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NORTHWEST MEDICAL ISOTOPES

Chapter 4.0 – Radioisotope Production Facility Description

Construction Permit Application for Radioisotope Production Facility

NWMI-2015-021, Rev. 3
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TERMS

Acronyms and Abbreviations

^{89}Sr	strontium-89
^{90}Sr	strontium-90
^{99}Mo	molybdenum-99
^{99m}Tc	technetium-99m
^{131}I	iodine-131
^{133}Xe	xenon-133
^{234}U	uranium-234
^{235}U	uranium-235
^{236}U	uranium-236
^{237}U	uranium-237
^{238}U	uranium-238
^{239}Np	neptunium-239
^{239}Pu	plutonium-239
AC	administrative control
ACI	American Concrete Institute
ADUN	acid-deficient uranyl nitrate
AEF	active engineered feature
AHS	ammonium hydroxide solution
ALARA	as low as reasonably achievable
As	arsenic
ASME	American Society of Mechanical Engineers
Ba	barium
BHMA	Builders Hardware Manufacturers Association
Br	bromine
BRR	BEA Research Reactor
CFR	Code of Federal Regulations
CO_2	carbon dioxide
CSE	criticality safety evaluation
DBE	design basis event
Discovery Ridge	Discovery Ridge Research Park
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EBC	equivalent boron content
EOI	end of irradiation
EPDM	ethylene propylene diene monomer
FDA	U.S. Food and Drug Administration
$Fe(SO_3NH_2)_2$	ferrous sulfamate
H_2	hydrogen gas
H_2O	water
H_3PO_4	phosphoric acid
HEPA	high-efficiency particulate air
HIC	high-integrity container
HMTA	hexamethylenetetramine
HNO_3	nitric acid
HSO_3NH_2	sulfamic acid
HVAC	heating, ventilation, and air conditioning
I	iodine
ICP-MS	inductively coupled plasma mass spectrometry

ICRP	International Commission on Radiation Protection
IROFS	items relied on for safety
IRU	iodine removal unit
IX	ion exchange
Kr	krypton
LEU	low-enriched uranium
MC&A	material control and accountability
MCNP	Monte Carlo N-Particle
Mo	molybdenum
MOC	materials of construction
MURR	University of Missouri Research Reactor
Na_2SO_3	sodium sulfite
NaH_2PO_4	sodium dihydrogen phosphate
$NaNO_2$	sodium nitrite
NaOCl	sodium hypochlorite
NaOH	sodium hydroxide
Nb	niobium
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_4OH	ammonium hydroxide
NO	nitric oxide
NO_x	nitrogen oxide
NO_2	nitrogen dioxide
NRC	U.S. Nuclear Regulatory Commission
NWMI	Northwest Medical Isotopes, LLC
ORNL	Oak Ridge National Laboratory
OSTR	Oregon State University TRIGA Reactor
OSU	Oregon State University
Pb	lead
PDF	passive design feature
QC	quality control
QRA	qualitative risk analysis
R&D	research and development
RCT	radiological control technician
Rh	rhodium
RPF	Radioisotope Production Facility
Ru	ruthenium
Sb	antimony
Se	selenium
Sn	tin
SNM	special nuclear material
SS	stainless steel
SSC	structures, systems and components
TBP	tributyl phosphate
TCE	trichloroethylene
Tc	technetium
Te	tellurium
[Proprietary Information]	[Proprietary Information]
TMI	total metallic impurities
TRU	transuranic
U	uranium
U.S.	United States

UN	uranyl nitrate
UNH	uranyl nitrate hexahydrate
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
USP	U.S. Pharmacopeial Convention
Xe	xenon

Units

°C	degrees Celsius
°F	degrees Fahrenheit
μ	micron
μCi	microcurie
μg	microgram
μm	micrometer
atm	atmospheres
Bq	becquerel
BV	bed volume
Ci	curie
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
CV	column volume
ft	feet
ft^2	square feet
g	gram
gal	gallon
GBq	gigabecquerel
gmol	gram-mol
ha	hectare
hr	hour
in.	inch
$in.^2$	square inch
kg	kilogram
km	kilometer
kW	kilowatt
L	liter
lb	pound
m	meter
M	molar
m^2	square meter
mCi	millicurie
MBq	megabecquerel
MeV	megaelectron volt
mg	milligram
mi	mile
min	minute
mL	milliliter
mm	millimeter
mol	mole
mR	milliroentgen
mrem	millirem

MT	metric ton
MW	megawatt
nCi	nanocurie
rem	roentgen equivalent in man
ppm	parts per million
ppmp U	parts per million parts uranium by mass
sec	second
t	tonne
vol%	volume percent
W	watt
wk	week
wt%	weight percent

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4.0 RADIOISOTOPE PRODUCTION FACILITY DESCRIPTION

This chapter describes the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF) and the processes within the RPF involving special nuclear material (SNM). The RPF will produce molybdenum-99 (^{99}Mo) from low-enriched uranium (LEU) irradiated by a network of university research reactors.

The primary RPF operations will include the following:

- Receiving LEU from the U.S. Department of Energy (DOE)
- Producing LEU target materials and fabrication of targets
- Packaging and shipping LEU targets to the university reactor network for irradiation
- Returning irradiated LEU targets for dissolution, recovery, and purification of ^{99}Mo
- Recovering and recycling LEU to minimize radioactive, mixed, and hazardous waste generation

Treating/packaging wastes generated by RPF process steps to enable transport to a disposal site

This chapter provides an overview of the following:

- RPF description
- Detailed RPF design descriptions
- Biological shield
- Processes involving SNM

The design description includes the design basis, equipment design, process control strategy, hazards identification, and items relied on for safety (IROFS) to prevent or mitigate facility accidents.

In addition, the overview provides the name, amount, and specifications (including chemical and physical forms) of the SNM that is part of the RPF process, a list of byproduct materials (e.g., identity, amounts) in the process solutions, extracted and purified products, and associated generated wastes. A detailed description of the equipment design and construction used when processing SNM outside the RPF is also provided. Sufficient detail is provided of the identified materials to understand the associated moderating, reflecting, or other nuclear-reactive properties.

4.1 FACILITY AND PROCESS DESCRIPTION

4.1.1 Radioisotope Production Facility Summary

The proposed RPF site is situated within Discovery Ridge Research Park (Discovery Ridge). Discovery Ridge is located in the City of Columbia, Boone County, Missouri. The site is situated in central Missouri, approximately 201 kilometer (km) (125 miles [mi]) east of Kansas City and 201 km (125 mi) west of St. Louis. The site is 7.2 km (4.5 mi) south of U.S. Interstate 70, just north of U.S. Highway 63 (see Chapter 19.0, "Environmental Review," Figure 19-4). The Missouri River lies 15.3 km (9.5 mi) west of the site. The site is located 5.6 km (3.5 mi) southeast of the main University of Missouri campus.

The RPF will support target fabrication, recovery and purification of the ^{99}Mo product from irradiated LEU targets that would be generated by irradiation in multiple university research reactors, and uranium recovery and recycle to produce ^{99}Mo.

The RPF site is 3.0 hectare (ha) (7.4-acre) and is located on property owned by University of Missouri. Figure 4-1 shows the layout of the NWMI site including the RPF. Three adjacent, separate buildings will be located on the site: an Administrative Building (outside of the protected area), a Waste Staging and Shipping Building for additional Class A waste storage (inside the protected area), and a Diesel Generator Building. These major facilities also receive, store/hold, or process chemicals, oil, diesel fuel, and other hazardous and radioactive materials.

Figure 4-1. Radioisotope Production Facility Site Layout

The building will be divided into material accountability areas that are regulated by Title 10, *Code of Federal Regulations*, Part 50 (10 CFR 50), "Domestic Licensing of Production and Utilization Facilities," and 10 CFR 70, "Domestic Licensing of Special Nuclear Material," as shown in Figure 4-2. The target fabrication area will be governed by 10 CFR 70, and the remainder of the production areas (irradiated target receipt bay, hot cells, waste management, laboratory, and utilities) will be governed by 10 CFR 50. The administration and support area will provide the main personnel access to the RPF and include personnel support areas such as access control, change rooms, and office spaces.

Figure 4-2 provides a building model view of the RPF.

Figure 4-2. Building Model of the Radioisotope Production Facility

The first level (excluding the tank pit area) and second levels of the RPF are currently estimated to contain approximately 4,282 square meter (m^2) (46,088 square feet [ft^2]) and 1,569 m^2 (16,884 ft^2) of floor space, respectively. The processing hot cell and waste management temporary storage floor space area is approximately 544 m^2 (5,857 ft^2). The maximum height of the building is 19.8 m (65 ft) with a maximum stack height of 22.9 m (75 ft). The depth of the processing hot cell below-grade, without footers, is 4.6 m (15 ft) of enclosure height in rooms containing process equipment. The site will be enclosed by perimeter fencing to satisfy safeguards and security and other regulatory requirements.

Figure 4-3 is first level general layout of the RPF and presents the seven major areas, including the target fabrication area, irradiated target receipt area, tank hot cell area, laboratory area, waste management area, utility area, and administrative support area. Figure 4-4 provides a ground-floor layout of the facility, including processing, laboratory, and operating personnel support areas and also provides the general dimension of the RPF. Figure 4-5 is a preliminary layout of the second level of the RPF. A mezzanine area above a portion of the process area will be for utility, ventilation and offgas equipment. Figure 4-6 illustrates the hot cell details for target disassembly dissolution, Mo recovery and purification, uranium recovery and recycle, and waste management.

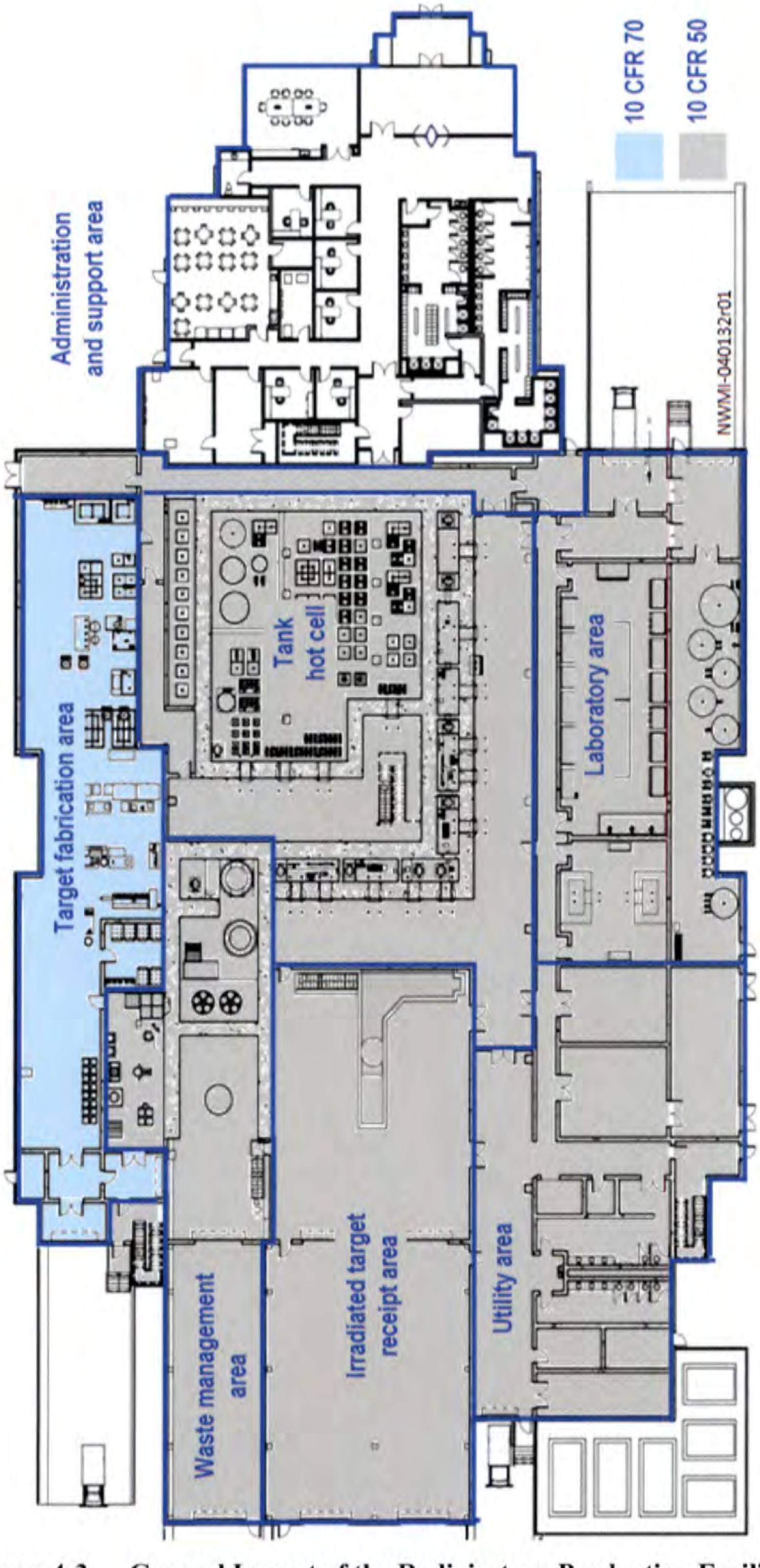

Figure 4-3. General Layout of the Radioisotope Production Facility

[Proprietary Information]

Figure 4-4. Preliminary Layout of the Radioisotope Production Facility First Level Floor Plan and Associated Dimensions

[Proprietary Information]

Figure is not drawn to scale.

Figure 4-5. Preliminary Layout of the Radioisotope Production Facility Second Level Floor Plan

[Proprietary Information]

Figure is not drawn to scale.

