundaries.

Fire Protection Features

The target fabrication area requires the following fire protection features to provide a defense-in-depth approach to fire protection. This approach will result in a fire being quickly detected and suppressed, reducing fire-induced damage.

- **Automatic** – An automatic fire suppression system will be installed throughout the target fabrication area. An automatic fire detection and alarm system will be also installed throughout the target fabrication area. The system specifics will be determined during detailed design and included in the Operating License Application.
- **Manual** – Manual fire suppression will be provided within the target fabrication area and consist of portable fire extinguishers and Class I standpipe system hose valves. Manual fire alarm pull stations will be provided at exits from the target fabrication area.
- **Passive** – Passive fire protection will be provided in the form of fire-rated construction to protect the means of egress from the facility and separation between fire areas.

Fire Hazards, Ignition Sources, and Design Basis Fire Scenarios

The following fire hazards and ignition sources were considered for evaluation of a DBF scenario within the target fabrication area.

- **Scenario 1** – A fire or explosion starts within the reduction subsystem, caused by ignition of a nitrogen or hydrogen gas mixture by the high temperature created by the oven (determined to be highly unlikely based on credible physical conditions [Chapter 13.0]).
- **Scenario 2** – A pyrophoric fire of uranium metal (determined to be highly unlikely based on credible physical conditions [Chapter 13.0]).
- **Scenario 3** – A fire starts with combustible materials or equipment in the target fabrication area.

The DBF event was determined to be a fire of combustible materials such as paper products (Scenario 3). The DBF for the target fabrication area involves ignition of in situ combustibles located within the area caused by an electrical short circuit or a maintenance welding operation. The combustible loading of the area was considered low. The fire also consumes other transient combustibles located within the area.

Consequences of an Automatic Fire Suppression Failure

Failure of the automatic fire suppression system will cause a delay in responding to a fire, resulting in the combustibles being completely consumed during the DBF. The adoption of administrative controls will limit combustibles and minimize the spread of fire. However, smoke and hot gases could damage equipment located within the target fabrication area.

In the event of a fire, the Columbia Fire Department will be notified by either actuation of a manual fire alarm pull box station or the automatic smoke or temperature detection systems. The DBF would be contained within the target fabrication area by the 2-hr rated fire walls. If the automatic fire suppression system fails to operate, the fire department is expected to arrive well before the 2-hr fire walls have failed and extinguish the fire using portable extinguishers or the hose stream supported by the Class I standpipe system. The required response time of the fire department will be determined for the Operating License Application.

Conclusion

The above analysis and description show that the fire protection and life safety systems within the target fabrication area are designed such that they will function in a manner, whether operational or not, consistent with occupational safety and protection of the public and environment. Two of the three scenarios described are considered highly unlikely. The DBF for this fire area would result in minimal or no release to the public because of the low radiological source term and the fact that the standard combustibles described are unlikely to be mixed with the LEU materials. Therefore, this system will likely not be considered an IROFS.

9.3.3.1.3 Administration and Support Area

The administration and support area will be located adjacent to the production area on the south side of the RPF and will be a single-story, noncombustible structure with business (Group B) and assembly (Group A-2) occupancies. The administration and support area will be Type IIB construction and separated from the remainder of the RPF by 3-hr fire-rated barrier walls.

The administration and support area will include the main entry and security access points, break room, control room, conference room, men's and women's lavatories, and several small offices. The control room will be separated from the remainder of the administration and support area by 2-hr fire-rated barrier walls.

The operations performed within the administration and support areas will be consistent with office space uses. The occupant load of the administration and support area will include non-production work staff.

Life Safety Considerations

The administration and support area is required to meet IBC life safety criteria (ICC, 2012) and will be provided with emergency lighting, illuminated exit signs, automatic sprinklers, and an automatic and manually actuated fire alarm system with audible and visual indicating devices as necessary.

An accessible means of egress will be provided to the area in accordance with the IBC. Exit access will be provided to the administration and support area by one main exit at the front of the building and a secondary exit located to the south side of the RPF. A break room will also be provided with an additional exit. The maximum distances to the exit access within the administration and support area will be within the following parameters. The travel distance for the common path of egress travel for a mixed use business (B) and assembly (A-2) occupancy equipped throughout with an automatic sprinkler system will be 23 m (75 ft), in accordance with IBC Table 1014.3. The exit access travel distance for a fully sprinklered mixed-use business (B) and assembly (A-2) occupancy will be limited to 76 m (250 ft), in accordance with IBC Table 1016.2. Dead-ends in corridors will not exceed 6.1 m (20 ft), in accordance with IBC Section 1018.4.

Exposure Fire Potential/Potential for Fire Spread between Fire Areas

The administration and support area will be separated from other fire areas of the RPF by 3-hr fire-rated barriers. Penetrations in the fire-rated barrier walls will be protected with penetration seals, providing a fire rating equivalent to the barriers. Load-bearing structural elements are not required to be protected by fire-resistive construction.

To prevent a fire from spreading between areas, administrative controls will be implemented that dictate personnel procedures and limit combustibles around access doors. Fire spread between areas will be therefore mitigated by personnel actions, limited combustibles, and 3-hr fire-rated boundaries.

Fire Protection Features

The administration and support area requires the following fire protection features to provide a defense-in-depth approach to fire protection. This approach will result in a fire being quickly detected and suppressed, reducing fire-induced damage.

- **Automatic** – An automatic wet-pipe sprinkler system will be installed throughout the administration and support area. An automatic fire detection and alarm system will also be installed throughout this area. Additional detailed information will be developed for the Operating License Application.
- **Manual** – Manual fire suppression will be provided within the administration and support area and consist of portable fire extinguishers and Class I standpipe system hose valves. Manual fire alarm pull stations will be provided at the exits from the administration and support area.
- **Passive** – Passive fire protection will be provided in the form of fire-rated construction to protect the administration and support area from other occupied areas of the facility.

Fire Hazards, Ignition Sources, and Design Basis Fire Scenarios

The DBF was determined to consist of ordinary combustibles (e.g. paper products and office furniture) ignited within a closed office caused by an electrical short circuit. The combustible loading of the office was considered low. The fire also consumes other transient combustibles located within the office and spreads to nearby cubicles.

The DBF would result in the complete combustion of the combustible materials in the area of origin. No credit was taken for fire suppression activities. The administration and support area was considered a single fire area, and the result of the DBF was the complete loss of function of the area.

Consequences of an Automatic Fire Suppression Failure

Failure of the automatic fire suppression system will cause a delay in responding to a fire, resulting in the combustibles being completely consumed during the DBF. The adoption of administrative controls will limit combustibles and minimize the spread of fire. However, smoke and hot gases could damage equipment located within the administrative and support area.

In the event of a fire, the Columbia Fire Department will be notified of a fire by either actuation of a manual fire alarm pull box station or the automatic smoke or temperature detection systems. The DBF would be contained within the administrative and support area by the 3-hr rated fire walls. If the automatic fire suppression system fails to operate, the fire department is expected to arrive well before the 3-hr fire walls have failed and extinguish the fire using portable extinguishers or the hose stream supported by the Class I standpipe system. The required response time of the fire department will be determined for the Operating License Application.

Conclusion

The above analysis and description show that the fire protection and life safety systems within the administration and support area are designed such that they will function in a manner, whether operational or not, consistent with occupational safety and protection of the public and environment. Because this fire area is not expected to contain anything other than check sources for instrumentation, no releases to the public are expected to occur. Therefore, this system will likely not be considered an IROFS. Additional detailed information will be developed for the Operating License Application.

9.3.3.1.4 Irradiated Target Receipt and Waste Management Truck Bay Areas

The irradiated target receipt and waste management truck bay areas will be located adjacent to the production area on the north side of the RPF and will be a noncombustible enclosure that is considered a storage S-2 occupancy area. The truck bay will be capable of accepting three semi-tractor trailers at the same time. Each truck bay will be separated from the production area (cask unloading) by a 2-hr fire-rated rollup door. The doors to the production area will be closed when the doors to the outside are open.

This area will be used for the receipt of irradiated LEU targets and shipments involved with the disposal of radiological waste material. Radiological material will be transported in approved containers. The casks will reside on the heavy-duty tractor-trailer for delivery and removal from the RPF. The heavy-duty tractor-trailer will be present when the retractable doors are open to the production area.

Life Safety Considerations

The irradiated target receipt and waste management truck bay areas will be required to meet IBC life safety criteria (ICC, 2012) and will be provided with emergency lighting, illuminated exit signs, automatic sprinklers, and an automatic and manually actuated fire alarm system with audible and visual indicating devices as necessary.

An accessible means of egress will be provided in accordance with the IBC. Exit access will be provided to the truck bays. The maximum distances to the exit access within the truck bay will be established and conform to IBC code based on industrial occupancies. The common path of egress travel for an S-1 occupancy equipped throughout with an automatic sprinkler system will be 30.5 m (100 ft), in accordance with IBC Table 1014.3. The exit access travel distance for a fully sprinklered S-1 occupancy will be limited to 76.2 m (250 ft), in accordance with IBC Table 1016.2. Dead-ends in corridors will not exceed 15.2 m (50 ft), in accordance with IBC Section 1018.4, Exception 2.

No deviations from the IBC life safety criteria have been identified.

Exposure Fire Potential/Potential for Fire Spread between Fire Areas

The irradiated target receipt and waste management truck bay areas will be separated from other fire areas in the building by 2-hr fire-rated barriers. Penetrations in the fire-rated barrier walls will be protected with penetration seals, providing a fire rating equivalent to the barriers. Load-bearing structural elements are not required to be protected by fire-resistive construction, as indicated in the IBC (ICC, 2012).

The truck bay could be exposed to a fire in an adjacent fire area when the large access doors are opened to attach or disconnect a trailer to or from a tractor. To prevent a fire from spreading between these areas, administrative controls will be implemented that dictate personnel procedures and limit combustibles around the interface access doors. Personnel actions, limited combustibles, and 2-hr fire-rated boundaries will therefore mitigate fire spread between areas.

Fire Protection Features

The irradiated target receipt and waste management truck bay areas will require the following fire protection features to provide a defense-in-depth approach to fire protection. This approach will result in a fire being quickly detected and suppressed, reducing fire-induced damage.

- **Automatic** – An automatic sprinkler system will be installed throughout the truck bay area. However, due to the large quantity of diesel fuel and number of tires on the heavy-duty tractor-trailer, alternative suppression systems may be considered. An automatic fire detection and alarm system will be installed throughout the truck bay area. Additional detailed information will be developed for the Operating License Application.
- **Manual** – Manual fire suppression will be provided within the truck bay area and consist of portable fire extinguishers and Class I standpipe system hose valves. Manual fire alarm pull stations will be provided within the truck drive-through.
- **Passive** – Passive fire protection will be provided in the form of fire-rated construction to protect the means of egress from the facility and separation between fire areas. Built-in fuel traps and sloped floors will be provided to control potential fuel spills within the area. The fuel traps and sloped floors will also be used for containment of potentially contaminated firefighting water. The fuel and/or water will drain to outdoor underground collection tanks for testing and removal.

Fire Hazards, Ignition Sources, and Design Basis Fire Scenarios

The following fire hazards and ignition sources were considered for evaluation of a DBF scenario within the truck bay area.

- **Scenario 1** – A fire starts due to maintenance activities (e.g., spark ignition or open flame).
- **Scenario 2** – A fire is caused by hot work (e.g., welding, flame, or plasma cutting).
- **Scenario 3** – A fire starts adjacent to a semi-tractor trailer that is caused by the rupture of the fuel tank and ignition of the unconfined (static) diesel spill.
- **Scenario 4** – A fire starts on a diesel-driven forklift that is caused by the rupture of the fuel tank and ignition of the unconfined (static) diesel spill.

The DBF for the truck bay consists of a diesel fuel spill and ignition from an unknown source caused by the operation of a diesel-powered semi-tractor trailer (Scenarios 3 and 4). The truck is assumed to have two 284 L (75-gal) diesel fuel tanks, along with 32 hard rubber tires, a battery, and small amounts of other combustible material. The truck may also carry some combustibles on noncombustible pallets when supporting radiological material-handling operations. Administrative controls will be used to limit temporary combustible items within the production area.

The DBF scenario postulates that the entire contents of the fuel tanks will spill and drain to the built-in fuel trap. The area of the fire will be limited to the area of the built-in fuel trap trench, which was estimated to be approximately 2.6 m^2 (28 ft^2).

The results of the DBF were postulated as the complete combustion of the combustible materials in the irradiated target receipt truck bay area. No credit was taken for fire suppression activities. The DBF fire could result in the complete loss of function for the systems and/or equipment in the area.

Consequences of an Automatic Fire Suppression Failure

Failure of the automatic fire suppression system will cause a delay in responding to a fire, resulting in the combustibles being completely consumed during the DBF. The adoption of administrative controls will limit combustibles and minimize the spread of fire. However, smoke and hot gases could damage equipment located within the truck bay area.

In the event of a fire, the Columbia Fire Department will be notified of a fire by either actuation of a manual fire alarm pull box station or the automatic smoke or temperature detection systems. The DBF would be contained within the truck bay area by the 2-hr rated fire walls. If the automatic fire suppression system fails to operate, the fire department is expected to arrive well before the 2-hr fire walls have failed and extinguish the fire using portable extinguishers or the hose stream supported by the Class I standpipe system. The required response time of the fire department will be determined for the Operating License Application.

Conclusion

The above analysis and description show that the fire protection and life safety systems within the truck bay are designed such that they will function in a manner, whether operational or not, consistent with occupational safety and protection of the public and environment. Because the radioactive material will be contained in DOT Type B casks, a fire in this area should not result in a radiological release to the public. Therefore, this system will likely not be considered an IROFS. Additional detailed information will be developed for the Operating License Application.

9.3.3.1.5 Laboratory Area

The laboratory area will be located adjacent to the production area on the west side of the RPF and will be a single-story, noncombustible structure with a High Hazard H-3 and H-4 occupancy. The footprint of the laboratory area will be approximately [Proprietary Information] over most of the area. This area will process and analyze quality and process control samples during production of the molybdenum-99 (^{99}Mo) product, fabrication of targets for irradiation, and processing of waste for disposal.

Typical RPF analysis will include:

- An inductively coupled plasma mass spectrometry (ICP-MS) to analyze mass quantities of isotopic [Proprietary Information]
- A kinetic phosphorescence analyzer for [Proprietary Information]
- Alpha spectroscopy for [Proprietary Information]
- Beta activity by liquid scintillation spectrometry for strontium-89/strontium-90 (^{89}Sr/^{90}Sr)
- Gamma energy analysis

A variety of gloveboxes and fume hoods will be located within the analytical laboratory area.

Life Safety Considerations

The laboratory area is required to meet IBC life safety criteria (ICC, 2012) and will be provided with emergency lighting, illuminated exit signs, automatic sprinklers, and an automatic and manually actuated fire alarm system with audible and visual indicating devices as necessary.

An accessible means of egress will be provided in accordance with the IBC. Exit access will be provided to the laboratory area, with direct exit discharge from the RPF. The maximum distances to the exit access within the laboratory area will be within the following parameters. The common path of egress travel for a mixed High Hazard H-3 occupancy equipped throughout with an automatic sprinkler system will be 7.6 m (25 ft), in accordance with IBC Table 1014.3. The exit access travel distance for a fully sprinklered mixed H-3 occupancy will be limited to 45.7 m (150 ft), in accordance with IBC Table 1016.2. Dead-ends in corridors will not exceed 6.1 m (20 ft), in accordance with IBC Section 1018.4. No deviations from the IBC life safety criteria have been identified.

Exposure Fire Potential/Potential for Fire Spread between Fire Areas

The laboratory area will be separated from other fire areas of the building by 2-hr fire-rated barriers. Penetrations in the fire-rated barrier walls will be protected with penetration seals, providing a fire rating equivalent to the barriers. The laboratory area could be exposed to a fire in an adjacent fire area when the large access doors are opened during material transfer activities. The primary area of concern in this case is an open doorway to the production area. To prevent a fire from spreading between these areas, administrative controls will be implemented that dictate personnel procedures and limit combustibles around the interface access doors. Fire spread between areas will therefore be mitigated by personnel actions, limited combustibles, and 2-hr fire-rated boundaries.

Fire Protection Features

The laboratory area requires the following fire protection features to provide a defense-in-depth approach to fire protection. This approach will result in a fire being quickly detected and suppressed, reducing fire-induced damage.

- **Automatic** – An automatic fire suppression system will be designed and installed throughout the laboratory area. An automatic fire detection and alarm system will also be installed throughout the laboratory area. The system specifics will be determined during detailed design and provided in the Operating License Application.
- **Manual** – Manual fire suppression will be provided within the laboratory area and consist of portable fire extinguishers and Class I standpipe system hose valves. Manual fire alarm pull stations will be provided at the exits from the laboratory area.
- **Passive** – Passive fire protection will be provided in the form of fire-rated construction to protect the means of egress from the facility and separation between fire areas.

Fire Hazards, Ignition Sources, and Design Basis Fire Scenarios

The DBF scenario for the laboratory area will be developed for the Operating License Application.

Consequences of an Automatic Fire Suppression Failure

The consequences of the failure of the automatic fire suppression system in the laboratory area will be determined for the Operating License Application.

Conclusion

More analysis is needed to determine if the fire protection system in this area would be considered an IROFS. Additional detailed information will be developed for the Operating License Application.

9.3.3.1.6 Utility Areas

Utility areas (e.g., electrical rooms, mechanical rooms, fire riser rooms, etc.) will be noncombustible spaces separated from other fire areas by fire-rated barrier walls. The footprint of each utility room will vary, but will be classified as utility (Group U) occupancies in accordance with the IBC (ICC, 2012). These utility areas will include rooms that house electrical equipment (e.g., power and lighting panels, transformers, and associated operations equipment distribution systems) and other common industrial equipment (e.g., air handling units, boilers, fans, pumps, and associated piping distribution systems). Personnel will not normally occupy the utility areas.

Life Safety Considerations

The utility areas are required to meet IBC life safety and means of egress criteria (ICC, 2012) and will be provided with emergency lighting, illuminated exit signs, automatic sprinklers, and an automatic and manually actuated fire alarm system with audible and visual indicating devices as necessary.

An accessible means of egress will be provided in accordance with the IBC. The maximum distances to the exit access within the utility areas will be within the following parameters for utility occupancies. The common path of egress travel for a utility occupancy equipped throughout with an automatic sprinkler system will be 22.9 m (75 ft), in accordance with IBC Table 1014.3. The exit access travel distance for a fully sprinklered utility occupancy will be limited to 121.9 m (400 ft), in accordance with IBC Table 1016.1. Dead-ends in corridors will not exceed 15.2 m (50 ft), in accordance with IBC Section 1018.4, Exception 2.