Figure 4-6. Radioisotope Production Facility Hot Cell Details

4.1.2 Process Summary

A flow diagram of the primary process to be performed at the RPF is provided in Figure 4-7. The primary purpose of these RPF operations will be to provide ^{99}Mo product in a safe, economic, and environmentally protective manner.

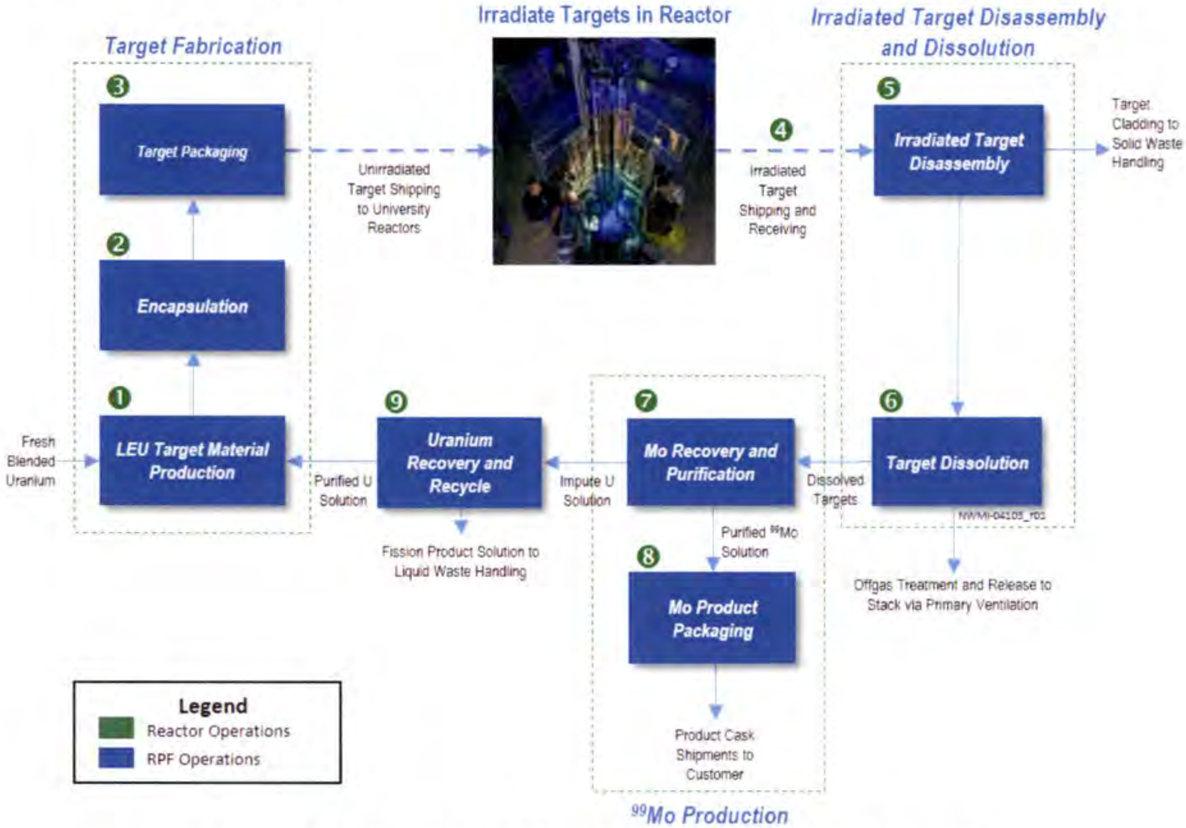

Figure 4-7. Radioisotope Production Facility Block Flow Diagram

Facility operation will include the following general process steps (which correspond with Figure 4-7).

Target Fabrication

1. LEU target material is fabricated using a combination of fresh LEU and recycled uranium.
2. Target material is encapsulated using metal cladding to contain the LEU and fission products produced during irradiation.
3. Fabricated targets are packaged and shipped to university reactors for irradiation.

Target Receipt, Disassembly, and Dissolution

4. After irradiation, targets are shipped back to the RPF.
5. Irradiated targets are disassembled and metal cladding is removed.
6. Targets are then dissolved into a solution for processing.

Molybdenum Recovery and Purification

7. Dissolved LEU solution is processed to recover and purify ^{99}Mo.
8. Purified ^{99}Mo is packaged in certified shipping containers and shipped to a radiopharmaceutical distributor.

Uranium Recovery and Recycle

⑨ LEU solution is treated to recover uranium and remove trace contaminants and is recycled back to Step 1 to be made into new targets via the target fabrication system.

4.1.2.1 Process Design Basis

The process design requirements are identified in NMWI-2013-049, *Process System Functional Specification*. The RPF is designed to have a nominal operational processing capability of [Proprietary Information]. The following summarizes key requirements for the RPF and the primary process systems:

- Decay targets more than [Proprietary Information] end of irradiation (EOI) prior processing
- Process a target batch within [Proprietary Information]
- Receive MURR targets nominally [Proprietary Information] EOI
- Control/prevent flammable gas from reaching lower flammability limit conditions of 5 percent hydrogen gas (H_2); design for 25 percent of lower flammability limit
- Ensure that uranium-235 (^{235}U) processing and storage meet security and criticality safety requirements

The **target fabrication function** will receive and store fresh LEU from DOE, produce [Proprietary Information] as target material, assemble LEU targets and packages, and ship LEU targets. The overall process functional requirements include:

- Fabricating a [Proprietary Information]
- Considering target fabrication as a material balance accountability area requiring measurements for SNM

The **process irradiated LEU targets function** will receive, disassemble, and dissolve irradiated targets. The overall process functional requirements include:

- Accepting weekly irradiated targets in [Proprietary Information]
- Disassembling irradiated targets to remove the irradiated LEU target material, and containing fission gases released during target disassembly
- Dissolving irradiated LEU target material in nitric acid (HNO_3)
- Providing the capability to transfer dissolved solution to the molybdenum (Mo) recovery and purification system
- Removing nitrogen oxides (NO_x), as needed, to ensure proper operation of downstream process steps
- Providing the capability to collect scrubber liquid waste generated during dissolution
- Providing the capability to treat fission gases generated during dissolution
- Removing radioiodine sufficiently to allow discharge to the stack

- Retaining fission product noble gases for a period of time until the gases have decayed sufficiently to allow discharge to the stack
  - [Proprietary Information]
  - [Proprietary Information]

The **Mo recovery and purification function** will produce ^{99}Mo product from the acidified target solution stream. The overall process functional requirements include:

- Providing the capability to recovery ^{99}Mo from dissolver solutions at nominally [Proprietary Information]
- Providing the capability to stage and transfer dissolver solution to the ion exchange (IX) resin beds
- Providing the capability to transfer LEU effluent to the U recovery and recycle system
- Providing the capability for ^{99}Mo product packaging and shipping
- Recovering more than [Proprietary Information] of ^{99}Mo from the target solution
- Removing radioiodine sufficiently from vessel ventilation to allow discharge to the stack
- Providing hot cell capability to transfer ^{99}Mo solution to a "clean cell" for an appropriate level of purification per U.S. Food and Drug Administration requirements
- Confirming that the ^{99}Mo product meets the product specifications
- Shipping the ^{99}Mo product per 49 CFR 173, "Shippers - General Requirements for Shipments and Packages"

The **U recovery and recycle function** will receive, purify, and recycle U from the Mo recovery and purification system. The overall process functional requirements include:

- Providing the capability to recover U from the Mo waste solution
- Providing the capability to [Proprietary Information]
- Providing the capability to dilute the [Proprietary Information]
- Recovering the U-bearing solution using [Proprietary Information]
- Providing the capability for first-stage IX [Proprietary Information]
- Ensuring that each concentrator has [Proprietary Information]
- Providing [Proprietary Information]

The **handle waste function** will process the waste streams generated by the fabricate LEU targets, process irradiated LEU targets, Mo recovery and purification, and U recovery and recycle functions. The overall process functional requirements include:

- Providing the capability to handle waste generated from processing up to [Proprietary Information]

- Providing the capability to treat, package, and transfer Class A waste to the separate waste storage building prior to disposal
- Providing the capability to package waste streams from all RPF systems
- Measuring SNM (material accountability) prior to transfer to the waste handling system
- Accumulating and segregating waste based on waste type (e.g., Class A, Class C, hazardous waste, chemical compatibility) and/or dose level
- Providing the capability to shield the waste storage area in the RPF to decay waste – to meet shipping and disposal requirement
- Treating waste to comply with the disposal facility's waste acceptance criteria
- Assaying waste to verify compliance with shipping and disposal limits

4.1.2.2 Summary of Reagent, Product and Waste Streams

This section presents a summary of the reagents, byproducts, wastes, and finished products of the RPF. Figure 4-8 provides a summary flow diagram of the reagents, product, and wastes. Trace impurities are identified later in this chapter in Table 4-43 and Table 4-56.

[Proprietary Information]

Figure 4-8. Reagents, Product, and Waste Summary Flow Diagram

The amount, concentration, and impurities of the reagent, product, byproduct, and waste streams are provided in later sections of this chapter.

4.1.2.3 Radioisotope Production Facility Spent Nuclear Material Inventory

The SNM inventory of the RPF is summarized below based on material accountability areas. The target fabrication area is governed by 10 CFR 70 and described by Table 4-1. [Proprietary Information] The dissolver process enclosure will include uranium metal that is being dissolved to produce uranyl nitrate (UN) solution. Composition ranges indicate the variation of solution compositions present in different vessels at a particular location.

Table 4-1. Special Nuclear Material Inventory of Target Fabrication Area

Location[a]	Form	Concentration	Volume	SNM mass[b]	
				Bounding[c,d]	Nominal[c,d]
[Proprietary Information]	Solid U-metal pieces/LEU target material in sealed containers	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Dissolver process enclosure	U-metal/UNH	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Recycled uranium process enclosures	UNH	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
ADUN concentration and storage process enclosures	ADUN	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Wash column and drying tray enclosures	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	LEU target material in sealed targets	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] All process enclosures and storage systems are located in the target fabrication process area.

[b] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤19.95 wt% ^{235}U).

[c] [Proprietary Information]

[d] The indicated masses are not additive to describe the total 10 CFR 70 area inventory because material is transferred from one location to another during a processing week.

[Proprietary Information].

ADUN = acid deficient uranyl nitrate solution.
LEU = low-enriched uranium.
N/A = not applicable.
SNM = special nuclear material.
U = uranium.
UNH = uranyl nitrate hexahydrate.
[Proprietary Information] = [Proprietary Information]

Bounding and nominal SNM inventories are indicated on Table 4-1 and shown in terms of the equivalent mass of uranium, independent of the physical form. The bounding inventory in each location is based on the full vessel capacity and composition of in-process solution. The nominal inventory is based on the assumption that storage areas are generally operated at half capacity to provide a buffer for potential variations in process throughput during normal operation. Summation of the location inventories does not necessarily provide an accurate description of the total target fabrication area inventory due to the batch processing operation. Material from one process location is used as input to a subsequent location so that material cannot be present in all locations at the indicated inventories under normal operating conditions.

Irradiated material areas are governed by 10 CFR 50 and described by Table 4-2. Equipment and vessels containing SNM will be located in a variety of hot cells within the RPF. Multiple forms are shown for the target dissolution hot cell because material entering [Proprietary Information] to produce UN solution.

Table 4-2. Special Nuclear Material Inventory of Irradiated Material Areas

Location	Form	Concentration	Volume	SNM mass[a]	
				Bounding[b,c]	Nominal[c,d]
Target receipt hot cell	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target disassembly hot cells[e]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target dissolution hot cells[e]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Mo recovery and purification hot cells	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Tank hot cell					
Mo recovery tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Impure U collection tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
IX columns and support tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Uranium concentrator #1	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Uranium concentrator #2	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U decay tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U IX waste tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
High dose liquid accumulation[g]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Solid waste vessels[h]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at $\leq$ 19.95 wt% ^{235}U).

[b] [Proprietary Information]

[c] The indicated masses are not additive to describe the total 10 CFR 50 area inventory, as the material is transferred from one location to another during a processing week.

[d] [Proprietary Information].

[e] [Proprietary Information].

[f] [Proprietary Information].

[g] [Proprietary Information].

[h] [Proprietary Information].

IX	= ion exchange.	OSTR	= Oregon State University TRIGA Reactor.
LEU	= low-enriched uranium.	SNM	= special nuclear material.
Mo	= molybdenum.	U	= uranium
MURR	= University of Missouri Research Reactor.	UNH	= uranyl nitrate hexahydrate solution
N/A	= not applicable.	[Proprietary Information]	= [Proprietary Information]

[Proprietary Information]. A more detailed description of the vessel volume and composition ranges is described in Section 4.4.1.4.

Summation of the location inventories does not necessarily provide an accurate description of the total irradiated material area inventory due to the batch processing operation. Material from one process location is used as input to a subsequent location such that material cannot be present in all locations at the indicated inventories under normal operating conditions.

4.1.2.4 Radioisotope Production Facility Anticipated Maximum Radionuclide Inventory

The anticipated radionuclide inventory in the RPF is based on [Proprietary Information]. The maximum radionuclide inventory is based on the accumulation in the various systems dependent on the process material decay times, as noted in Table 4-3. Table 4-3 provides the calculated radionuclide inventory (curies [Ci]) for the different process streams in the RPF. The radionuclide inventory values are discussed further in the Radiological Hazards (Sections 4.3.x.5) subsections of each RPF process area.