Exposure Fire Potential/Potential for Fire Spread between Fire Areas

For the purpose of this analysis, the utility areas are each considered separate areas, each with 2-hr fire-rated barrier walls used to limit the spread of fire.

HEPA filters and exhaust carbon beds will be encased by stainless steel housings that can be isolated from the inlet and outlet ductwork by isolation dampers. Fire detectors will also be provided in each HEPA filter housing and inlet ductwork. Therefore, isolation dampers will prevent the fire from propagating from the filter housing to other fire areas.

Fire Protection Features

The utility areas require the following fire protection features to provide a defense-in-depth approach to fire protection. This approach results in a fire being quickly detected and suppressed, reducing fire-induced damage.

- **Automatic** – An automatic wet-pipe sprinkler or other approved fire suppression system will be installed throughout each utility area. An automatic fire detection and alarm system will also be installed throughout each utility area. Additional detailed information will be developed for the Operating License Application.
- **Manual** – Manual fire suppression will be provided within each utility area that consists of portable fire extinguishers.
- **Passive** – Passive fire protection will be provided in the form of fire-rated construction to protect separation between fire areas. Isolation dampers will be provided in the inlet and outlet of each HEPA filter housing to prevent fire from spreading to other fire areas.

Fire Hazards, Ignition Sources, and Design Basis Fire Scenarios

The following were considered DBF scenarios for the utility areas.

- **Scenario 1** – A fire starts due to maintenance activities, ignited from a spark or open flame.
- **Scenario 2** – A fire starts from overheated electrical systems and equipment.
- **Scenario 3** – A fire starts in or near a transformer.
- **Scenario 4** – A natural gas leak occurs.

The DBF for the utility area consists of a natural gas leak resulting in an explosive mixture of natural gas and a detonation or deflagration. Additional information for this accident sequence will be provided in the Operating License Application.

Consequences of an Automatic Fire Suppression Failure

The consequences of a failure of the automatic fire suppression system in the utility area will be determined for the Operating License Application.

Conclusion

More analysis is needed to determine if the fire protection system in this area should be considered an IROFS. Additional detailed information will be developed for the Operating License Application.

9.3.3.2 Other Radioisotope Production Facility Systems

9.3.3.2.1 Facility Ventilation and Smoke Management

The RPF ventilation system requirements must satisfy the process, building, safety, and regulatory requirements unique to the ^{99}Mo production process. To assist in the confinement of airborne radioactive contamination, the RPF ventilation system is designed to create pressure gradients and cause air to flow from areas of lesser contamination potential to areas of greater contamination potential. Confinement zone exhaust ductwork will have fire dampers consistent with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, and will be constructed to maintain fire ratings where ducting penetrates fire-rated barriers, as appropriate. The confinement ventilation systems will also include HEPA and high-efficiency gas adsorption (HEGA) filtration systems located in a dedicated mechanical area. The Zone I ventilation system will comprise the secondary confinement boundary and be classified as an IROFS (RS-03). Chapter 13.0 provides additional information on the accident analysis that identified this IROFS.

A combination of passive and active smoke management strategies will be used to minimize the spread of smoke, maintain tenable conditions for the evacuation of building occupants, and limit the damage caused by smoke. These strategies will be designed in accordance with NFPA 92, *Standard for Smoke Control Systems*. The smoke control methods for each fire area will be developed for the Operating License Application.

9.3.3.2.2 HEPA Filtration Systems

The HEPA filters and housings are a component of the hot cell secondary confinement boundary that will be classified as an IROFS (RS-03). The HEPA filters are expected to contain low levels of radiological material and will be located in designated fire areas. The filter housings are expected to be large, with a maximum size being approximately [Proprietary Information] in face area. The large filter face area will require automatic and manual sprinklers in the plenum housings and contaminated water collection or retention. In addition, the HEPA filter housings will be located within 2-hr fire-rated barrier walls that are protected by automatic sprinkler systems.

9.3.3.2.3 Crane Superstructure

The structural steel supporting the facility overhead crane has been classified as an IROFS (FS-02, "Overhead Cranes"). Therefore, the crane superstructure must remain standing during and after a fire event to prevent damage to irradiated material. Additional detailed information will be developed for the Operating License Application.

9.3.3.2.4 Security and Safeguard Components

Security systems are discussed in Chapter 12.0, "Conduct of Operations."

9.3.3.3 Architectural Features

The codes and standards applicable to the RPF are defined in Chapter 3.0. The objectives of the NRC fire protection program will primarily be achieved through compliance with prescriptive criteria, as defined by the PFHA (NWMI-2013-039).

Types of Construction

All structures within the RPF complex confines will be constructed of Type IIB, noncombustible material, as defined by IBC Chapter 6 (ICC, 2012). Additional detailed information will be developed for the Operating License Application.

9.3.4 Instrumentation and Control Requirements

The fire protection system will report the status of the fire protection equipment to the central alarm station and the RPF control room, with sufficient information to identify the general location and progress of a fire within the protected area boundaries. Initiating devices for the fire detection and alarm subsystem, which will include monitoring devices for the fire suppression subsystem, will indicate the presence of a fire within the facility. Once an initiating device activates, signals will be sent to the fire alarm control panel. The fire alarm control panel will transmit signals to the central alarm station and perform any ancillary functions, such as shutting down the ventilation equipment or actuating the deluge valves.

As required by NFPA 101 and NFPA 72, smoke detection will be provided above the main fire alarm control panel and any subpanels necessary to perform control functions for the system. For ventilation units, smoke and heat detection will be provided in support of several safety aspects. Smoke detectors will be provided in non-nuclear ventilation systems in accordance with NFPA 90A and the IFC. Smoke detectors will also be provided in air intakes to address smoke infiltration from wildland fires and fires in other facilities that might spread smoke to the surrounding area.

Smoke detection will be provided in ventilation systems servicing potentially contaminated zones to support shutdown and minimize the spread of contaminated smoke to other areas of the RPF. Heat detectors will be provided in these ventilation system exhausts for both notification of high temperatures and release of the automatic portion of the HEPA filter plenum deluge subsystem.

Control modules and relays will be integrated into the fire detection and alarm subsystem to initiate reactions required for safety. Control modules will provide signals for releasing of deluge valves on the HEPA filter plenum deluge subsystem. Control methods will also be integrated for shutdown of the HVAC systems. Shutdown of electrical equipment or computers will also occur as deemed necessary by the design effort.

Alarms received by the fire alarm control panel will be transmitted via a copper cable or fiber optic cable network to monitoring stations in the RPF. The fire alarm control panel will also provide notification through the sitewide infrastructure to the central alarm station. The alarm stations will provide data to the Columbia Fire Department for response.

System Monitoring

The fire protection system will be monitored by the fire alarm control panel, which will transmit signals to the central alarm station via a digital alarm communicator transmitter and to the RPF control room. Command and control functions will be exclusively available at the fire alarm control panel. Localized monitoring of the various fire pumps will occur at the respective pump controllers.

Control Capability and Locations

The fire detection and alarm subsystem will be controlled exclusively from the fire alarm control panel. Numerous devices in the fire suppression subsystem can be operated manually. The fire pumps can be started manually via their respective controllers. Valves and hydrants will be turned manually, and no air or electrically operated valves will be provided. Deluge valves for the HEPA filter plenum water spray can be activated manually, in addition to the bypass valves that are integrated into the design.

Automatic and Manual Actions

The fire detection and alarm subsystem is intended to operate automatically. Manual intervention will be required for some operations, such as shutdown of outside air intake fans or dampers, due to the need to avoid false activation or to maintain operational status in emergency conditions.

The fire suppression subsystem will be split between automatic and manual operations. The sprinkler systems (including the pumps) and the demister section of the HEPA filter plenum deluge subsystem are designed to operate automatically. The filter section of the plenum deluge subsystem and fire hydrants are designed for manual operation. Certain portions, however, can be operated manually as necessary.

The demister section of the HEPA filter plenum deluge subsystem will have a manual bypass and a manual actuator as part of the deluge valve. Portable fire extinguishers will be manually operated.

Maintenance and testing activities on both systems will require manual interaction. The maintenance and testing requirements included in NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, and NFPA 72 require manual operation of valves, starting of pumps, testing of circuits with meters, and other functions that necessitate manual actions.

Interlocks, Bypasses, and Permissives

The fire protection system, as designed, will not be subject to external interlocks, bypasses, or permissives (i.e., those outside the system itself). There will be inherent interlocks, bypasses, and permissives within the various fire protection system equipment, which will be designed to the criteria and requirements discussed in Chapter 3.0. For example, the fire detection and alarm subsystem can be controlled via passwords and allow for bypassing certain functions; however, the passwords will be limited to testing technicians and are not available to general building personnel. Thus, there will be no ability for the system to be locally manipulated without proper authorization. Additional information will be provided in Chapter 7.0 for the Operating License Application.

9.3.5 Required Technical Specifications

The technical specifications associated with the fire protection systems, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.4 COMMUNICATION SYSTEMS

The RPF communication systems will relay information during normal and emergency conditions for general operations and emergencies within the RPF. These systems are designed to enable the RPF operator on duty to be in communication with the supervisor on duty, health physics staff, and other personnel required by the technical specifications, and to enable the operator, or other staff, to announce the existence of an emergency in all areas of the RPF complex. Two-way communication will be provided between all operational areas and the control room.

9.4.1 Design Basis

The communications system design basis is to provide communications during normal and emergency conditions between vital areas of the RPF and the Administration Building. This communications capability will include the ability of operators or other designated staff members to announce an emergency in all areas of the RPF and provide two-way communications between all operational areas and the control room. Design of the telecommunication system also complies with Electronic Industries Alliance and Telecommunications Industry Association requirements.