Table 4-3. Radionuclide Inventory for Radioisotope Production Facility Process Streams

System	Ci	Time (hr EOI)
Target dissolution	[Proprietary Information]	[Proprietary Information]
Mo feed tanks	[Proprietary Information]	[Proprietary Information]
U system	[Proprietary Information]	[Proprietary Information]
Mo system	[Proprietary Information]	[Proprietary Information]
Mo waste tank	[Proprietary Information]	[Proprietary Information]
Offgas system[a]	[Proprietary Information]	[Proprietary Information]
High-dose waste tanks[c]	[Proprietary Information]	[Proprietary Information]
Uranium recycle[d]	[Proprietary Information]	[Proprietary Information]

[a] Offgas system radionuclide inventory is based on NWMI-2013-CALC-011[b] to account for accumulation of isotope buildup in the offgas system [Proprietary Information].

[b] Material decay time is based on the total equilibrium in-process inventory, as described in NWMI-2013-CALC-011, *Source Term Calculations*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[c] [Proprietary Information].

[d] [Proprietary Information].

EOI = end of irradiation.
HIC = high-integrity container.
IX = ion exchange.
Mo = molybdenum.
U = uranium.

Figure 4-9 shows the anticipated radionuclide inventory and provides a color key indicating the amount of curies for the different process areas depending on the EOI.

[Proprietary Information]

Figure 4-9. Radioisotope Processing Facility at 0 to 40 Hours End of Irradiation

Figure 4-10 shows the anticipated maximum radionuclide inventory in the RPF at the completion of processing [Proprietary Information]at an operation time greater than 40 hr EOI.

[Proprietary Information]

Figure 4-10. Radioisotope Processing Facility at Greater than 40 Hours End of Irradiation

4.1.3 Process Overview

4.1.3.1 Target Fabrication

4.1.3.1.1 Target Fabrication Process Overview

The target fabrication process centers on the production of LEU target material that will be generated through an [Proprietary Information], which will subsequently be loaded into aluminum target elements. The LEU feed for the [Proprietary Information] will be chilled uranyl nitrate and consist of a combination of fresh LEU, recovered recycled LEU, and LEU recovered from the processing of irradiated targets. The [Proprietary Information].

The aluminum target components will be cleaned, and then a target subassembly will be welded and loaded with LEU target material. This target subassembly will subsequently be filled with a helium or air cover gas and sealed by welding on the remaining hardware end cap. The completed targets will be inspected and quality checked using a process similar to that performed for commercial nuclear fuel. The targets will then be shipped back to the reactor sites for irradiation.

The target fabrication process will begin with the receipt of fresh uranium from DOE, target hardware, and chemicals associated with microsphere production and target assembly. [Proprietary Information]

The target hardware components will be cleaned, and a target subassembly will be welded and loaded with [Proprietary Information] LEU target material by means of a vibratory target loading assembly. This target subassembly will subsequently be filled with helium or air cover gas and sealed by welding on the remaining hardware end cap. The completed targets will then be inspected and quality checked.

A simplified target fabrication diagram is shown in Figure 4-11. The figure shows the fresh and recycled LEU feeds and the chemical reagents that will be used to produce the target material. The target assembly steps are summarized in the flow diagram and shown in more detail in Figure 4-12.

Target fabrication subsystems will include the following:

- Fresh uranium dissolution
- Nitrate extraction
- ADUN concentration
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- Target fabrication waste
- Target assembly
- LEU storage

Section 4.4.2 provides further detail on the target fabrication system.

[Proprietary Information]

Figure 4-11. Target Fabrication Block Flow Diagram

[Proprietary Information]

Figure 4-12. Target Assembly Diagram

4.1.3.1.2 Target Fabrication Physical Location

The target fabrication area will be located as shown in the area outlined in yellow in Figure 4-13. Additional information on the layout of the equipment and subsystems for the target fabrication system is provided in Section 4.1.4.4.

[Proprietary Information]

Figure 4-13. Target Fabrication Location

4.1.3.1.3 Target Fabrication Process Functions

The primary system functions of the target fabrication system include:

- Storing fresh LEU, LEU target material, and new LEU targets
- Producing LEU target material from fresh and recycled LEU material
- Assembling, loading, and fabricating LEU targets
- Minimizing uranium losses through the target fabrication system

4.1.3.1.4 Target Fabrication Safety Functions

The target fabrication system will perform safety functions that provide protection of on-site and off-site personnel from radiological and other industrial related hazards by:

- Preventing criticality within the target fabrication system
- Preventing flammable gas composition within the target fabrication system
- Limiting personnel exposure to hazardous chemicals and offgases

4.1.3.2 Target Receipt and Disassembly

4.1.3.2.1 Target Receipt and Disassembly Overview

The target receipt and disassembly process will be operated in a batch mode, starting with receipt of a batch of targets inside a shipping cask. The targets will be disassembled one at a time, and the irradiated LEU target material will be transferred to a dissolver. A simplified target receipt and disassembly flow diagram is shown in Figure 4-14.

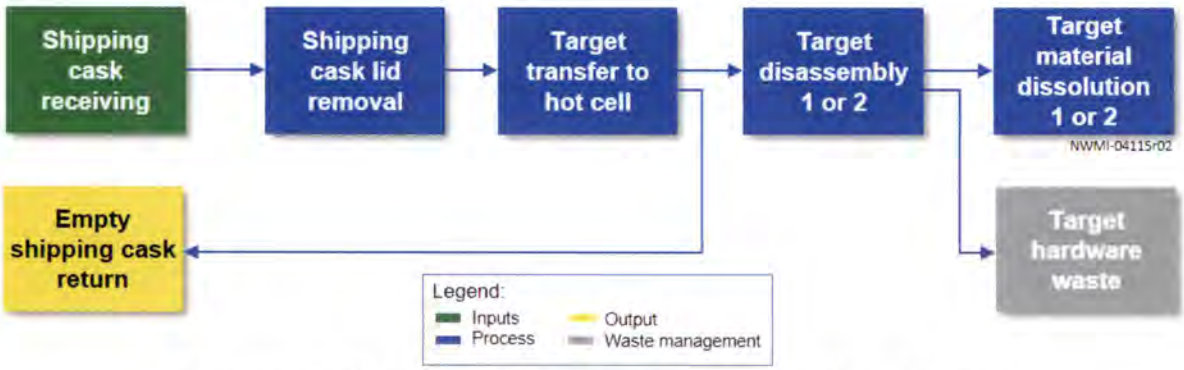

Figure 4-14. Target Receipt and Disassembly System Flow Diagram

The target receipt and disassembly subsystems will include the following:

- Cask receipt
- Target receipt
- Target disassembly 1
- Target disassembly 2

The trailer containing the shipping cask will be positioned in the receipt bay, and the truck will be disconnected from the trailer and exit the facility via the high bay doors in which it entered. The shipping cask will first be checked for radiological contamination prior to further cask unloading activities. Operators will remove the shipping cask's upper impact limiter. The operators will then use the facility overhead crane (TD-L-100) to lift and locate the shipping cask onto the transfer cart. The powered transfer cart will transfer the shipping cask into the cask preparation airlock.

The cask air space will be sampled and the cask lid removal. Operators will raise the cask using the [Proprietary Information] shipping cask lift to the transfer port sealing surface of the target receipt hot cell. The port will be opened and the shielding plug removed. The target basket will be retrieved and placed in one of two basket storage location in the target receipt hot cell.

Two target disassembly stations will be provided. Individual targets will be transferred from the target receipt hot cell into either of the target disassembly hot cell for processing. The targets will be disassembled, and the irradiated target material collected. The target material container will be filled with the contents of the targets and then physically transferred to the dissolver hot cell.

Sections 4.3.2 and 4.3.3 provide further detail on the target receipt and disassembly process.

4.1.3.2.2 Target Receipt and Disassembly Physical Location

The target receipt and disassembly hot cells will be located along the rows of the processing hot cells within the RPF. The target receipt, target disassembly 1, and target disassembly 2 subsystems will be located in the tank hot cell. The subsystem locations are shown in Figure 4-15.

[Proprietary Information]

Figure 4-15. Target Receipt and Disassembly System Facility Location

4.1.3.2.3 Target Receipt and Disassembly Process Functions

The functions of the target receipt and disassembly system include:

- Handling the irradiated target shipping cask, including all opening, closing, and lifting operations
- Retrieving irradiated targets from a shipping cask
- Disassembling targets and retrieving irradiated target material from targets
- Reducing or eliminating the buildup of static electricity wherever target material is handled

4.1.3.2.4 Target Receipt and Disassembly Safety Functions

The target receipt and disassembly system will perform safety functions that provide protection of on-site and off-site personnel from radiological and other industrial related hazards by:

- Providing radiological shielding during target handling
- Preventing inadvertent criticality through inherently safe design of the target receipt and disassembly equipment
- Preventing radiological release during shipping cask and target handling
- Maintaining positive control of radiological materials (irradiated target material and target hardware)
- Protecting personnel and equipment from industrial hazards associated with the system equipment, such as moving parts, high temperatures, and electric shock

4.1.3.3 Target Dissolution

4.1.3.3.1 Target Dissolution Process Overview

The target dissolution hot cell operations will begin with transfer of the collection containers holding irradiated LEU target material from the target disassembly hot cells. A dissolver basket will be filled with the LEU target material and then be lowered into place in the dissolver assembly via the open valve. After loading the dissolver basket into the dissolver assembly, the valves will be closed in preparation for the start of dissolution. The LEU target material will be dissolved in hot nitric acid.

The offgas containing the fission product gases will go through a series of cleanup columns. The NO_x will be removed by a reflux condenser and several NO_x scrubbers, the fission product gases (noble and iodine) captured, and the remaining gas filtered and discharged into the process ventilation header. The dissolver solution will be diluted, cooled, filtered, and pumped to the ^{99}Mo system feed tank. Only one of the two dissolvers is planned to be actively dissolving LEU target material at a time.

A simplified target dissolution diagram is shown in Figure 4-16. The target dissolution subsystems will include the following:

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

[Proprietary Information]

Figure 4-16. Simplified Target Dissolution Process Flow Diagram

Section 4.3.4 provides further detail on the target dissolution system.

4.1.3.3.2 Target Dissolution Physical Location

The target dissolution 1 and target dissolution 2 subsystems will be located along the rows of the processing hot cells within the RPF. The NO_x treatment 1, NO_x treatment 2, pressure relief, primary fission gas treatment, and waste collection subsystems will be located in the tank hot cell. The subsystem locations are shown in Figure 4-17.

[Proprietary Information]

Figure 4-17. Target Dissolution System Facility Location

4.1.3.3.3 Target Dissolution Process Functions

The target dissolution system functions will provide a means to:

- Receive the collection containers holding recovered LEU target material
- Fill the dissolver basket with the LEU target material
- Dissolve the LEU target material within the dissolver basket
- Treat the offgas from the target dissolution system
- Handle and package solid waste created by normal operational activities

4.1.3.3.4 Target Dissolution Safety Functions

The target dissolution system will perform safety functions that provide protection of on-site and off-site personnel from radiological and other industrial related hazards by:

- Providing radiological shielding during target dissolution activities

- Preventing inadvertent criticality through inherently safe design of the target dissolution equipment
- Preventing radiological materials from being released during target dissolution operations to limit the exposure of workers, the public, and environment to radioactive material
- Maintaining positive control of radiological materials (LEU target material and radiological waste)
- Protecting personnel and equipment from industrial hazards associated with the system equipment such as moving parts, high temperatures, and electric shock

4.1.3.4 Molybdenum Recovery and Purification

4.1.3.4.1 Molybdenum Recovery and Purification Process Overview

Acidified dissolver solution from the target dissolution operation will be processed by the Mo recovery and purification system to recover the ^{99}Mo. The Mo recovery and purification process will primarily consist of a series of chemical adjustments and IX columns to remove unwanted isotopes from the Mo product solution. Product solution will be sampled to verify compliance with acceptance criteria after a final chemical adjustment. The product solution will then be placed into shipping containers that are sequentially loaded into shipping casks for transfer to the customer.

Waste solutions from the IX columns will contain the LEU present in the incoming dissolver solution and transferred to the LEU recovery system. The remaining waste solutions will be sent to low-or high-dose waste storage tanks. A simplified Mo recovery and purification diagram is shown in Figure 4-18.

[Proprietary Information]

Figure 4-18. Simplified Molybdenum Recovery and Purification Process Flow Diagram

Mo recovery and purification subsystems will include the following:

- Primary ion exchange
- Secondary ion exchange
- Tertiary ion exchange
- Molybdenum product

Section 4.3.5 provides further detail on the Mo recovery and purification process system.

4.1.3.4.2 Molybdenum Recovery and Purification Physical Location

The primary IX, secondary IX, tertiary IX, and Mo product subsystems will be located in the tank hot cell within the RPF. The subsystem locations are shown in Figure 4-19.

[Proprietary Information]

Figure 4-19. Molybdenum Recovery and Purification System Facility Location

4.1.3.4.3 Molybdenum Recovery and Purification Process Function

The Mo recovery and purification system will provide programmatic system functions, including the following two main functions:

- Recovery of Mo product from a nitric acid solution created from dissolved irradiated uranium targets
- Purification of the recovered Mo product to reach specified purity requirements, followed by shipment of the Mo product

The high-dose nitric acid solution created from dissolved irradiated uranium targets, along with the high-dose Mo product solution, will require that all functions be carried out in a remote environment that includes the containment and confinement of the material.

4.1.3.4.4 Molybdenum Recovery and Purification Safety Functions

The Mo recovery and purification system will perform safety functions that provide protection of on-site and off-site personnel from radiological and other industrial related hazards by:

- Preventing inadvertent criticality through inherently safe design of components that could handle high-uranium content fluid
- Preventing radiological materials from being released by containing the fluids in appropriate tubing, valves, and other components

- Maintaining positive control of radiological materials (^{99}Mo product, intermediate streams, and radiological waste)
- Providing appropriate containers and handling systems to protect personnel from industrial hazards such as chemical exposure (e.g., nitric acid, caustic, etc.)