9.4.2 System Description

The communication system is designed to provide two-way communication between the RPF control room and other site locations necessary for safe RPF operations. This system will provide (1) communications capability between RPF operators, their supervisor, health physics personnel, and other personnel as required by the technical specification, and (2) the ability to make facility-wide emergency announcements and summon emergency assistance.

The telephone and data/local area network (LAN) telecommunications system will include a service entrance communications room. The service provider's outside plant optical fiber will terminate on a wall-mounted service provider entrance patch panel. An optional outside plant copper telephone cable from the service provider will terminate at the wall-mounted overvoltage entrance protection terminal modules for use in legacy non-Voice over Internet Protocol (VoIP)-based equipment. The main entrance room will be connected with a telecommunications room with fiber and copper backbone cable. The telecommunications room will support the offices, laboratory area, target fabrication area, shipping and receiving areas, and other required telephone and data/LAN outlets. Grounding of the telecommunication system will comply with Telecommunications Industry Association and NFPA requirements. The process control system will be physically separated from and not connected to the communication system. Additional information will be provided in the Operating License Application.

9.4.3 Operational Analysis and Safety Function

Chapter 13.0 identifies and evaluates adverse events and accident sequences. The accident analysis has not identified the need to credit the communication system. The communication system is designed such that it will function in a manner, whether operational or not, consistent with occupational safety and protection of the public and environment.

9.4.4 Instrumentation and Control Requirements

Chapter 7.0 discusses the instrumentation and control requirements associated with the communication systems.

9.4.5 Required Technical Specifications

The technical specifications associated with the communication systems, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.5 POSSESSION AND USE OF BYPRODUCT, SOURCE, AND SPECIAL NUCLEAR MATERIAL

The RPF is designed to ensure that:

- No uncontrolled release of radioactive materials (solid, liquid, or airborne) from the facilities can occur
- Personnel exposures to radiation, including ingestion or inhalation, do not exceed limiting values in 10 CFR 20, as defined in Chapter 11.0, and are consistent with the NWMI ALARA program.

The operating procedures developed for the Operating License Application will ensure that only radioactive byproducts handled by the RPF are permitted, unless specifically authorized by the 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," license or an additional license.

9.5.1 Design Basis

The design basis for the possession and use of special nuclear material (SNM) and byproduct material is to ensure that no uncontrolled release of radioactive materials (solid, liquid, or airborne) from the facilities can occur and that personnel exposures to radiation, including ingestion or inhalation, do not exceed limiting values in 10 CFR 20 and are consistent with the NWMI ALARA program. Additional information on the design basis is provided in Chapter 3.0.

9.5.2 System Description

SNM is defined by Title I of the *Atomic Energy Act of 1954* (42 U.S.C. 2011 et seq.) as plutonium, uranium-233 (^{233}U), or uranium enriched in the isotopes ^{233}U or ^{235}U. The RPF will receive, store, and process fresh unirradiated uranium metal and irradiated uranium with an enrichment of 19.75 weight percent (wt%) ±0.20 wt% ^{235}U (LEU).

Byproduct material, as defined by the Atomic Energy Act, is radioactive material (except SNM) yielded in or made radioactive by exposure to radiation incident to the process of producing or using SNM. As defined by NRC regulations, byproduct material includes any radioactive material (except enriched uranium or plutonium) produced by a nuclear reactor. The RPF will handle byproduct material during the separation of ^{99}Mo and the recycling of the irradiated LEU.

Source material is defined as the element thorium or the element uranium, provided that the uranium has not been enriched in the isotope ^{235}U. Source materials will not be present in the RPF.

9.5.2.1 Special Nuclear Materials

SNM will be handled in two areas of the RPF: the target fabrication and irradiated material areas (i.e. hot cells). The target fabrication area SNM inventory is listed in Chapter 4.0, Table 4-1, and the irradiated material area SNM inventory is provided in Chapter 4.0, Table 4-2.

Chapter 4.0 also provides a description of the design of spaces and equipment to ensure that there is no uncontrolled release of radioactive materials (solid, liquid, or airborne) from the RPF and that personnel exposures to radiation, including ingestion or inhalation, do not exceed limiting values in 10 CFR 20 consistent with the RPF ALARA program, as described in Chapter 11.0. Associated procedures are defined in Chapter 12.0. The NWMI emergency preparedness and physical security plans are provided in Chapter 12.0, Appendix A and B, respectively. Fire protection provisions are described in Section 9.3.2.1.

9.5.2.2 Byproduct Materials

Byproduct materials handled in the RPF include ^{99}Mo and radioactive waste materials. A description of the Mo recovery process design is provided in Chapter 4.0, Section 4.3.5. A description of the waste processing design is provided in Chapter 11.0, Section 11.2. A detailed inventory of byproduct materials within each of the main systems within the RPF is provided in the following chapters:

- Target fabrication – Chapter 4.0, Section 4.4.2
- Target receipt and disassembly – Chapter 4.0, Sections 4.3.2 and 4.3.3
- Target dissolution – Chapter 4.0, Section 4.3.4
- Molybdenum recovery and purification – Chapter 4.0, Section 4.3.5
- Uranium recovery and recycle – Chapter 4 0, Section 4.4.1
- Waste handling – Chapter 11.0, Section 11.2

Chapter 4.0 and Section 9.7.2 provide descriptions of the design of spaces and equipment to ensure that there is no uncontrolled release of radioactive materials (solid, liquid, or airborne) from the RPF and that personnel exposures to radiation, including ingestion or inhalation, do not exceed limiting values in 10 CFR 20 consistent with the NWMI ALARA program (Chapter 11.0). Associated procedures will be defined in Chapter 12.0, as part of the Operating License Application.

9.5.3 Operational Analysis and Safety Function

The criticality safety of SNM is discussed in Chapters 4.0 and 6.0, and the material control and accounting of SNM is discussed in Chapter 12.0, Section 12.13. The byproduct materials associated with the RPF process are addressed in Chapter 4.0, and byproduct materials within the waste processing and storage areas are described in Section 9.7.2 and Chapter 11.0, Section 11.2.

9.5.4 Instrumentation and Control Requirements

Instrumentation and control requirements for the processes associated with the possession and use of byproduct materials and SNM are discussed in Chapter 7.0 and Chapter 12.0, Section 12.13.

9.5.5 Required Technical Specifications

The technical specifications associated with the possession and use of byproduct materials and SNM, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.6 COVER GAS CONTROL IN CLOSED PRIMARY COOLANT SYSTEMS

As discussed in Section 9.7.1.2.2, the RPF provides cooling water to numerous process tanks. The radiolytic decomposition of water within this system could result in the production of hydrogen (H_2) and oxygen mixtures. This section provides a discussion of the cover gas control system within the process coolant system.

9.6.1 Design Basis

Information on the design basis of cover gas control in the closed primary coolant system (process chilled water system) is provided in Chapter 3.0, Section 3.5.2.7.

9.6.2 System Description

The process chilled water system is described in Section 9.7.1.2.2. The accumulation of combustible gases within this system will be controlled by the "sweep" gas system that is described in Section 9.7.1.2.6. Gases entrained in the chilled water system will be released in the cooling water collection tanks. Hydrogen, which is the primary component of evolved combustible gases, diffuses very rapidly and will be diluted by the airflow provided by the sweep gas flow.

The plant air supply system (described in Section 9.7.1.2.4) will provide low-flow [Proprietary Information] purge gases to Tanks TK-420 and TK-320. The process vessel vent system will collect the purge gas from each of the tanks and merge the collected vent subsystems into the main facility ventilation system for treatment and filtration. These systems will work together to prevent explosive gas mixtures from developing.

9.6.3 Operational Analysis and Safety Function

Chapter 13.0 evaluates the accident sequences that involve either combustible solids or liquids, or explosive gases, in close proximity to the high uranium process streams or the high-dose process streams. This analysis determined that if the purge air system was not operational, a hydrogen-air concentration in selected tanks could rise above 25 percent of the lower explosive limit, and an ignition source could cause a deflagration or detonation, resulting in the release of radionuclides into the air. The tanks associated with the cooling system are not anticipated to require IROFS controls.

9.6.4 Instrumentation and Control Requirements

Instrumentation and control requirements for the cover gas control in the closed primary coolant system are discussed in Chapter 7.0.

9.6.5 Required Technical Specifications

The technical specifications associated with the cover gas control in the closed primary coolant system, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.7 OTHER AUXILIARY SYSTEMS

Other RPF auxiliary systems that are important to the safety of workers, the public, and environment will include the following:

- Process utilities
- Control and storage of radioactive waste (waste management)
- Analytical laboratory
- Chemical supply

The followings subsections describe these auxiliary systems, including their design basis, system description, operational analysis and safety function, instrumentation and control requirements, and technical specifications.

9.7.1 Utility Systems

The utility systems will provide heating, cooling, process water, compressed gases, instrument, motive force, and other functions to support uranium processing, waste handling, and ventilation. The utility systems will include the following subsystems:

- Process steam
- Process chilled water
- Demineralized water
- Plant and instrument air
- Gas supply, which supplies nitrogen, helium, hydrogen, and oxygen
- Purge/sweep gas

The utility systems are designed to ensure that any potential malfunctions do not cause accidents in the RPF or an uncontrolled release of radioactivity. The systems are designed to ensure that in the event radioactive material is released by the operation of one of these systems, potential radiation exposures would not exceed the limits of 10 CFR 20 and are consistent with the NWMI ALARA program. No function or malfunction of the auxiliary systems will interfere with or prevent safe shutdown of the RPF.

9.7.1.1 Design Basis

The utility systems design basis is provided in Chapter 3.0, Section 3.5.2.7.

9.7.1.2 System Description

Figure 9-9 shows the second floor mechanical utility area where the process steam, chilled process water, demineralized water, and plant or instrument supply air units will be housed. Helium, hydrogen, and oxygen will be provided by bottled gases located near the point of use either in the laboratory area or the target fabrication area. Nitrogen will be provided by a tube trailer for nitrogen located outside of the laboratory area.

[Proprietary Information]

Figure 9-9. Second Floor Mechanical Utility Area

9.7.1.2.1 Process Steam

The process steam system will be divided into a medium-pressure central heating loop (Figure 9-10) and a low-pressure secondary loop within the hot cell (Figure 9-11). Medium pressure steam will be generated by a natural gas-fired boiler (ST-H-100). Low-pressure steam in the secondary loop will be generated by medium-pressure steam in a shell-and-tube heat exchanger (ST-E-200). Medium-pressure steam will be at least 4.2 kilograms (kg)/square centimeter (cm^2) (60 pounds [lb]/square inch [$in.^2$]) gauge, to provide an adequate temperature differential to generate 1.7 kg/cm^2 (25 $lb/in.^2$) gauge steam for the low-pressure steam loop.

[Proprietary Information]

Figure 9-10. Medium-Pressure Steam System

[Proprietary Information]

Figure 9-11. Low-Pressure Steam System

Low-pressure steam will be generated in a vertical shell-and-tube heat exchanger. Automatic blowdown and makeup water streams will limit the content of sludge or dissolved solids in the boiler and steam generation heat exchanger.

9.7.1.2.2 Chilled Water

Process Chilled Water

The process chilled water system is a central process chilled water loop that will cool the three secondary loops:

- One large geometry secondary loop in the hot cell (Figure 9-12)
- One criticality-safe geometry secondary loop in the hot cell (Figure 9-13)
- One criticality-safe geometry secondary loop in the target fabrication area (Figure 9-14).

The central process chilled water loop will rely on three air-cooled chillers, each sized to accommodate 50 percent of the process cooling demands (Figure 9-15). The secondary loops will be cooled by the central chilled water system through plate-and-frame heat exchangers.

Several process demands will require cooling at less than the freezing point of water. These demands will be met with water-cooled refrigerant chiller units, cooled by the secondary chilled water loops.

The chilled water system will operate with cascading pressure differentials. The central system will operate at the highest pressure, and the secondary loops will operate at a pressure between the central system and the process fluid. The large-geometry secondary loop in the hot cell will meet the cooling demands where fissile material leaking through a heat exchanger is not a credible event. The other cooling loops will be inherently criticality-safe by geometry, so active controls will not be required to keep fissile material out of the chilled water return. At each process cooling demand where fissile material may be present, conductivity sensors will monitor the chilled water return to detect heat exchanger leaks.

Facility Chilled and Heating Water

The HVAC system will maintain the occupied space at 24°C (75°F) (summer) and 22°C (72°F) (winter), with active ventilation to support workers and equipment. The facility chilled water and heating water systems will provide heating and cooling media to the HVAC system.

The facility chilled water system (FCW) will supply the HVAC system with cooling water that is circulated through the chilled water coils in the air-handling units. The air will be drawn across the coils and cooled to be delivered to the RPF production area to maintain temperature. The FCW will provide cooling water at a temperature of 9°C (48°F) to the HVAC air-handling unit cooling coils. There will be three equal-sized facility chillers located adjacent to the RPF: two in operation and one spare.

The heating water system (HW) will supply the HVAC system with heating water that is circulated through the heating water coils in the air handling units. The air will be drawn across the coils and cooled to be delivered to the RPF production area to maintain temperature. The HW will provide heating water at a temperature of 82°C (180°F) to the HVAC air-handling unit heating coils and reheat coils. The heating water will be generated as a byproduct stream of the steam boilers.

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Figure 9-12. Chilled Water System Large Geometry Hot Cell Loop

[Proprietary Information]

Figure 9-13. Chilled Water System Critically Safe Hot Cell Loop

[Proprietary Information]

Figure 9-14. Chilled Water System Target Fabrication Loop

[Proprietary Information]

Figure 9-15. Process Chilled Water System

9.7.1.2.3 Demineralized Water

Demineralized water will be produced by removing mineral ions from municipal water through an ion exchange (IX) process (Figure 9-16). Water passes through anion and cation exchange media located in separate IX tanks (DX-IX-100 and 110), and the demineralized water will accumulate in a storage tank (DW-TK-120). A feed pump will provide the water at 4.2 kg/cm^2 (60 lb/in.^{2}) gauge (DW-P-125) for RPF process activities. The IX media will be regenerable using a strong acid and a strong base (DW-P-105 and 115). Acid and base will be fed from local chemical drums by toe pumps.

9.7.1.2.4 Plant and Instrument Air

Plant air will be provided for several activities (e.g., tool operation, pump power, purge gas in tanks, valve actuation, and bubbler tank level measurement) (Figure 9-17). Small, advective flows of plant air will be used throughout the RPF to prevent accumulation of combustible gases to hazardous concentrations. Combustible gases will be evolved from process liquids due to exposure of these liquids to ionizing radiation.

The plant air system will provide air to the instrument air subsystem. The instrument air subsystem will use plant air that is filtered and dried (IA-V-110A, 110B, and IA-F-110). Plant air will be generated by a compressor (PA-K-100) and cooled to near-ambient temperatures by an aftercooler (PA-E-100). The lead/lag configuration can supply reduced flow after a single compressor failure. The plant air receiver will provide buffer capacity to make up the difference between peak demand and compressor capacity (PA-V-100).

Instrument air will be dried in regenerable desiccant beds to a dew point of no greater than -40°C (-40°F) and filtered to a maximum 40 micron (μ) particle size. The instrument air receiver will provide buffer capacity (IA-V-120) to make up the difference between peak demand and compressor capacity.

9.7.1.2.5 Gas Supply

Gas supply of helium (Figure 9-18), hydrogen, and oxygen (Figure 9-19) will be supplied by standard gas bottles. Nitrogen will be provided from a tube truck (Figure 9-18). The nominal capacity of the gas bottles will be 8,495 L (300 ft^3). The nitrogen will be fed from the tube truck (GS-Z-100) to the chemical supply room where manifold piping will be used to distribute the gas. The primary use of nitrogen will be in the reducing furnaces during target fabrication.

Helium, hydrogen, and oxygen gas bottles will be located near the points of use. Gas supply pressures will be regulated to 1.7 kg/cm^2 (25 lb/in.^{2}) gauge at the bottle (Figure 9-19. Where lower pressures are required, point-of-use gas regulators will be installed. Automatic gas cylinder changeover valves will provide a continuous gas supply when one bottle (or rack of bottles) is empty, and alert the operator when bottles need to be replaced. Hydrogen and oxygen gas bottles will be stored in ventilated gas cabinets with 13 air changes/min to mitigate the risk of leaks. The ventilation demand will be 8.8 L/min (250 ft^3/min) air for each gas cabinet.

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Figure 9-16. Demineralized Water System

[Proprietary Information]

Figure 9-17. Plant Air System

[Proprietary Information]

Figure 9-18. Nitrogen and Helium Supply System

[Proprietary Information]

Figure 9-19. Hydrogen and Oxygen Supply System

9.7.1.2.6 Purge Gas

The plant air and nitrogen supply systems, described in Section 9.7.1.2.4 and Section 9.7.1.2.5, provide purge gases to the required tanks. Depending on the tank, the purge gas will be provided through the bubbler tank level measurement device or other means. The purge gas flow rates are specified as either high flow for conditions of a large tank or high radioactivity, or low flow where the tank is small and radioactivity is low. Table 9-3 provides the purge gas flows for both the high and low flow rates.

Table 9-3. Purge Gas Flows

	Flow rate		
Gas flow	L/min	gal/min	Units (basis)
High purge	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Low purge	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] NWMI-2013-CALC-005, *Tank Air Bleed Estimate*, Rev. B, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2014.

[b] NWMI-2013-CALC-009, *Uranium Purification System Equipment Sizing*, Rev. B, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2014.

H_2 = hydrogen gas. U = uranium.

The process vessel vent system will collect the purge gas from each of the vessels and treat it before discharge to the Zone I exhaust. The process vessel vent system merges the collected vent subsystems into the main facility ventilation system for treatment and filtration. These systems will work together to prevent explosive gas mixtures from developing in the headspace of the process vessels. The tanks anticipated to require purge gas are listed in Table 9-4. Additional information on the purge gas system will be developed for the Operating License Application.

Table 9-4. Tanks Requiring Purge Gas

Tank number	Tank name	Tank number	Tank name
DS-D-100	Dissolver 1	UR-TK-120A	Impure uranium collection tank 2A
DS-D-200	Dissolver 2	UR-TK-120B	Impure uranium collection tank 2B
DS-TK-800	Waste collection and sampling tank 1	UR-TK-140A	Impure uranium collection tank 3A
DS-TK-820	Waste collection and sampling tank 2	UR-TK-140B	Impure uranium collection tank 3B
MR-TK-100	Feed tank 1A	UR-TK-160A	Impure uranium collection tank 4A
MR-TK-140	Feed tank 1B	UR-TK-160B	Impure uranium collection tank 4B
MR-TK-180	U solution collection tank	UR-TK-200	IX feed tank 1
MR-TK-200	Feed tank 2	UR-TK-900	IX waste collection tank 1
MR-TK-340	Waste collection tank	UR-TK-920	IX waste collection tank 2
UR-TK-100A	Impure uranium collection tank 1A	WH-TK-100	High-dose waste collection tank
UR-TK-100B	Impure uranium collection tank 1B	WH-TK-240	High-dose concentrate collection tank

IX = ion exchange. U = uranium.