4.1.3.5 Uranium Recovery and Recycle

4.1.3.5.1 Uranium Recovery and Recycle Process Overview

The U recovery and recycle system will process aqueous LEU solutions generated in the Mo recovery and purification system to separate unwanted radioisotopes from uranium. Uranium will be separated from the unwanted radioisotopes using two IX cycles. A concentrator will be provided for the uranium-bearing solution as part of each IX cycle to adjust the LEU solution uranium concentration. Vent gases from process vessels will be treated by the process vessel vent system prior to merging with the main facility ventilation system and release to the environment. Recycled uranium product is an aqueous LEU solution that will be transferred to the target fabrication system for use as a source to fabricate new reactor targets. Waste generated by the U recovery and recycle system operation will be transferred to the waste handling system for solidification, packaging, and shipping to a disposal site.

A simplified U recovery and recycle diagram is shown in Figure 4-20. The U recovery and recycle subsystems will include the following:

- 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

[Proprietary Information]

Figure 4-20. Simplified Uranium Recovery and Recycle Process Flow Diagram

4.1.3.5.2 Uranium Recovery and Recycle Physical Layout

The U recovery and recycle system equipment will be located in the tank hot cell, as shown in Figure 4-21.

[Proprietary Information]

Figure 4-21. Uranium Recovery and Recycle System Location

4.1.3.5.3 Uranium Recovery and Recycle Process Functions

The U recovery and recycle structures, systems and components (SSC) will be housed within the RPF process facility, and rely on shielding and confinement features of that facility for confinement of radioactive materials, shielding, worker safety, and protection of public safety.

The U recovery and recycle system will provide the following programmatic system functions:

- **Receive and decay impure LEU solution** – This sub-function will collect the aqueous solutions containing U and other radioisotopes from the Mo recovery and purification system and provide a [Proprietary Information] in preparation for the purification process (NWMI-2013-049, Section 3.6.1).
- **Recover and purify impure LEU solution** – This sub-function will separate uranium from unwanted radioisotopes present as other elements in the decayed impure uranium solution (NWMI-2013-049, Section 3.6.2).

- **Decay and recycle LEU solution** – [Proprietary Information] (NWMI-2013-049, Section 3.6.3).
- **Transfer process waste** – This sub-function will provide storage and monitoring of process wastes prior to transfer to the waste handling system.

4.1.3.5.4 Uranium Recovery and Recycle Safety Functions

The U recovery and recycle system will perform safety functions that provide protection of on-site and off-site personnel from radiological and other industrial related hazards by:

- Providing radiological shielding during U recovery and recycle system activities
- Preventing inadvertent criticality through inherently safe design of the U recovery and recycle equipment
- Preventing radiological release during U recovery and recycle system activities
- Controlling and preventing flammable gas from reaching lower flammability limit conditions
- Maintaining positive control of radiological materials
- Protecting personnel and equipment from industrial hazards associated with the system equipment, such as moving parts, high temperatures, and electric shock

4.1.3.6 Waste Handling

4.1.3.6.1 Waste Handling System Process Overview

The waste handling system will consist of three subsystems: (1) liquid waste system, (2) solid waste system, and (3) specialty waste system. The liquid waste system will consist of a group of storage tanks for accumulating waste liquids and adjusting the waste composition. Liquid waste will be split into high-dose and low-dose streams by concentration. The high-dose fraction composition will be adjusted and mixed with adsorbent material in high-integrity containers (HIC), stored, and loaded into a shipping cask for disposal. A portion of the low-dose fraction is expected to be suitable for recycle to selected hot cell systems as process water. Water that is not recycled will be adjusted and then mixed with an adsorbent material in 55-gallon (gal) drums.

The solid waste disposal system will consist of an area for collection, size-reduction, and staging of solid wastes. The solids will be placed in a 208 L (55-gal) waste drum and encapsulated by adding a cement material to fill voids remaining within the drum. Encapsulated waste will be stored until the drums are loaded into a shipping cask and transported to a disposal site.

A specialty waste disposal system will deal with the small quantities of unique wastes generated by other processes. The following are examples of these processes:

- A reclamation process to recycle organic solvent
- [Proprietary Information]
- Operation of a trichloroethylene (TCE) reclamation unit

All waste streams will be containerized, stabilized as appropriate, and shipped offsite for treatment and disposal.

The high-dose and low-dose liquid waste operations are shown in Figure 4-22 and Figure 4-23. Chapter 9, "Auxiliary Systems," Section 9.7 provides details on the waste handling system processes.

[Proprietary Information]

Figure 4-22. High-Dose Liquid Waste Disposition Process

[Proprietary Information]

Figure 4-23. Low-Dose Liquid Waste Disposition Process

4.1.3.6.2 Waste Handling System Physical Layout

The location of the waste handling systems is shown in Figure 4-24 and Figure 4-25. The liquid waste tanks will be located in the tank hot cell, and the waste solidification and container handling activities will take place in the waste management area. This area will include the waste management loading bay, the low-dose waste area, and the HIC storage area in the basement (Chapter 9.0, "Auxiliary Systems," provides additional details).

[Proprietary Information]

Figure 4-24. Waste Handling Locations

The low-dose liquid waste evaporation equipment arrangement located on the mezzanine level is shown in Figure 4-25.

[Proprietary Information]

Figure 4-25. Low-Dose Liquid Waste Evaporation Facility Location

4.1.3.6.3 Waste Handling System Process Functions

The waste handling system will provide the capability for:

- Transferring liquid waste that is divided into high-dose source terms and low-dose source terms to lag storage
- Transferring remotely loaded drums with high-activity solid waste via a solid waste drum transit system to a waste encapsulation area
- Loading drums with low-dose liquid waste
- Loading HICs with high-dose liquid waste
- Solidifying high-dose and low-dose liquid waste drums or containers
- Encapsulating solid waste drums
- Handling and loading a waste shipping cask with radiological waste drums/containers

4.1.3.6.4 Waste Handling Safety Functions

The waste handling system will perform safety functions that provide protection of on-site and off-site personnel from radiological and other industrial related hazards by:

- Maintaining uranium solids and solutions in a non-critical inventory or composition to eliminate the possibility of a criticality
- Preventing spread of contamination to manned areas of the facility that could result in personnel exposure to radioactive materials or toxic chemicals
- Providing shielding, distance, or other means to minimize personnel exposure to penetrating radiation

4.1.4 Facility Description

This subsection describes the RPF construction and functions, beginning with discussions of the general construction and facility ventilation, followed by descriptions of the RPF areas. The RPF will be divided into seven areas with generally different functions, as shown in Figure 4-26.

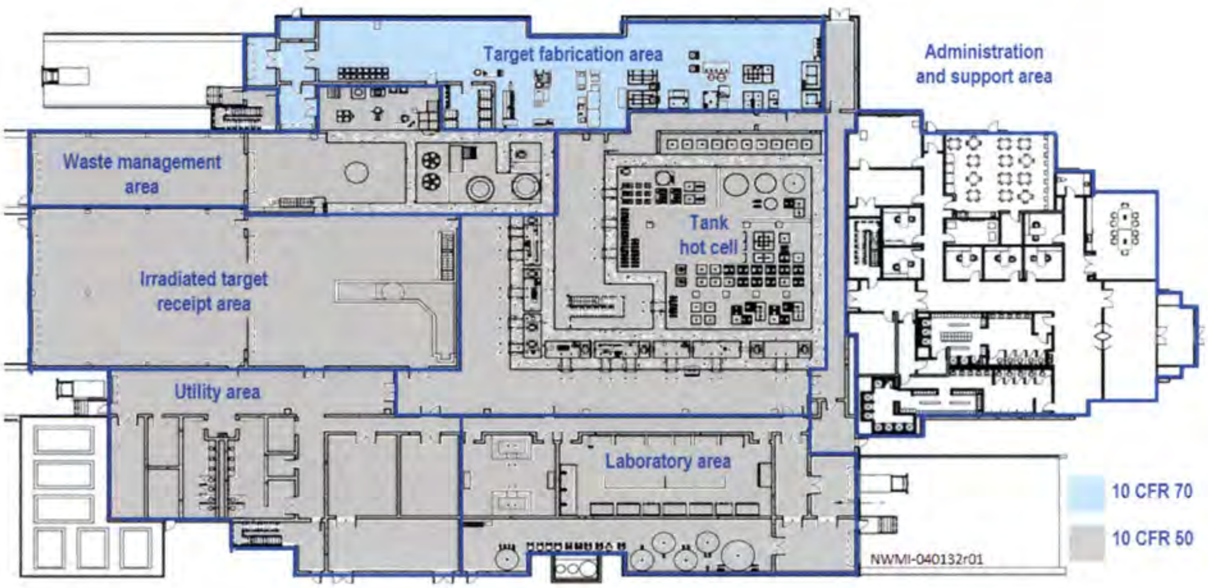

Figure 4-26. Radioisotope Production Facility Areas

Table 4-4 provides a crosswalk of the seven different areas with the primary functions and primary systems.

Table 4-4. Radioisotope Production Facility Area Crosswalk

Area (room designator)	Primary functions	Primary systems	License area
Target fabrication (T)	Fabricate LEU targets	• Target fabrication (TF) • Material handling (MH)	10 CFR 70[a]
Irradiated target receipt bay (R)	Process irradiated LEU targets	• Material handling (MH) • Target receipt and disassembly (TD)	10 CFR 50[b]
Hot cell (H or G[c])	Process irradiated LEU targets	• Target receipt and disassembly (TD) • Target dissolution (DS)	10 CFR 50[b]
	Recover and purify ^{99}Mo product	• Molybdenum recover and purification (MR)	10 CFR 50[b]
	Recover and recycle LEU solution	• Uranium recovery and recycle (UR)	10 CFR 50[b]
	Handle waste	• Waste handling	10 CFR 50[b]
Waste management (W)	Handle waste	• Waste handling (WH) • Material handling (MH)	10 CFR 50[b]
Laboratory (L)	Support systems	• Chemical supply (CS) • Gas supply (GS) • Material handling (MH)	10 CFR 50[b]
Utility (U)	Support systems	• Normal facility electrical power • Process utility systems • Facility ventilation systems	10 CFR 50[b]
Administration and support (S)	Support systems	• Facility process control and communications (FPC) • Fire protection (FP) • Radiation protection • Safeguards and security	N/A

[a] 10 CFR 70, "Domestic Licensing of Special Nuclear Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.
[b] 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.
[c] H indicates a hot cell, G indicates a hot cell operator gallery, or other room that may be occupied.

^{99}Mo = molybdenum-99
LEU = low-enriched uranium.
N/A = not applicable.

4.1.4.1 General Construction

This section describes the facility construction that is not part of the force-resisting systems (described in Chapter 3.0, "Design of Structures, Systems, and Components," Section 3.2) or the fire-rated wall construction (described in Chapter 9.0, Section 9.3).

4.1.4.1.1 Building Envelope

Roofing – The low-slope roofing will be single-ply EPDM (ethylene propylene diene monomer) rubber over a cover board with two layers of polyisocyanurate insulation. This material will provide continuous insulation with an R-value of 25. The entire assembly will be fully adhered to meet design wind-uplift loads. The metal building portion of the roof over the truck receiving bays will be metal standing-seam roofing with R19 batt insulation between purlins, and R11 batt insulation on a vapor barrier liner under the purlins on a linear support system. The insulation liner will be a white, reinforced polypropylene material with a less than 75 flame-spread rating and less than 450 smoke-developed rating.

Wall cladding – The wall cladding system will be insulated metal wall panels attached over sub-girts to the structural backup wall system. The cladding will provide a primary weather barrier and insulation. The backup wall will be treated with a liquid-applied membrane product to provide an air, vapor, and water barrier. The cavity at the top of the wall will be sealed to the roofing system through a transition membrane that will maintain the continuity of the air barrier. Subgrade walls and slab will be treated with continuous waterproofing that will also provide a vapor barrier. The walls will be covered with a drainage medium to relieve hydrostatic pressure and closed-cell insulation to minimize heat loss and protect the waterproofing and drainage medium during placement of backfill.

Windows – Windows will be limited to the administration and support area and the outer walls of the stair towers. Windows will be fixed (non-operable) and designed to resist design wind loads and wind-driven missiles in ASCE 7 *Minimum Design Loads for Buildings and Other Structures*, requirements. A heavy aluminum curtain wall system with thermal break will support the glass. Glass will be insulating units, each comprising a transparent, laminated inner pane, airspace, and outer pane of tinted, low-e coated, heat strengthened, or fully tempered glass.

4.1.4.1.2 Interior Construction

Ceilings – The ceilings in the office, conference, break rooms, locker room, and corridors in the administration and support area will be suspended acoustical panels on a prefinished grid system. Restroom ceilings will be painted gypsum wallboard. Shower ceilings will be ceramic tile on gypsum tile backer. Ceilings in the production areas (e.g., target fabrication, utility, laboratory, waste management, and irradiated target receipt areas) requiring radiation control, decontamination, or cleaning and disinfecting will be gypsum board with a scrubbable resinous finish. Ceilings in the production areas without radiation control or disinfection concerns will be exposed structure with a paint finish.

Partitions – Partitions in the administration and support area will generally be steel stud framing with gypsum wallboard cladding and a commercial-grade paint finish. Partitions in the production areas will be cast-in-place concrete for structural walls and either concrete masonry unit or metal stud walls for internal partitions. Where radiation control or cleaning and disinfecting are required, the finish will consist of gypsum board cladding with resinous paint finish over the backup wall on furring. In wet areas, a high-build resinous finish will be applied directly to the walls.