9.7.1.3 Operational Analysis and Safety Function

Chapter 13.0 evaluates the accident sequences that involve fissile solution or solid materials being introduced into systems not normally designed to process these solutions or solid materials. The accident analysis associated with utilities addresses fissile solution leaks across a mechanical boundary between process vessels or backflows into a utility system.

Defense-in-depth – The tank and vessel walls will be made of corrosion-resistant materials and have wall thicknesses that are rated for long service with harsh acidic or basic chemicals.

Items relied on for safety – Based on the analysis conducted in Chapter 13.0, Section 13.2, the following IROFS are implemented.

- IROFS CS-10, "Closed Safe Geometry Heating/Cooling Loop with Monitoring and Alarm"
- IROFS CS-20, "Evaporator/Concentrator Condensate Monitoring"
- IROFS CS-27, "Closed Heating/Cooling Loop with Monitoring and Alarm"
- IROFS FS-03, "Process Vessel Emergency Purge System"
- IROFS CS-18, "Backflow Prevention Device"

The analyses that identified these IROFS and the associated system descriptions are addressed in Chapter 13.0 and Chapter 6.0, respectively.

9.7.1.4 Instrumentation and Control Requirements

Instrumentation and control requirements for the processes associated with the utility system are discussed in Chapter 7.0.

9.7.1.5 Required Technical Specifications

The technical specifications associated with the utility system, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.7.2 Control and Storage of Radioactive Waste

The radioactive waste control and storage systems are designed to ensure that (1) any potential malfunctions do not cause accidents in the RPF or uncontrolled release of radioactivity, and (2) in the event radioactive material is released by the operation of one of these systems, potential radiation exposures would not exceed the limits of 10 CFR 20 and remain consistent with the NWMI ALARA program. No function or malfunction of the auxiliary systems will interfere with or prevent safe shutdown of the RPF.

9.7.2.1 Design Basis

The waste handling system design basis is provided in Chapter 3.5.2.7.

9.7.2.2 System Description

To fulfill the design basis, the control and storage of radioactive waste will include the following functions:

- High-dose liquid waste handling (collection, concentration, and solidification)
- Low-dose liquid waste handling (collection, evaporation, recycle and solidification)
- Spent resin dewatering
- Solid waste encapsulation
- High-dose waste decay
- High-dose waste handling
- Waste handling
- Waste Staging and Shipping Building (Class A storage)

These functions are described in detail in the following subsections.

Figure 9-21 summarizes the weekly design basis volumes and the average annual weekly volumes of all waste handling process streams. The design basis volume is based on eight University of Missouri Research Reactor (MURR) targets and 30 Oregon State University (OSU) TRIGA[1] Reactor (OSTR) targets per week to provide appropriately sized tanks. The annual weekly average is based on processing eight MURR targets per week for 44 weeks per year and 30 OSTR targets per week for eight weeks per year and is used in the sizing of the high-dose decay storage.

[1] TRIGA (Training, Research, Isotopes, General Atomics) is a registered trademark of General Atomics, San Diego, California.

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[Proprietary Information]

Figure 9-20. Waste Management Process Flow Diagram and Process Flow Streams

9.7.2.2.1 High-Dose Liquid Waste Handling

Figure 9-21 shows the location in the hot cell area where the high-dose liquid waste will be processed. High-dose liquid waste will be collected in the high-dose waste collection tank (shown in Figure 9-22), which will provide the needed handling capacity to match the volume of liquid waste generated by the upstream processes. Chapter 4.0 provides descriptions of the high-dose liquid streams that will be directed to the collection tank.

[Proprietary Information]

Figure 9-21. High-Dose Liquid Waste Solidification Subsystem and Low-Dose Collection Tank Location

The process stream volumes are summarized in Figure 9-20, and Table 9-5 provides the high-dose waste tank capacities. The process streams include:

- Caustic scrubber waste
- Oxidizing column waste
- NO_x absorber waste
- Regeneration waste from TiO_2 #1 IX
- Raffinate/rinsate from #2 IX
- Raffinate/rinsate from #3 IX
- U IX waste

[Proprietary Information]

Figure 9-22. Simplified High-Dose Waste Handling Process Flow Diagram

Table 9-5. High-Dose Waste Tank Capacities

Tank ID	Description/purpose	Tank capacity	
		gal	L
WH-TK-100	High-dose waste accumulation tank	5,050	19,000
WH-TK-240	High-dose concentrate accumulation tank	1,270	4,800

Additions to the collection tank are in discrete, analyzed batches. Sodium hydroxide solution will be added as needed to neutralize any excess acidity. The neutralized liquid will be forwarded to the high-dose waste concentrator, where water is evaporated from the high-dose liquid, condensed, and directed to the condensate collection tank. The evaporator bottoms will be directed to a high-dose concentrate collection tank.

Figure 9-23 shows the arrangement of the high-dose waste handling equipment. A HIC will be transferred into the high-dose waste treatment hot cell through the HIC transfer drawer, and docked with the high-dose solidification mixer. Solidification agent will be transferred to the designated bin from the distribution hopper, which will be loaded by operators in the low-dose waste solidification area. High-dose liquid waste concentrate from the waste concentrate collection tank and solidification agent will be metered into the HIC by the high-dose solidification mixer that may consist of an in-line mixer or a sacrificial paddle within the HIC. After filling and mixing are complete, the high-dose solidification mixer will be disengaged, and the HIC lidded and prepared for transfer to the high-dose waste decay subsystem for storage.

[Proprietary Information]

Figure 9-23. High-Dose Waste Treatment and Handling Equipment Arrangement

9.7.2.2.2 Low-Dose Liquid Waste Handling

Figure 9-24 shows the location of the low-dose liquid waste collection tank. Low-dose condensate from the high-dose concentrator will be held in the condensate collection tank (Figure 9-25). Chapter 4.0 provides descriptions of the low-dose liquid streams that will be directed to the collection tank. The process stream volumes are summarized in Figure 9-20, and Table 9-6 provides the low-dose waste tank capacities. Low-dose liquid received from other upstream processes, combined with the low-dose condensate not recycled, will be transferred to the low-dose waste collection tank where the contents of the tank will be analyzed and adjusted with sodium hydroxide (NaOH) to neutralize any residual acids. Once neutralized, the low-dose waste will then be forwarded to the first of two evaporation tanks located on the second floor (Figure 9-24). In these heated tanks, the liquid will be held at elevated temperatures (60°C [140°F]), and high rates of ventilation air will be passed through the tank. The heated tank contents, plus the high rate of ventilation, will evaporate excess water, reducing the volume of solid waste generated. Samples will be collected and analyzed to ensure compliance with waste acceptance criteria.

[Proprietary Information]

Figure 9-24. Low-Dose Liquid Waste Evaporation System Location

[Proprietary Information]

Figure 9-25. Low-Dose Liquid Waste Disposition Process

Table 9-6. Low-Dose Waste Tank Capacities

Tank ID	Description/purpose	Tank capacity	
		gal	L
WT-TK-400	Condensate tank for high-dose evaporator	4,300	16,250
WH-TK-420	Low-dose waste accumulation tank	5,900	22,300
WH-TK-500	Low-dose waste evaporation tank (LD-1)	5,900	22,300
WH-TK-530	Low-dose evaporation tank (LD-2)	2,600	9,800

The partially concentrated low-dose liquid waste will be transferred to the low-dose waste solidification area (Figure 9-26), where the waste will be metered into a drum that has been placed in the low-dose solidification hood (WH-EN-600). Solidification product vendor information indicates that a ratio of 56.7 to 79.4 kg (125 to 175 lb) of solidification agent is sufficient to solidify 59 to 178 L (42 to 47 gal) of liquid waste within a 55-gal drum. The drum will be lidded at the drum lidding station. With time, the mixture will solidify within the waste drum. The filled waste drum will be loaded onto a shipping pallet and transferred by pallet jack to the shipping and receiving airlock door.

[Proprietary Information]

Figure 9-26. Low-Dose Liquid Waste Solidification Equipment Arrangement

9.7.2.2.3 Spent Resin Dewatering

Spent resin dewatering will be conducted in the high-dose waste treatment hot cell. Figure 9-27 provides the flow diagram for the spent resin dewatering subsystem. This subsystem will transfer uranium recovery and recycle system spent IX resin slurry from the spent resin collection tanks located in the tank hot cell (Figure 9-28) to the dewatering filling head in the high-dose waste treatment hot cell (Figure 9-23). The dewatering filler head will remove liquid from the resin. Dry resin will be collected in a waste drum, and the liquid returned to the low-dose waste collection tank.

The solid waste drum transfer drawer (WH-TP-810) (Figure 9-23) will be opened, and the high-dose waste handling crane will be used to lift the drum and place it in the solid waste drum scan for characterization. After characterization is complete, the drum will be transferred by the high-dose waste handling crane from the solid waste drum scan feed conveyor and placed into a five-drum rack. As determined by characterization, the drum will either be held for decay storage or transferred to the high-dose waste handling system for transfer to a shipping cask.

[Proprietary Information]

Figure 9-27. Spent Resin Dewatering Operational Flow Diagram

[Proprietary Information]

Figure 9-28. Spent Resin Collection Tanks Location

9.7.2.2.4 Solid Waste Encapsulation

Figure 9-29 provides the flow diagram for the solid waste encapsulation subsystem. Operators will enter the maintenance gallery and retrieve the solid waste drum cart from the waste collection port and transfer the drum cart into the high-dose waste treatment hot cell (Figure 9-23). The solid waste drum access port will be opened, and the solid waste encapsulation grout mixer (WH-Z-800) filling nozzle will be docked for waste encapsulation. After the grout filling is complete, the solid waste encapsulation grout mixer filling nozzle will be removed, and the solid waste drum access port closed. The solid waste drum transfer drawer will be opened, and the high-dose waste handling crane will be used to lift the drum and place it in the solid waste drum scan for characterization. After characterization is complete, the drum will be transferred by the high-dose waste handling crane from the solid waste drum scan feed conveyor and placed into a five-drum rack. As determined by the drum's characterization, the drum will either be held for decay storage or transferred to the high-dose waste handling subsystem for transfer to a shipping cask.

[Proprietary Information]

Figure 9-29. Solid Waste Encapsulation Operational Flow Diagram

9.7.2.2.5 High-Dose Waste Decay

Figure 9-30 provides the flow diagram for the high-dose waste decay subsystem. This subsystem will provide lag storage capability for solidified liquid waste and the five-drum racks with high-dose source terms. After HICs or five-drum racks have been filled and lidded in the high-dose waste treatment hot cell, they will be transferred to the high-dose waste decay subsystem.

[Proprietary Information]

Figure 9-30. High-Dose Waste Decay Operational Flow Diagram

The high-dose waste decay cell lift (WH-L-900) (Figure 9-31) will lower the HIC or five-drum rack into the high-dose waste decay cell, where the high-dose waste decay cell conveyor (WH-CN-900) will transfer the HIC or five-drum rack to its decay storage position. The HIC or five-drum rack will remain in storage for a set amount time to allow for short-lived radioisotopes in the waste to decay to lower levels. When the HIC or five-drum rack has decayed to an acceptable activity level, the high-dose waste decay cell conveyor (WH-CN-900) will transfer the HIC or five-drum rack to the high-dose waste decay cell lift, where the HIC or rack will be raised into the high-dose waste treatment hot cell and then transferred to the high-dose waste handling area.

[Proprietary Information]

Figure 9-31. High Dose Waste Decay Cell Equipment Arrangement

9.7.2.2.6 High-Dose Waste Handling

Figure 9-32 provides the flow diagram for the high-dose waste handling subsystem. This subsystem will provide the capability to remotely transfer high-dose waste containers into a shipping cask. When a HIC or two five-drum racks are ready for shipment, the high-dose waste handling crane will be used to open the high-dose waste shipping transfer port (WH-TP-1000) and then transfer the HIC or two five-drum racks, from within the high-dose waste handling area, through the high-dose waste shipping transfer port, and into a shipping cask.

[Proprietary Information]

Figure 9-32. High Dose Waste Handling Operational Flow Diagram

9.7.2.2.7 Waste Handling

The simplified operational flow diagram for the waste handling subsystem is shown in Figure 9-33.

[Proprietary Information]

Figure 9-33. Waste Handling Flow Diagram

The waste handling subsystem will have multiple material handling capabilities. The liquid high-dose radiological waste and solid radiological waste handling will begin with the arrival of a truck and lowboy trailer transporting an empty DOT-approved cask (Figure 9-34). The truck, trailer, and shipping cask will enter the RPF to the waste management loading bay via an exterior facility high-bay door. The shipping cask will then be documented for material tracking and accountability per the safeguards and security system requirements. Operators will use the utility system's truck bay spray wand for any necessary wash-down of the truck, trailer, or shipping cask while located in the waste management loading bay. The operators will remove the shipping cask's upper impact limiter using the waste shipping overhead crane (WH-L-1100) (Figure 9-34). The upper impact limiter will be placed in the designated impact limiter landing zone and secured. Operators will unbolt the lid and prepare the DOT-approved shipping cask for loading per the cask loading and unloading procedure. At this point, the truck, trailer, and shipping cask will enter the waste loading area via a high-bay door. The trailer containing the DOT-approved shipping cask will be positioned below the high-dose waste shipping transfer port (WH-TP-1000) of the contaminated waste system. The truck will be disconnected from the trailer and exit the RPF via the high-bay doors in which the vehicle entered. All high-bay doors will be verified as closed and the shipping cask will then be in position and ready for loading per the contaminated waste system procedures.

[Proprietary Information]

Figure 9-34. Waste Handling Equipment Arrangement

After the DOT-approved cask has been loaded, the shipping cask will be separated from the high-dose waste shipping transfer port (WH-TP-1000). The truck will enter the RPF into the waste management loading bay via an exterior facility high-bay door, and operators will use the utility system's truck bay overhead spray wand for any necessary wash-down of the truck while located in the waste management loading bay. The truck will then enter the waste loading area via a high-bay door. The truck will be connected to the trailer and exit to the waste loading area in the waste management loading bay. At this point, the facility process control and communications system will allow operators to replace the shipping cask's upper impact limiter using the waste shipping overhead crane (WH-L-1100). The shipping cask will be documented for material tracking and accountability per the safeguards and security system requirements (Chapter 12.0). The truck, trailer, and shipping cask will exit the RPF through the high-bay doors in which the vehicle entered.

The liquid low-dose radiological waste handling process will begin with the arrival of a truck transporting the empty waste drum pallets to the fresh and unirradiated shipping and receiving area. The receiving area door will be opened, and the truck will be docked to the receiving bay, allowing for transfer of the waste drum pallets into the RPF. Pallet-loaded empty waste drums will be unloaded from the truck using the waste handling pallet jack (WH-PH-1100). All unloaded empty waste drum pallets will then be documented for material tracking and accountability per the safeguards and security system requirements. The pallet jack carrying an empty waste drum pallet will be transferred to the shipping and receiving airlock door, where the empty waste drums will enter the contaminated waste system for loading.

After the waste drums have been loaded with liquid low-dose radiological waste and re-palletized, a pallet containing full waste drums will be transferred via the waste handling pallet jack (WH-PH-1100) from the shipping and receiving airlock door to the waste loading area. The waste handling forklift (WH-PH-1110) will then enter the waste management loading bay via an exterior facility high-bay door.

A waste shipping truck will also enter the waste management loading bay via an exterior facility high-bay door. Operators will open the high-bay door to the waste loading area and use the forklift to load the waste drum pallet into the truck. The shipping truck will then be documented for material tracking and accountability per the safeguards and security system requirements. The truck containing the waste pallets will exit the RPF through the high-bay doors in which the vehicle entered.

9.7.2.2.8 Waste Staging and Shipping Building (Class A Storage)

The Waste Staging and Shipping Building will be approximately [Proprietary Information] and will provide additional waste storage and shipping preparation for Class A radioactive waste prior to disposal.

9.7.2.3 Operational Analysis and Safety Function

Chapter 13.0, Section 13.2 evaluates the accident sequences that involve fissile solution or solid materials being introduced into systems not normally designed to process these solutions or solid materials. The waste handling system is not geometrically safe; therefore, a number of IROFS have been identified.

- IROFS RS-01, "Hot Cell Liquid Confinement Boundary"
- IROFS RS-03, "Hot Cell Secondary Confinement Boundary"
- IROFS RS-04, "Hot Cell Shielding Boundary"
- IROFS RS-08, "Sample and Analysis of Low Dose Waste Tank Dose Rate Prior to Transfer Outside the Hot Cell Shielding Boundary"
- IROFS RS-10, "Active Radiation Monitoring and Isolation of Low Dose Waste Transfer"
- IROFS CS-14, "Active Discharge Monitoring and Isolation"
- IROFS CS-15, "Independent Active Discharge Monitoring and Isolation"
- IROFS CS-16, "Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal"
- IROFS CS-17, "Independent Sampling and Analysis of U Concentration Prior to Discharge or Disposal"
- IROFS CS-18, "Backflow Prevention Device"
- IROFS CS-21, "Visual Inspection of Accessible Surfaces for Foreign Debris"
- IROFS CS-22, "Gram Estimator Survey of Accessible Surfaces for Gamma Activity"
- IROFS CS-23, "Non-Destructive Assay (NDA) of Items with Inaccessible Surfaces"
- IROFS CS-24, "Independent NDA of Items with Inaccessible Surfaces"
- IROFS CS-25, "Target Housing Weighing Prior to Disposal"
- IROFS CS-26, "Active Discharge Monitoring and Isolation"
- IROFS FS-01, "Enhanced Lift Procedure"
- IROFS FS-02, "Overhead Cranes"

Additional information on the analyses that identified these IROFS is provided in Chapter 13.0.

9.7.2.4 Instrumentation and Control Requirements

Instrumentation and control requirements for the processes associated with the control and storage of radioactive waste are discussed in Chapter 7.0.

9.7.2.5 Required Technical Specifications

The technical specifications associated with the control and storage of radioactive waste, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.7.3 Analytical Laboratory

The analytical laboratory will support production of the ^{99}Mo product and recycle of uranium. Samples from the process will be collected, transported to the laboratory, and prepared in the laboratory gloveboxes and hoods, depending on the analysis to be performed.