Floors – In production areas where cleanliness is required, the floor finish will be a trowel-grade, chemical-resistant resinous system with integral cove and wall base. The floor finish in the truck bays and material transport areas will be an industrial, concrete hardener, densifier, sealer system to provide durability against wear and impact, prevent contamination penetration, and provide long-term appearance retention. The floor finish in corridors, utility rooms, and rooms not subject to water or radiological contamination will be sealed concrete.

Doors in high-traffic areas such as restrooms, locker rooms, stairs, and airlock will be fiberglass doors for maximum durability. Other doors exposed to light traffic in the administration and support area will be Level 2 (18-gauge) hollow metal with a durable paint finish. Doors exposed to light traffic in the production area will be Level 3 (16-gauge) galvanized hollow metal with an industrial paint finish. All high-traffic doors to work areas will have vision lights for safety. Door hardware will be Builders Hardware Manufacturers Association (BHMA) Grade 1. Where available, hardware will have a brushed stainless-steel finish for durability and resistance to chemical exposure. Otherwise, the finish will be brushed chrome plate, except closer covers, which will have an aluminum paint finish. High-frequency and security doors will have full-height, continuous geared hinges. Other doors will have mortised, anti-friction hinges, with mortise locksets and rim exit devices. Closers will be adjustable for closing force and size.

4.1.4.2 Site and Facility Access

Vehicular and personnel access to the site and personnel access within the facility will be controlled as part of the physical security requirements. Additional information on the site and facility access is provided in the NWMI RPF Physical Security Plan (Chapter 12.0, "Conduct of Operations," Appendix B).

4.1.4.3 Facility Ventilation

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 III will be the cleanest of the potentially contaminated areas, with each subsequent zone being more contaminated and having lower pressures. Table 4-5 defines the ventilation zone applicable to major spaces.

Table 4-5. 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.

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:

- Zone I exhaust system will service the hot cell, waste loading areas, target fabrication enclosures, and process offgas subsystems in Zone I
- Zone II/III exhaust system will service exhaust flow needs from Zone II and Zone III in excess of the flow cascaded to interior zones
- A laboratory exhaust system will service fume hoods in the laboratory area.

The 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 sampling system will be employed to demonstrate compliance with the stated regulatory requirements for exhaust.

The systems and components of the facility ventilation system are described in Section 9.0, Section 9.1.

The process offgas subsystem will be connected directly to the process vessels and will maintain a negative pressure within the vessels. Process vessel ventilation systems will include a set of subsystems that are specialized to the equipment that the subsystems support. These systems will merge together at the process offgas filter train prior to merging with the Zone I exhaust system. Each process offgas subsystem will treat the process offgas components separately to prevent mixing of waste constituents. The process offgas systems are described in Section 4.2.5.

4.1.4.4 Target Fabrication Area

Target fabrication rooms will contain target fabrication equipment and support the target fabrication system. Material processed by the system will be unirradiated LEU obtained as feed from DOE and recycled LEU from processing irradiated targets. Recycled LEU will be purified in the remote hot cell and transferred as a solution to the target fabrication tanks. Verification measurements on the recycled LEU solutions will confirm that the LEU material can be handled without shielding.

Figure 4-27 illustrates the layout of the target fabrication rooms. The function of each room in the target fabrication area is summarized in Table 4-6.

[Proprietary Information]

Figure 4-27. Target Fabrication Area Layout

Table 4-6. Target Fabrication Area Room Descriptions and Functions (2 pages)

Room no.	Room name	Area (ft^2)	Ventilation zone	Room functions/features
T101	Fresh LEU and unirradiated shipping and receiving	147	IV	• Shipping bay and truck loading dock for unirradiated target shipping • Receiving bay and truck unloading dock for fresh LEU receipt
T103	Target fabrication airlock	139	III	• Separates the Zone IV ventilation of Room T101 and Zone II ventilation of Room T104A
T104A	Target fabrication room	1445	II	• Shipping and receiving area within the target fabrication room • Staging area for incoming and outgoing shipping containers
T104B	Target fabrication room	920	II	• Target assembly activities from [Proprietary Information] through welded LEU target quality checks

Table 4-6. Target Fabrication Area Room Descriptions and Functions (2 pages)

Room no.	Room name	Area (ft²)	Ventilation zone	Room functions/features
T104C	Target fabrication room	1748	II	• [Proprietary Information]
T105	Water entry #2	65	IV	• Fire riser room
[Proprietary Information]	[Proprietary Information]	225	II	• [Proprietary Information] • [Proprietary Information] • [Proprietary Information]

LEU = low-enriched uranium. UO_3 = uranium trioxide.

The target fabrication rooms will include the following.

- **Room T101 (Fresh LEU and unirradiated shipping and receiving)** – Room T101 is the truck loading and unloading dock that will support target fabrication shipping and receiving. The exterior wall material is undefined. The interior walls will be 1- and 2-hr fire-rated partition walls. Fresh uranium will be unloaded in ES-3100 shipping containers by pallet jacks and transported immediately through Room T103 to [Proprietary Information]. Sealed targets will enter the loading dock from Room T103 in ES-3100 shipping containers and immediately be loaded onto the truck.
- **Room T103 (Target fabrication airlock)** – Room T103 is the airlock that will separate the Zone II ventilation of Room T104C from the Zone IV ventilation of Room T101. The walls will consist of concrete shear wall and 1- and 2-hr fire-rated partition walls. Fresh uranium in ES-3100 shipping containers will be transported through the airlock on pallet jacks from Room T101 to Room T104A. Sealed targets in ES-3100 shipping containers will be transported through the airlock on pallet jacks from Room T104A to Room T101.
- **Room T104A (Target fabrication room)** – Room T104A is part of Room T104, and no dividing walls will separate the room from Room T104B. The north wall will be an exterior concrete wall. The west wall and parts of the south wall will be 2-hr fire-rated interior partition walls; the remaining south wall will be an interior partition wall. This room will support shipping and receiving activities, and staging for incoming and outgoing shipping containers. [Proprietary Information]. Room T104C will provide the main personnel access point.
- **Room T104B (Target fabrication room)** – Room T104B is part of Room T104, and no dividing walls will separate the room from Rooms T104A and T104C. The north wall will be an exterior concrete wall, and the south wall will be an interior concrete wall. This room will support target assembly activities from [Proprietary Information] through target quality checks. Other activities within this room will include receipt and disassembly of off-specification targets. Room T104B will open to Rooms T104A and T104C on either side. Room T104C will provide the main personnel access point, and Room T104A will provide the main material access point. [Proprietary Information] will be transferred manually in containers from Room T104C. Finished targets will be transferred to [Proprietary Information] for storage, or Room T104A for packaging in shipping containers.
- **Room T105 (Water entry #2)** – Room T105 is one of two rooms where fire-protection water will enter the RPF. The walls will consist of 1-hr and 2-hr fire-rated interior partitions. The only access to Room T105 will be from the exterior.

- [Proprietary Information]

4.1.4.5 Irradiated Target Receipt Area

The irradiated target receipt area will receive irradiated targets and associated shipping casks loaded on semi-truck trailers. The bay will be designed to operate as a Zone II airspace during target unloading procedures and when the hot cell cover block is removed for maintenance. The 67.8 metric ton (MT) (75-ton) traveling bridge crane will service the target basket receipt bay and the hot cells. The crane will span 15.24 m (50 ft) and a run of 36.58 m (120 ft). The crane will be serviced in this area from a crane platform.

[Proprietary Information]

Figure 4-28. Irradiated Target Receipt Area Layout

Figure 4-28 illustrates the layout for the irradiated target receipt truck bay area. The function of each room in the irradiated target receipt area is summarized in Table 4-7.

Table 4-7. Irradiated Target Receipt Area Room Descriptions and Functions

Room no.	Room name	Area (ft²)	Ventilation zone	Room functions/ features
R011	Cask transfer tunnel	323	III	• Transport of cask from truck trailer to R012
R012	Cask preparation airlock	314	II	• Ventilation confinement from Zone III R011 to Zone I H105/H106 • Cask de-lidding and cask gas sampling
R013	Irradiated target bay stairwell	314	III	• Personnel access/egress
R101A/B	Irradiated target receipt truck bay A and B	3,206	IV	• Truck entry port and truck wash down
R102A/B	Irradiated target receipt bay A and B	3,150	III	• Cask impact limiter removal • Cask impact limiter removal • Move cask to transfer tunnel
R201	Irradiated target receipt mezzanine	TBD	III	• Crane access space

The irradiated target receipt rooms will include the following.

- **Room R011 (Cask transfer tunnel)** – Room R011 is the transfer tunnel that will transport casks to the cask preparation airlock. The walls will consist of concrete shielding and concrete shear wall. Casks will be lowered by crane onto a powered transfer cart, which will transfer the cask to Room R012.
- **Room R012 (Cask preparation airlock)** – Room R012 is the airlock where the cask gas is sampled and the cask lid is removed. The shielding plug will remain in place. The walls will consist of concrete shielding and concrete shear wall. Casks will enter from Room R011 on a powered transfer cart and will be lifted to mate with Rooms H015/H016 in the hot cell area.
- **Room R013 (Irradiated target bay stairwell)** – Room R013 is the stairwell connecting the irradiated target receipt bay (R102A) with the cask transfer tunnel (R011). Room R013 will be open to Rooms R011 and R102A.
- **Room R101A/B (Irradiated target receipt truck bay A and B)** – Rooms R101A and R101B are the truck bays where trucks will enter the facility. The irradiated target receipt truck bays may be in a pre-engineered metal building attached to the concrete shear wall. This truck bay will provide a place to wash down the truck, trailer, or cask as required. Trucks will enter the facility through high bay doors and transport the trailers to Rooms R102A/B through the high bay doors.
- **Room R102A/B (Irradiated target receipt bay A and B)** – Rooms R102A and R102B are the truck bays where casks will be removed from the trailers. The walls in the irradiated target receipt bays will consist of a concrete shear wall, 2-hr fire-rated interior partitions, and a non-fire-rated interior partition to the hot cell operating gallery. The tractor-trailer will enter from Rooms R101A/B, the trailer will be disconnected, and the tractor will then exit to R101A/B during cask unloading operations. The cask impact limiters will be removed, and an overhead crane will transfer the cask to a cart in Room R011.
- **Room R201 (Irradiated target receipt mezzanine)** – Room R201 is the high bay above the hot cell operating gallery. The high bay will provide crane access to the irradiated target receipt bay, maintenance space for the crane, and personnel egress. Room R201 will be open to H201. The walls will consist of concrete shear wall.

4.1.4.6 Hot Cell Area

Irradiated target processing will be performed using equipment that is located in heavily shielded hot cells to protect operating personnel from doses generated by radioactive materials. The hot cells will provide the capability for remote operation and maintenance of the process equipment by features that include shielding windows and in-cell and through-wall manipulators for operation and maintenance of equipment, access via cover blocks and bridge crane to support remote maintenance activities, and equipment (e.g., pumps and valves) that will be remotely operated from outside the hot cell. The hot cells and associated ventilation equipment will also provide containment and confinement for the potential release of radioactive materials from a process vessel during maintenance activities or off-normal operating conditions. The hot cell will have a geometry-favorable sump configuration and HEPA filters on the ventilation inlets and outlets. The hot cell and its galleries will include the following:

- Target receipt, target disassembly, and target dissolution cells
- Mo recovery and purification cells
- LEU recovery and recycle area
- Parts of the waste handling process
- Operating gallery
- Maintenance gallery
- Remote support systems

Figure 4-29 shows the layout of the hot cell area rooms. The function of each room in the hot cell area is summarized in Table 4-8.

[Proprietary Information]

Figure 4-29. Hot Cell Area Layout

Table 4-8. Hot Cell Area Room Descriptions and Functions (2 pages)

Room no.	Room name	Area (ft²)	Ventilation zone	Room functions/features
H013	Uranium decay and accountability vault	240	I	• Uranium lag storage
H014B	Waste collection tanks	-	I	• Bermed area on the floor to contain waste collection tanks within the hot cell area
G101A	Operating gallery – B	769	III	• Manipulators and window –access for hot cells H101, H102 and H103
G101B	Operating gallery – A	1,564	III	• Manipulators and window –access for hot cells H104, H105, H106, H107 and H108
G101C	Operating gallery – C	278	III	• Access to truck bay and maintenance rooms-
G102	Maintenance gallery	1,200	II	• Manipulators and window access to H014A, solid waste ports and solid waste hot cells
G103	Maintenance gallery airlock	339	II	• Airlock between maintenance gallery and corridor L106A
H101	Dissolver 2 hot cell	92	I	• Target dissolution activities
H102	Target disassembly 2 hot cell	77	I	• Target disassembly activities
H103	Target receipt hot cell	81	I	• Transfer of targets from the target transfer port docked to the shipping cask into the target staging rack hot cell

Table 4-8. Hot Cell Area Room Descriptions and Functions (2 pages)

Room no.	Room name	Area (ft²)	Ventilation zone	Room functions/features
H104	Target disassembly 1 hot cell	77	I	• Target disassembly activities
H105	Dissolver 1 hot cell	93	I	• Target dissolution activities
H106	Mo recovery hot cell	61	I	• Mo recovery activities
H107	Mo purification hot cell	79	I	• Mo purification activities
H108	Product and sample hot cell	101	I	• Mo packaging and loading the product shipping container • Sampling and sample load out activities
G201	Hot cell cover block access	-	III	• Cover block access and high bay
G202	Exit passageway	209	III	• Personnel egress

Mo = molybdenum.

The hot cell rooms will include the following.

- **Room H013 (Uranium decay and accountability vault)** – The uranium decay and accountability vault will be for decay storage of uranyl nitrate. The walls will consist of concrete with a steel liner, as described in Section 4.2. Purified uranyl nitrate will be piped from the south wall, and once decayed, will be piped to the target fabrication room through the north wall.
- **Room H014B (Waste collection tank hot cell)** – The waste collection tank hot cell will be open to Room H104A, but a berm will divide the two cells. The walls and berm will consist of concrete with steel liners. Room H014B will contain process equipment associated with liquid waste in the waste handling system.
- **Room G101A/B/C (Operating gallery – A/B/C)** – Room G101 will be the operating gallery for hot cells H101 through H111. The south wall will be a concrete shear wall, and walls dividing the gallery from the hot cells will serve as biological shielding, as described in Section 4.2. Local control stations will be provided in the operating gallery to physically operate remote wall-mounted manipulators and support system operation. Personnel access will be through the access corridor, L108.
- **Room G102 (Maintenance Gallery)** – Room G102 on the back side of the hot cells (H101 to H105) and tank hot cell (H014). The north, south, east, and west wall material will be concrete. The maintenance galleries will include enclosures for repair of contaminated equipment, areas for tool storage, and spare parts storage. G103 will provide the main personnel access point.
- **Room G103 (Maintenance gallery airlock)** – The north and south wall material will be concrete. Corridor L108B will provide the main personnel access point to Room G103.
- **Room H101 (Dissolver 2 hot cell)** – Room H101 wall material will be concrete required for shielding. Rooms G101B and G102A will be adjacent to Room H101. Room H102 will be the hot cell next to Room H102. The Room H101 hot cell area will support the target dissolution process and will house the dissolver.

- **Room H102 (Target disassembly 2 hot cell)** – Room H102 wall material will be concrete required for shielding. Rooms G101B and G102B will be adjacent to Room H102. This hot cell area will support the target disassembly process. The target disassembly station will pick one target at a time from the shipping basket, de-lid the target, and pour target material into a transfer container or funnel and then into the dissolver. The spent target will be inspected to ensure that it is empty, passed through to the waste management area, and disposed of as solid waste. The disassembly stations will be supported with leaded windows and/or cameras and master-slave manipulators.
- **Room H103 (Target receipt hot cell)** – Room H106 wall material will be concrete required for shielding. Rooms G101A and G102B will be adjacent to Room H103. Rooms H102 and H104 will be the hot cells next to Room H103. The Room H103 hot cell area will support target receipt and include a feature that mates with the shielded transfer cask to lower the target basket into the hot cell.
- **Room H104 (Target disassembly 1 hot cell)** – Room H104 wall material will be concrete required for shielding. Rooms G102 and G102B will be adjacent to Room H107. This hot cell area will support the target disassembly process. The disassembly station will pick one target at a time from the shipping basket, de-lid the target, and pour target material into a transfer container or funnel and then into the dissolver. The spent target will be inspected to ensure that it is empty, passed through to the waste management area, and disposed of as solid waste. The disassembly stations will be supported with leaded windows and/or cameras and master-slave manipulators.
- **Room H105 (Dissolver 1 hot cell)** – Room H105 wall material will be concrete required for shielding. Rooms G101A and G102B will be adjacent to Room H105. Rooms H104 and H106 will be the hot cells next to Room H105. The H105 hot cell area will support the target dissolution process and house the dissolver.
- **Room H106 (Mo recovery hot cell)** – Room H106 wall material will be concrete required for shielding. Room G102B will be adjacent to Room H106. Hot cells H105 and H107 will be next to Room H106. The hot cell will include the primary and secondary small IX columns with containers, peristaltic pumps, and collection tanks. Operation of the process will be performed using the hot cell remote manipulators.
- **Room H107 (Mo purification hot cell)** – Room H107 wall material will be concrete required for shielding. Room G102B will be adjacent to Room H107. Hot cells H106 and H108 will be next to Room H107. The cell will include tertiary IX column with containers, peristaltic pumps, and collection tanks. Operation of the process will be performed using the hot cell remote manipulators from Room G102. This area of the hot cell will have design features that support U.S. Food and Drug Administration (FDA) cleanroom requirements.
- **Room H108 (Product and sample hot cell)** – Room H108 wall material will be concrete required for shielding. Room G102B will be adjacent to Room H108, with hot cell H107 next to Room H111. An access point will be included for load-in and load-out of the ^{99}Mo shipping cask.
- **Room G201 (Hot cell cover block access)** – Room G201 will provide crane access to the hot cells and hot cell cover blocks for maintenance. Room G201 will be open to the irradiated target receipt mezzanine (R201). The walls will consist of concrete shear wall.
- **Room G202 (Exit passageway)** – Room G202 will provide personnel egress from the maintenance gallery (G102).

4.1.4.7 Waste Management Area

The waste management area will include shielded enclosures for tanks collecting liquid waste and containers used to stage solid wastes generated by the other process systems. Parts of the waste management system that are dedicated for high-dose liquid waste will be included in the remote hot cell. There will be three shielded areas in the waste management area, including:

- HIC vault, where filled waste containers will be held for several months to allow short-lived radioisotopes to decay to lower doses
- Hot cell solid waste export area, where equipment and empty targets will pass out of the hot cell
- Solidification cell, where liquid waste will be processed or mixed with materials to prepare a low-level waste package for disposal

Solid waste will be moved to the waste loading area where the waste will be loaded into a shipping cask (already on a trailer) to be transported to a disposal site. The waste management area will be serviced by a second bridge crane.

The HIC storage and decay cell zones that are located in the basement of the RPF are shown in Figure 4-30. Figure 4-31 and Figure 4-32 show the waste management loading bay and the ground floor of the waste management area, respectively. Figure 4-33 shows the low-dose liquid solidification rooms within the waste management area.

[Proprietary Information]

Figure 4-30. High-Integrity Container Storage and Decay Cells Layout

[Proprietary Information]

Figure 4-31. Waste Management Loading Bay and Area Layout

[Proprietary Information]

Figure 4-32. Waste Management Area – Ground Floor

[Proprietary Information]

Figure 4-33. Waste Management Area – Low-Dose Waste Solidification Location

The function of each room in the waste management area is summarized in Table 4-9.

Table 4-9. Waste Management Room Descriptions and Functions

Room no.	Room name	Area (ft^2)	Ventilation zone	Room functions/features
W011A/B	HIC vault	1,865	IV	• Decay storage for HICs
W101	Waste management loading bay	1,647	IV	• Truck entry port for waste shipment • Remove upper impact limiter
W102	Waste loading area	1,086	III	• Loading area, where drums of high- and low-dose waste are loaded into cask
W103A/B	High-dose waste handling hot cell	534	II	• Movement of high-dose waste containers by crane
W104	High dose waste treatment hot cell			• Add encapsulation agent to drums • Add high dose liquid and solidification agent to HIC
W105	Stair #3	209	III	• Stairwell in the target fabrication area provides access between the airlock or outdoors and the mechanical/ electrical room in the utility area on the second floor
W106	Waste management airlock	161	III	• Separates the Zone IV ventilation of stairwell and Zone II ventilation of room W107
W107	Low-dose liquid solidification	550	II	• Houses equipment for the low-dose solidification process • Control station for waste handling operations
W201	Stair #3	209	III	• Access between first and second floor

HIC = high-integrity container.

The waste management area rooms will include the following.

- **Room W011 (HIC vault)** – The HIC vault will provide decay storage of high-dose waste. The waste will be packaged in HICs, and a conveyor system will provide for first-in, first-out inventory management. The HIC vault will be below the hot cells, operating gallery, and maintenance gallery. The walls, floor, and ceiling will be shielding concrete, as described in Section 4.2. A single lift will transfer HICs into and out of Room W103.
- **Room W101 (Waste management loading bay)** – Room W101 will provide truck access from outside the RPF to the sub-grade waste loading area. The walls have not been defined and may be part of a pre-engineered metal building. The wall to Room W102 will be a concrete shear wall with a high bay door.
- **Room W102 (Waste loading area)** – Room W102 will house the trailer during cask loading operations. Room W102 will be beneath a portion of Room W103. The loading operations will consist of a crane transporting the HIC into the cask through a telescoping port, which will connect Room W103 to the cask. The walls will consist of concrete shear wall, shielding concrete, and 2-hr fire-rated interior partitions. Bollards or other means will be used to prevent the trailer from contacting the shielding walls.
- **Room W103 (High-dose waste handling hot cell)** – Room W103 will house equipment for the transport of sealed HICs and drums from Room W104. A crane will lift the HIC from the waste transfer drawer and lower the container into the shipping cask. A telescoping port will create a confinement boundary between the hot cell and the shipping cask to minimize radiation exposure. The walls, floor, and ceiling will be shielding concrete, as described in Section 4.2.
- **Room W104 (High dose waste treatment hot cell)** – Room W104 will house the equipment to solidify the high-dose liquid waste in HICs and encapsulate the solid waste in drums.
- **Room W105 (Stair #3)** – Room W105 will be the stairwell connecting Room W106 with Room U201. Walls will consist of concrete shear wall and 2-hr fire-rated interior partitions. Room W105 will provide personnel access to the second floor and egress from the second floor.
- **Room W106 (Waste management airlock)** – Room W106 is the airlock that will separate the Zone II ventilation of the low dose liquid solidification room (W107) from the Zone IV ventilation of the waste management loading bay (W101). The walls will consist of concrete shear wall and 1-hr fire-rated interior partitions. Low-dose waste containers will be transported from Room T101 to Room T104C by pallet jack.
- **Room W107 (Low-dose liquid solidification)** – Room W107 will house equipment for the low-dose waste solidification process. Low-dose 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. Room W107 will also serve as a control room for the high-dose and solid waste hot cell operations. The walls will consist of concrete shear wall and 1- and 2-hr fire-rated interior partitions.
- **Room W201 (Stair #3)** – Room W201 is the second floor of the stairwell that will connect Room W106 with Room U201. Walls will consist of concrete shear wall and 2-hr fire-rated interior partitions. Room W105 will provide personnel access to the second floor and egress from the second floor.

4.1.4.8 Laboratory Area

An on-site analytical laboratory will support production of the ^{99}Mo product and fabrication of targets for irradiation. The target fabrication area will have tools and systems installed to perform local analyses like radiography, helium leak detection, and dimensional analyses. Samples from each batch of purified ^{99}Mo product will be collected, transported to the laboratory, and prepared in the laboratory hot cell space.

Other laboratory features will include the following:

- Hoods and/or gloveboxes to complete sample preparation, waste handling, and standards preparations
- Rooms with specialty instruments, [Proprietary Information]
- Chemical and laboratory supplies storage
- Bench-top systems like balances, pH meters, ion-chromatography, etc.

Figure 4-34 shows the layout of the laboratory area rooms. The function of each room in the laboratory area is presented in Table 4-10.

[Proprietary Information]

Figure 4-34. Laboratory Area Layout

Table 4-10. Laboratory Area Room Descriptions and Functions

Room no.	Room name	Area (ft²)	Ventilation zone	Room functions/features
L101	Receiving	424	I	Allows the flow of material supplies into the facility
L102A/B	Chemical supply	932	III	Storage of chemicals
L103	^{99}Mo product shipping	265	IV	Preparation of ^{99}Mo product for shipping
L104	Shipping airlock	264	III	Separate confinement zones
L105	Analytical laboratory	1694	II	Area for laboratory activities (e.g., sample analysis) with glovebox ventilation 1
L106	R&D hot cell laboratory	724	II	Containment area for R&D with glovebox ventilation Zone 1
L107	Laboratory corridor	694	III	Personnel access/egress
L108	Access corridor	1289	III	Personnel access/egress

^{99}Mo = molybdenum-99. R&D = research and development.

The laboratory rooms will include the following.

- **Room L101 (Receiving)** – Room L101 will be adjacent to Rooms L102, L103, and L104. The north and west walls will be interior concrete walls. The east wall will be an exterior concrete wall with a rollup door access. The south wall will be an exterior concrete wall. Room L101 will support receipt of chemical supplies and materials for the laboratory.
- **Room L102 (Chemical supply)** – The chemical makeup room 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.
- **Room L103 (^{99}Mo product shipping)** – Room L103 will support shipping and receiving activities, and the staging of outgoing shipping containers
- **Room L104 (Shipping airlock)** – Room L104 will have a 1-hr fire-rated partition wall adjacent to Rooms L105 and L107.
- **Room L105 (Analytical laboratory)** – Room L105 will have a 1-hr fire-rated partition wall adjacent to Room L107. The analytical laboratory will support production of the ^{99}Mo product and fabrication of targets.
- **Room L106 (R&D hot cell)** – Room L106 will have a 1-hr fire-rated partition wall adjacent to Rooms L105 and L107.
- **Room L107 (Laboratory corridor)** – Room L107 will be adjacent to Rooms L104, L105, and L106. The interior wall will be a 2-hr fire-rated partition wall adjacent to operating gallery A (G102). The interior wall will be a 1-hr fire-rated partition wall adjacent to Rooms L104 and L105. Room L107 will provide a main personnel access point.
- **Room L108 (Access corridor)** – Room L108 will provide access from the administration and support area to the production areas. The walls will consist of concrete shear wall and fire-rated interior partitions.

4.1.4.9 Chemical Makeup Room

The chemical makeup room 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. The gas distribution room (not shown) will serve as a location for storage of small quantity gases (stored in gas cylinders) and distribution manifolds.

Large quantities of gases will be stored outside the RPF in appropriate storage tanks or trailers. These areas will be designed to segregate incompatible chemicals. Figure 4-34 shows the layout of the chemical makeup room. Further detail for chemical supply system is provided in Chapter 9.0, Section 9.7.4.

4.1.4.10 Utility Area

A mechanical/electrical room will be located on the second floor over a corridor and portion of the target fabrication and waste management area rooms. The mechanical/electrical room will be the location of electrical systems, motor control centers, pumps, boilers, air compressors, and ventilation supply equipment.