9.7.3.1 Design Basis

The RPF analytical laboratory design basis is to provide on-site analysis to support the production of ^{99}Mo product and fabrication of targets for irradiation. This analysis will be used to determine (1) mass, concentration and purity of SNM, (2) concentration of ^{99}Mo product and product impurities, (3) process stream chemical and radionuclide concentrations, and (4) chemical and radionuclide analysis for waste handling and disposition. Analysis will be required to:

- Verify acceptable ^{99}Mo product to ship
- Confirm uranium content
- Determine adjustments for feed tanks and other associated adjustments
- Verify that recycled uranium product complies with product specification
- Ensure compliance with waste acceptance criteria

9.7.3.2 System Description

The RPF analytical laboratory space will include the following:

- Hoods to complete sample preparation, waste handling, and standards preparation
- Hoods for specialty instruments, including an ICP-MS and kinetic phosphorescence analyzer
- Glovebox for ICP-MS
- Gloveboxes for sample delivery and preparation prior to sample transfer to hoods
- Countertops for the gamma spectroscopy system, low-energy photon spectroscopy, alpha spectroscopy system, liquid scintillation system, and beta-counting system
- Storage for chemical and laboratory supplies
- Benchtop systems, such as balances, pH meters, and ion-chromatography

The analytical laboratory layout is presented in Figure 9-35 and provides space for eight hoods, four gloveboxes, and two countertops.

[Proprietary Information]

Figure 9-35. Analytical Laboratory Layout

Analytical instrumentation will include the ICP-MS, kinetic phosphorescence analyzer, gamma energy analysis, alpha spectroscopy, liquid scintillation spectrometry, and gamma energy analysis.

9.7.3.3 Operational Analysis and Safety Function

Chapter 13.0 evaluates the accident sequences that involve miscellaneous chemical safety process upsets in areas without significant fissile or high-dose licensed material present (chemical storage areas and the laboratory). The accidents analyzed that are associated with the analytical laboratory include Accident Sequence S.R.31, "Chemical Burns from Contaminated Solutions During Sample Analysis." No laboratory IROFS have been identified.

Defense-in-depth – Operators and laboratory technicians will follow set protocols on sampling and analysis to identify the sampling locations, sampling techniques, containers to be used, transport routes to take, analysis procedures, reagents to use, equipment requirements, and disposal protocol for the sample residue material. Each of these procedures will be evaluated for standard safety protocols, including requirements in the safety datasheets for the chemicals used and safety requirements for the equipment used.

9.7.3.4 Instrumentation and Control Requirements

Instrumentation and control requirements for the processes associated with the analytical laboratory will be discussed in Chapter 7.0 as part of the Operating License Application.

9.7.3.5 Required Technical Specifications

The technical specifications associated with the analytical laboratory, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.7.4 Chemical Supply

The chemical supply system will include tanks supplying aqueous chemicals to the process systems, flammable material storage cabinets used to segregate incompatible materials, and storage of chemical solids used in the process systems.

9.7.4.1 Design Basis

The chemical supply system design basis is to provide chemical solutions mixed to the required concentrations that are used within the target fabrication, target dissolution, Mo recovery and purification, and waste management systems. The system will provide nitric acid, NaOH, reductant and NO_x absorber solutions, hydrogen peroxide, and fresh uranium IX resin. Additional information is provided in Chapter 3.0, Section 3.5.2.7.

9.7.4.2 System Description

Figure 9-36 shows the layout of the chemical supply room within the RPF. Tanks are sized to provide support to the process requirements.

9.7.4.2.1 Subsystem 100, Nitric Acid

Subsystem 100 will consist of five tanks that provide the following functions:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]

[Proprietary Information]

Figure 9-36. Chemical Supply Room Equipment Layout

Figure 9-37 provides the flow diagram for Subsystem 100, and Table 9-7 provides a summary description of the tanks in this subsystem.

[Proprietary Information]

Figure 9-37. Nitric Acid Flow Diagram

Table 9-7. Subsystem 100, Nitric Acid Tank Sizes

Tank number	Chemical	Working volume (L)	Total volume (L)	Diameter (in.)	Height (in.)
CS-TK-100	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	120	135
CS-TK-130	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	12	20
CS-TK-150A	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	84	83
CS-TK-150B	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	84	83
CS-TK-180A	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	84	110
CS-TK-180B	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	84	110
CS-TK-300	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	18	21
CS-TK-320	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	18	21
CS-TK-600A/B/C/D	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]		

HNO_3 = nitric acid. IX = ion exchange.

9.7.4.2.2 Subsystem 200, Sodium Hydroxide

Subsystem 200 will consist of three tanks that provide the following functions:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]

Figure 9-38 provides the flow diagram for the NaOH subsystem, and Table 9-8 provides a summary description of the tanks in this subsystem.

[Proprietary Information]

Figure 9-38. Sodium Hydroxide Flow Diagram

Table 9-8. Subsystem 200, Sodium Hydroxide Tank Sizes

Tank number	Chemical	Working volume (L)	Total volume (L)	Diameter (in.)	Height (in.)
CS-TK-200	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	84	96
CS-TK-230	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	18	18
CS-TK-260	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	24	27
CS-TK-350	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	6	8

NaOH = sodium hydroxide. NO_x = nitrogen oxide.

9.7.4.2.3 Subsystem 300, Reductant and NO_x Absorber Solutions

Subsystem 300 will consist of three tanks that provide the following functions:

- [Proprietary Information]
- [Proprietary Information]

Table 9-9 provides a summary description of the tanks in Subsystem 300.

Table 9-9. Subsystem 300, Reductant and Nitrogen Oxide Absorber Solutions Tank Sizes

Tank number	Chemical	Working volume (L)	Total volume (L)	Diameter (in.)	Height (in.)
CS-TK-300	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	18	21
CS-TK-320	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	18	21
CS-TK-340	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	6	8

NO_x = nitrogen oxide.

9.7.4.2.4 Subsystem 400, Hydrogen Peroxide

Subsystem 400 will provide the following functions:

- [Proprietary Information]
- [Proprietary Information]

Figure 9-39 provides the flow diagram for the hydrogen peroxide subsystem. The subsystem will consist of one tank (CS-TK-400), which is summarized in Table 9-10.

[Proprietary Information]

Figure 9-39. Hydrogen Peroxide Flow Diagram

Table 9-10. Subsystem 400, Hydrogen Peroxide Tank Sizes

Tank number	Chemical	Working volume (L)	Total volume (L)	Diameter (in.)	Height (in.)
CS-TK-400	Hydrogen peroxide	[Proprietary Information]	[Proprietary Information]	9	12

9.7.4.2.5 Subsystem 600, Fresh Uranium Ion Exchange Resin

Subsystem 600 will consist of four tanks (one tank to support each uranium IX column) that provide the following functions:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]

Table 9-11 provides a summary description of the tanks in Subsystem 600.

Table 9-11. Subsystem 600, Fresh Uranium Ion Exchange Resin Tank Sizes

Tank number	Chemical	Working volume (L)	Total volume (L)	Diameter (in.)	Height (in.)
CS-TK-600A	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	24	24
CS-TK-600B	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	24	24
CS-TK-600C	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	24	24
CS-TK-600D	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	24	24

IX = ion exchange.

These tanks will support preparation of fresh resin for addition to an IX column after spent resin has been removed. A description of the fresh resin makeup activity is summarized as follows:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]

Once resin has been prepared by fines removal and washing, the makeup tank will be adjusted to contain a total volume of [Proprietary Information]. The makeup tank low-speed agitator will be started to suspend the resin inventory, and the valve opened to route the suspension to an IX column.

9.7.4.3 Operational Analysis and Safety Function

Chapter 13.0 evaluates accident sequences that involve miscellaneous chemical safety process upsets in areas without significant fissile or high-dose licensed material present (e.g., chemical storage areas and the laboratory). The backflow of fissile or radioactive solutions into auxiliary systems (e.g., chemical supply) was also analyzed and two preventive IROFS identified.

Defense-in-depth – NWMI will comply with U.S. Environmental Protection Agency and Occupational Safety and Health Administration regulations for the design, construction, and operation of chemical preparation and storage areas in the RPF. Chemical handling procedures will be provided to operators to ensure safe handling of chemicals according to applicable regulatory requirements and consistent with the material safety datasheets.

Items relied on for safety – Based on the analysis conducted in Chapter 13.0, Section 13.2, the following IROFS will be implemented:

- CS-18, "Backflow Prevention Device"
- CS-19, "Safe Geometry Day Tanks"

9.7.4.4 Instrumentation and Control Requirements

Instrumentation and control requirements for the processes associated with the chemical supply system will be discussed in Chapter 7.0 as part of the Operating License Application.

9.7.4.5 Required Technical Specifications

The technical specifications associated with the chemical supply system, if applicable, will be discussed in Chapter 14.0 as part of the Operating License Application.

9.8 REFERENCES

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NORTHWEST MEDICAL ISOTOPES

Chapter 10.0 – Experimental Facilities

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 3
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Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, OR 97330

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Chapter 10.0 – Experimental Facilities

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 3

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TERMS

Acronyms and Abbreviations

CFR	Code of Federal Regulations
NWMI	Northwest Medical Isotopes, LLC
RPF	Radioisotope Production Facility

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10.0 EXPERIMENTAL FACILITIES

This chapter of the Construction Permit Application addressing experimental facilities is not applicable to the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF). Specifically, NWMI will not have any laboratory-scale facilities designed or used for experimental or analytical purposes that relate to the processing of irradiated materials containing special nuclear material per the definition of a production facility in Title 10, *Code of Federal Regulations* (CFR), Part 50.2, "Definitions."

References

10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.