The utility area will provide support functions and include space for maintenance, parts storage, mechanical and electrical utility equipment, and ventilation handling equipment. The utility area will include parts of the ground floor and second floor. The heating, ventilation, and air-conditioning (HVAC) chillers will be located outside the facility, in the same area as the process chilled water chillers.

Figure 4-35, Figure 4-36, and Figure 4-37 show the layout of the utility area, second floor mechanical/electrical room, and mechanical area, respectively.

[Proprietary Information]

Figure 4-35. First Floor Utility Area

[Proprietary Information]

Figure 4-36. Second Floor Mechanical and Electrical Room

[Proprietary Information]

Figure 4-37. Second Floor Mechanical Area

The function of each room in the utility area is summarized in Table 4-11.

Table 4-11. Utility Area Room Descriptions and Functions

Room no.	Room name	Area (ft^2)	Ventilation zone	Room functions/features
U101	Electrical	698	IV	• Facility power supply
U102	Manipulator maintenance	473	II	• Perform maintenance on manipulators
U103	Maintenance shop	567	III	• Perform maintenance on equipment
U104	Stair #2	297	IV	• Personnel access/egress
U105	Corridor	227	IV	• Personnel access/egress
U106	Janitor	111	IV	• Storage
U107	Elevator machine room	60	IV	• Houses equipment for elevator operation
U108	Freight elevator	96	IV	• Moves equipment and supplies to/from second floor
U109	Utility area loading	1,487	IV	• Equipment receipt • Personnel access/egress
U110	Men's restroom	350	IV	• Personal hygiene
U111	Women's restroom	314	IV	• Personal hygiene
U112	Water entry #1	158	IV	• Fire-protection water
U113	Communications room	157	IV	• Houses communication equipment
U114	Process equipment and parts storage	342	IV	• Storage area for spare process equipment
U201	Electrical and mechanical supply	6,320	III	• Housing for electrical and mechanical utility equipment • Housing for supply air handling units
U202	Corridor	566	III	• Personnel access/egress
U203	Ventilation exhaust	8,616	II	• Housing for Zone I and Zone II/III Exhaust filter housings • Housing for process offgas final treatment

The utility area rooms will include the following.

- **Room U101 (Electrical)** – Room U101 will be the electrical service entrance room. The south wall will be a concrete exterior wall, and the other walls will be interior partition walls. The main electrical supply will enter the RPF at this room. Equipment within the room will include transformers, switchgear, and the automatic transfer switch for the diesel generator. Room U102 will provide the main personnel access point.
- **Room U102 (Manipulator maintenance shop)** – Room U102 will be a manipulator maintenance shop. The walls will be 1-hr fire-rated and non-fire-rated interior partitions. This room will provide space for manipulator maintenance activities. Personnel access will be from the building exterior.
- **Room U103 (Maintenance shop)** – Room U103 will be a maintenance shop. The north wall will be a 1-hr fire-rated interior partition, and the other walls will be non-fire-rated interior partition walls. This room will provide general space for maintenance activities, including maintenance of process equipment. Personnel access will be provided through corridor L107.

- **Room U104 (Stair #2)** – Room U104 will be a stairwell providing access to the second floor ventilation exhaust room (U203). Interior walls will be 2-hr fire-rated interior partitions. This room will have an exterior door for emergency egress. Personnel access will be through Corridor U105.
- **Room U105 (Corridor)** – Corridor U105 will provide personnel access to and egress from rooms. Walls will consist of concrete shear wall and 1-hr fire-rated interior partitions. Personnel access will be through corridor L107.
- **Room U106 (Janitor)** – Room U106 will be a janitor storage area. Walls will consist of fire-rated and non-fire-rated interior partitions and a concrete shear wall. Personnel access will be through Corridor U105.
- **Room U107 (Elevator machine room)** – Room U107 will provide space for elevator machinery. Walls will consist of concrete shear wall and 1-hr fire-rated interior partitions. Personnel access will be through Corridor U105.
- **Room U108 (Freight elevator)** – Room U108 will be the freight elevator. Walls will consist of concrete shear wall and 1-hr fire-rated interior partitions. Personnel access will be through Corridor U105.
- **Room U109 (Utility area loading)** – Room U109 will be a loading area for general shipping and receiving, including utility and process equipment. The room will also provide personnel access and egress to utility area and hot cell area rooms. Equipment will be brought in through a roll-up door at the loading dock. Walls will consist of concrete shear walls and 1- and 2-hr fire-rated walls.
- **Room U110 (Men's restroom)** – Room U110 will be the men's restroom. Walls will mainly be non-fire-rated interior partitions.
- **Room U111 (Women's restroom)** – Room U111 will be the women's restroom. Walls will mainly be non-fire-rated interior partitions.
- **Room U112 (Water entry #1)** – Room U112 will be one of two rooms where fire-protection water enters the RPF. The walls will consist of 1- and 2-hr fire-rated interior partitions. The only access to Room U112 will be from the exterior.
- **Room U113 (Communications room)** – Room U113 will house communications equipment. Walls will mainly be non-fire-rated interior partitions.
- **Room U114 (Process equipment storage)** – Room U114 will provide space for process equipment storage. Walls will mainly be non-fire-rated interior partitions.
- **Room U201 (Mechanical/electrical supply)** – Room U201 will provide space for the majority of the utility supply equipment. The room will be located on the second floor above the target fabrication area. The equipment in Room U201 will include supply air handling units, process boilers, air compressors, low-dose waste tanks, a demineralized water supply tank, heat exchangers, and motor control centers. Walls surrounding Room U201 will be concrete shear walls.
- **Room U202 (Corridor)** – Corridor U202 will provide personnel access and egress to Rooms U201 and U203. Room U202 will be above access corridor L108. Walls surrounding Room U202 will be 2-hr fire-rated interior partitions and 3-hr fire-rated concrete shear walls.

- **Room U203 (Ventilation exhaust)** – Room U203 will provide space for the Zone I, Zone II/III, laboratory and process offgas exhaust systems. The room will be located on the second floor above the utility and laboratory areas. The equipment in Room U203 will include blowers, filter housings, shielded offgas carbon beds, and high-efficiency gas adsorbers for the final process offgas treatment. Walls surrounding this room will be concrete shear walls.

Utilities External to Radioisotope Production Facility

The process and HVAC chillers will be located in a mechanical yard on the southwest side of the RPF, as shown in Figure 4-4. The chillers will be adjacent to the facility in an area enclosed by screen wall.

4.1.4.11 Administration and Support Area

[Proprietary Information]

Figure 4-38. Administration and Support Area Layout

The administration and support area will be an annex to the RPF and include various rooms supporting production. The general construction of the administration and support area will be gypsum wallboard mounted on metal studs for interior walls, and curtain or storefront walls on the exterior. The wall separating the administration area from the production areas will be a 3-hr fire-rated interior partition.

The function of each room in the administration and support area is summarized in Table 4-12. Figure 4-38 shows the layout of the administration and support area rooms.

Control Room

The control room will provide the majority of interfaces for the overall basic process control system, monitoring, and process alarms and acknowledgement for the facility. The control room will consist of a control console with two or three operator interface stations or human-machine interfaces (one being a dedicated engineering interface), a master programmable logic controller or distributed controller, and all related and necessary cabinetry and subcomponents (e.g., input/output boards, gateways, Ethernet switches, power supplies, uninterruptable power supply). 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. Details of the control room are provided in Chapter 7.0, "Instrumentation and Control Systems."

The control room door into the facility will be equipped with controlled access, as described in the NWMI RPF Physical Security Plan (Chapter 12, Appendix B).

Table 4-12. Administration and Support Area Room Descriptions and Functions

Room no.	Room name	Area (ft^2)	Ventilation zone	Room functions/ features
S101	Vestibule	225	IV	Personnel access/egress
S102	Entry	637	IV	Personnel access/egress
S103	Entry hall	1,033	IV	Personnel access/egress
S104	Corridor	1,033	IV	Personnel access/egress
S105	Women's change room	284	IV	Personnel area for changing clothes
S105A	Vestibule	46	IV	Personnel access/egress
S106	Women's restroom	281	IV	Personnel hygiene
S106A	Vestibule	38	IV	Personnel access/egress
S107	Men's restroom	426	IV	Personnel hygiene
S108	Men's change room hall	49	IV	Personnel access/egress
S109	Men's change room	199	IV	Personnel area for changing clothes
S110	Men's shower	164	IV	Shower enclosure
S112	Decontamination room	253	IV	Area to remove contamination
S113	Hall	94	IV	Personnel access/egress
S114	Airlock	193	IV	Personnel access/egress
S115	RCT office	119	IV	Functional RCT workspace
S116	Shift manager office	148	IV	Functional workspace
S117	Stair #1	200	IV	Personnel access/egress
S118	Closet	30	IV	Storage
S118A	Server room	267	IV	Space devoted to computer servers
S119	Control room	366	IV	Provides the majority of interfaces for the RPF process control system
S120	Corridor	275	IV	Personnel access/egress
S120A	Vestibule	36	IV	Personnel access/egress
S121	Break room	858	IV	Personnel lunch room
S122	Communications/electrical	134	IV	Housing for electrical utility equipment
S123	Office #4	121	IV	Functional workspace
S124	Janitor	70	IV	Storage
S125	Office #3	126	IV	Functional workspace
S126	Office #1	124	IV	Functional workspace
S127	Office #2	127	IV	Functional workspace
S128	Restroom	72	IV	Personnel hygiene
S129	Hall	192	IV	Personnel access/egress
S130	Conference room	598	IV	Workspace area for meetings

RCT = radiological control technician. RPF = Radioisotope Production Facility.

4.2 RADIOISOTOPE PRODUCTION FACILITY BIOLOGICAL SHIELD

4.2.1 Introduction

4.2.1.1 Biological Shield Functions

The RPF biological shield will provide an integrated system of features that protect workers from the high-dose radiation generated during the radioisotope processing to recover ^{99}Mo. The primary function of the biological shield will be to reduce the radiation dose rates and accumulated doses in occupied areas to not exceed the limits of 10 CFR 20, "Standards for Protection Against Radiation," and the guidelines of the facility ALARA (as low as reasonably achievable) program. The shielding and its components will withstand seismic and other concurrent loads, while maintaining containment and shielding during a design basis event (DBE).

Functions of the biological shield, as related to the RPF process systems, are described in Section 4.2.3.4.

4.2.1.2 Physical Layout of Biological Shield

The biological shield, located in the hot cell area, is shown in Figure 4-39. Hot cell arrangement within the biological shield is shown in Figure 4-40.

[Proprietary Information]

Figure 4-39. Facility Location of Biological Shield

[Proprietary Information]

Figure 4-40. Hot Cell Arrangement

4.2.1.2.1 Location of Hot Cell Appurtenances

The number and location of hot cell appurtenances (e.g., windows, manipulators, and optics) will be developed for the Operating License Application. The hot cell appurtenances are described in Sections 4.2.2.3 through 4.2.2.6.

4.2.2 Shielding Design

The radiation shield is designed consistent with standards found acceptable for construction of radiation shielding structures specified in U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.69, *Concrete Radiation Shields and Generic Shield Testing for Nuclear Power Plants*, to the extent that the recommended standards apply to a composite (concrete and steel) shield.

The design of the concrete for shielding structures, including materials selection, durability requirements, quality control (QC), mixing, placement, formwork, embedded pipes, construction joints, reinforcement, analysis, and design, conforms to the provisions outlined in Chapters 3 through 8 of American Concrete Institute (ACI) 349, *Code Requirements for Nuclear Safety-Related Concrete Structures*.

The final minimum thickness of a concrete shield structure is the greater of the: (1) thickness determined based on radiation shielding requirements, and (2) thickness determined based on structural requirements.

4.2.2.1 Shielding Materials of Construction

The RPF biological shield will be constructed primarily of steel-reinforced normal (2.2 to 2.4 g/cubic centimeter [cm^3]) and high-density (2.5 to 4.5 g/cm^3) concrete walls. In areas where shielding requirements are higher than the nominal average, steel cladding will be used to increase the radiation shielding.

4.2.2.1.1 Nuclear Properties of Shielding Materials

The nuclear properties of shielding materials are dictated by the fundamental cross-sections measured or otherwise established for a given nuclide. These cross-sections are used by computer codes to calculate interaction probabilities for both neutrons and photons. When used, the cross-section libraries used will be specifically identified.

4.2.2.2 Structural Integrity of Shielding

4.2.2.2.1 Evaluation of Shielding Structural Integrity

The bioshield will be designed and constructed using applicable structural and construction standards.

4.2.2.2.2 Effects of Radiation on Structural Materials

The effects of radiation on structural materials in the RPF were not quantified during preliminary design. ANS 6.4-2006, *Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants*, provides the following guidance that will be used to evaluate the effects of radiation on structural materials:

- ***Section 5.4*** – *"In the design of a concrete radiation shield, it is necessary that the temperature and temperature distribution throughout the shield be calculated prior to construction. In addition to radiation heating sources, these calculations must include detailed consideration of other heat sources and sinks. Although structural considerations are outside the scope of this standard, the shield designer should be aware that thermal changes resulting from the radiation environment may affect the ability of concrete to meet its structural requirements."*
- ***Section 8.1.1*** – *"The operating temperature of the concrete should be considered in the selection of concrete mixtures and in the prediction of the attenuation characteristics."*

  "When neutrons and gamma rays interact with concrete, energy is deposited in the concrete. The resultant increase in temperature is the primary radiation effect that has been found. For incident energy fluxes < 10^{10} megaelectron volt (MeV)/square centimeter (cm^2)/second (sec), a negligible temperature rise takes place in concrete. In addition, if concrete temperatures are to be maintained below 65 C, no special consideration needs to be given to temperature effects in concrete shields."
- ***Section 8.1.2*** – *"A major consideration of heating of concrete shields is the impact on the structural characteristics. Laboratory experiments clearly indicate that the mechanical properties of concrete are related to temperature. Compressive strength is reduced as the temperature of concrete is increased, and even greater relative losses in tensile strength, modulus of elasticity, and bond strength have been noted. The thermal properties of concrete are also known to be influenced by the type of aggregate employed. In the design of a concrete radiation shield, structural considerations are paramount in those cases where the shield also serves a necessary and vital structural role. This would be the case, for example, if the shield wall also provided a containment barrier in addition to forming an integral part of the building structure. In some instances, the structural characteristics of a concrete shield might not be important; concrete's dual role as shield and structure, however, is usually an important feature."*

[Proprietary Information]. This heat load is comparable to the heat generated by the lighting within the hot cells. Therefore, excessive heat to the level at which concrete is affected by temperature is not considered a credible situation and will not affect the structural integrity.

4.2.2.3 Design of Penetrations

The penetrations provided for ventilation, piping, construction detail, shield plugs, personnel entryways, and viewports in biological shield structures will reduce the shielding effectiveness. The magnitude of the reduced effectiveness will depend on geometry, material composition, and source characteristics. Each penetration in a shield will be evaluated for its impact on the effectiveness of the shield in which it is located. Penetrations are designed with offsets and steps to prevent direct streaming of radiation through the penetration.

4.2.2.4 Design of Material Entry and Exit Ports

[Proprietary Information]

Figure 4-41. Hot Cell Target Transfer Port

Material entry and exit ports are designed to provide safe and efficient transfer of process and routine maintenance materials into and out of the hot cell confinement boundary without breaking confinement. Material entry and exit ports are designed to maintain radiation shielding to protect the worker from high-dose radiation at all times during the transfer process. Workers will be stationed behind secondary shield walls or otherwise in a radiologically safe position during entry or exit port opening activities to prevent accidental exposure. Radiation monitoring devices will be placed near the entry and exit ports to alarm workers of a radiation leak within the entry or exit port cold side area.

- The target transfer port (TD-TP-210, TD-TP-220) in the target receipt hot cell (H103) is an adaptation of a double-door transfer system typically used with 55-gal drums. The system will use a double-door-type sealing concept. The BRR shipping cask lift (TD-L-110, TD-L-120) will position the cask in proper alignment with the port using the sensors and control system. A powered drive will operate the port door after the cask is properly positioned. Once the port is opened, the cask shield plug may be removed to access and retrieve the irradiated targets. Figure 4-41 provides details of the target transfer port in the target receipt hot cell.

- Cell-to-cell transfer doors will be provided for the movement of small items from a hot cell workstation to an adjacent hot cell workstation as required by process and maintenance activities. Doors may be interlocked as required by administrative safety controls and operating procedures.
- Waste drum transfer ports will be provided in some hot cell workstations. The waste drum transfer port will be a double-door transfer system that enables safe and efficient transfer of waste items out of the hot cell without breaking containment. The drum transfer cart will position the drum in proper alignment with the port using the sensors and control system. A powered-drive system will engage the port door with the drum's containment lid and open the port.
- The product transfer port (MR-TP-400) and sample transfer port (MR-TP-410) in the product and sample hot cell (H108) are an adaptation of a double-door transfer system typically used with 55-gal drums. The system will use a double-door-type sealing concept that will enable safe and efficient transfer of packaged product and process samples out of the hot cell. The Mo product container lift will position the cask in proper alignment with the port using sensors and a control system. A powered-drive will operate the port door after the cask is properly positioned. Once the port is opened, the cask can be de-lidded for package loading.
- The waste shipping transfer port, shown in Figure 4-42, will be located in the high-dose waste handling hot cell and include a port door (cover) that will be removed by crane during waste shipping cask loading and unloading activities. A telescoping shield sleeve (curtain) will provide radiation shielding between the shield wall of the hot cell and the cask.

[Proprietary Information]

Figure 4-42. Waste Shipping Transfer Port

4.2.2.5 Design of Operator Interfaces

Operator interfaces will include the following.

- Through-wall manipulators will be provided throughout the biological shield where activities requiring high dexterity are performed, including normal operation and periodic maintenance. Manipulator type and position will be determined through analysis of the reach envelopes, capacity, and interface requirements at each workstation, and operator ergonomics. A typical through-wall manipulator workstation is shown in Figure 4-43.

[Proprietary Information]

Figure 4-43. Manipulators and Shield Windows

- The biological shield will be fitted with windows at workstations to provide operators with direct visibility of the activities being performed. Each radiation shielding window will provide adequate radiation shielding for the radiation source in the respective cell. The attenuation of the window will be matched to the attenuation of the hot cell wall.

4.2.2.6 Design of Other Interfaces

Cover blocks, shown in Figure 4-44, will be positioned throughout the biological shield and provide access to the hot cells and vaults to facilitate major maintenance activities and facility decommissioning.

[Proprietary Information]

Figure 4-44. Cover Block Configuration

4.2.3 Methods and Assumptions for Shielding Calculations

The shielding analysis demonstrates that the production facility will comply with the regulatory requirements of 10 CFR 20. The intent of the shielding design is to limit the dose rate for the highest source term to 5 millirem (mrem)/hr at 30 centimeters (cm) from the most accessible the surface. Assuming an individual is working at this location for 200 hr/year, this will limit the total dose equivalent received to 1 roentgen equivalent in man (rem), which is half of the preliminary NWMI ALARA annual dose equivalent limit of 2 rem.

To evaluate the necessary shielding required to maintain these limits, a series of photon-spectrum source terms were generated for the following primary locations or process streams:

- Hot cell (dissolution) wall and window
- Target fabrication incoming material
- Offgas treatment
- High-dose waste container

Each of these process streams represents the expected maximum inventory for a given location requiring a bioshield within the RPF. A source term was estimated for each system based on the highest estimated radioactive material content entering the RPF and moving through each system, as designed at the minimum expected time from the end of irradiation. This source term was used to generate a photon energy spectrum indicative of the radioactive material inventory at a given time, which was then used by the particle transport code to estimate the thickness of the shielding material needed.

4.2.3.1 Initial Source Term

[Proprietary Information]. The NWMI LEU targets, described in Section 4.4.2.9.3, will be used regardless of the reactor at which the irradiation occurs. Because MURR has the [Proprietary Information] reactors providing irradiation services for NWMI [Proprietary Information].

[Proprietary Information] The SCALE package of neutronics and depletion codes was used to perform the calculation. Specifically, a two-dimensional model of the OSTR was created in SCALE using TRITON, the depletion was calculated with NEWT, and the output was formatted with OPUS.

The OSTR core was modeled in a configuration similar to the existing core configuration. [Proprietary Information]. The TRITON model consists of an x-y slice of the active core at approximately mid-height. The model only included the core, the graphite reflector assembly, and surrounding water. While composed of several different materials, the graphite assembly was simplified in the model to only be an aluminum-clad structured filled with graphite. Smear densities were created for each fuel element by smearing the fuel meat together with a central zirconium pin. Smear densities were created for each target by smearing [Proprietary Information] with the inner and outer cladding. [Proprietary Information]. Dimensions, locations, and number densities for the fuel elements were taken from the OSTR safety analysis report. Dimensional values of the targets were taken from the target drawings. The calculations using this model were run with the ENDF/B-V 44 group library (v5-44).

The TRITON model was used to calculate the relative distribution of fuel and target power for a designated irradiation (called "burn" in SCALE) [Proprietary Information] in the OSTR. Knowing the reactor power for the fuel, the power results were normalized. Based on the 89 fuel elements in the core and a reactor power of 980 kilowatt (kW) (reduction of 2 percent from licensed power to account for uncertainty in measured power [Proprietary Information].

Calculations were performed to predict the mass (g), activity (Ci), and decay heat power (W) before irradiation, at EOI, and at specific points in time following irradiation for the targets. The top 400 isotopes in order of importance at each requested decay (cooling) interval were provided. Because this code package was originally intended to perform depletion calculations for commercial power reactor fuel and a two-dimensional model was used to model the OSTR core, output of OPUS produces units of gram (or curies or watts) MT heavy metal/cm.

To convert this to more useful units, the output was multiplied by [Proprietary Information] (unit conversion) by [Proprietary Information] (the height of the fuel meat in each fuel element), and then by [Proprietary Information] (SCALE normalizing factor) and further divided by [Proprietary Information] (the number of targets in the model) to produce average target values in units of grams, curies, or watts, as applicable.

Finally, a power correction was applied. The output of the calculation does not represent a core that could be configured to meet the technical specifications of the OSTR because the total power exceeds the license limit. However, because the production of isotopes is largely going to be a function of the target power, this calculation was useful to predict the quantity of isotopes based on the distribution of isotopes identified by SCALE at the identified power. The average power per target predicted by the SCALE modeling was estimated to be [Proprietary Information]. Other work using the Monte Carlo N-Particle (MCNP) simulation on the OSTR and MURR reactors estimated prototypical target powers to be [Proprietary Information].

The photon source strength for the NWMI shielding analysis was determined based on the activity associated with [Proprietary Information] for different process streams and initial decay times because the MURR irradiated targets will present the highest source term. Photon source spectra are computed based on the associated radioisotope inventories for each process stream. The ORIGEN-S code was then used to evaluate the source photon spectra at the indicated minimum decay time and at subsequent decay times for each process stream. Photon spectra were evaluated using a 19 energy group structure that was based on the SCALE V7 27N19G gamma library. A suitable bremsstrahlung master photon library was employed to capture the effects of bremsstrahlung radiation production associated with beta decay processes in the process streams. For the preliminary safety analysis phase of the NWMI project, photon source terms were generated for the processes associated with the targets, pencil tanks, carbon bed absorber, waste containers, and hot cell walls. The generated photon source terms were then incorporated into the Monte Carlo transport models for analysis.

4.2.3.2 Shield Wall Material Composition

Except as noted below, material compositions for shielding walls were obtained from the SCALE Standard Composition Library. The SCALE Reg-Concrete composition at 2.3 g/cm^3 was used for the concrete material description. This represented density is conservatively lower than those listed for ordinary concretes in Table 1 of ANSI/ANS-6.4, *Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants*.

The lead-glass composition is based on the composition for glass code RWB46 offered by Radiation Protection Products, Inc. Relevant models employing leaded glass report results in both thickness and areal density. The areal density results are not sensitive to the particular leaded glass composition and were used to determine the required thickness for alternative leaded glass compositions.

The compositions and number densities of [Proprietary Information] were obtained using the SCALE Material Information Processor solution model.

The solidified high-dose waste stream is represented based on masses for water, solidifying agent, and sodium nitrite. No other constituents are credited.

Table 4-13 lists materials used in the analysis, along with nominal densities. Number densities are provided in NWMI-2015-SHIELD-001, *Radioisotope Production Facility Shielding Analysis*.

Table 4-13. Master Material List

Material	Description	Density (g/cm^3)
Air	Dry air	1.2929E-03
Poly	Polyethylene	9.2000E-01
Water	H_2O	1.0000E+00
SS304	Scale SCL SS304	7.9400E+00
Concrete	Scale SCL Reg-Concrete	2.3000E+00
Target material	Target material [Proprietary Information]	[Proprietary Information]
CarbonSteel	Scale SCL carbon steel	7.8212E+00
Aluminum	Scale SCL aluminum	2.7020E+00
LeadGlass	Leaded glass (48% Pb, 15% Ba)	4.8000E+00
UNSol150	[Proprietary Information]	[Proprietary Information]
GAC	Granular activated carbon	[Proprietary Information]
Hdsolid	Solidified high-dose waste	[Proprietary Information]
Ldsolid	Solidified low-dose waste	[Proprietary Information]

Source: NWMI-2015-SHIELD-001, *Radioisotope Production Facility Shielding Analysis*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

Ba	= barium.	UN	= uranyl nitrate.
Pb	= lead.	[Proprietary Information]	
U	= uranium.		

4.2.3.3 Methods of Calculating Dose Rates

A number of methods have been developed to calculate the penetration of neutrons and photons through material. For the RPF, a Monte Carlo simulation is used to track particles through the shielding. The Monte Carlo calculation simulates the penetration of radiation by compiling the life histories of individual particles that move about from the point where they enter the shield to the point where they are either absorbed in the shield or pass through it. The shielding methodology used for analysis of the RPF is consistent with standard industry practice and consists of source term generation, Monte Carlo transport model development, variance reduction technique application, and tally setup.

The Monte Carlo transport code MCNP6 version 1.0, developed by Los Alamos National Laboratory, was used to transport photons through the shield material and to determine a subsequent dose rate to the worker and the public. MCNP is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron, photon, and electron transport. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and fourth-degree elliptical tori. Pointwise cross-section data typically are used, although group-wise data are also available. For photons, the code accounts for incoherent and coherent scattering, the possibility of fluorescent emission after photoelectric absorption, absorption in pair production with local emission of annihilation radiation, and bremsstrahlung. Important standard features that make MCNP very versatile and easy to use include a powerful general source, criticality source, and surface source; both geometry and output tally plotters; a rich collection of variance reduction techniques; a flexible tally structure; and an extensive collection of cross-section data. MCNP contains numerous flexible tallies: surface current and flux, volume flux (track length), point or ring detectors, particle heating, fission heating, pulse height tally for energy or charge deposition, mesh tallies, and radiography tallies.

The number of particles that successfully penetrate the shield divided by the total number of histories is an estimate of the probability that a particle will not be stopped by the shield. For complicated geometries or excessively thick shields, the probability that a particle will not be stopped by the shield is so low that statistically meaningful results for such events would require large numbers of particle histories such that the computer run times would for all practical purposes approach infinity. Variance reduction techniques are used in Monte Carlo analysis to reduce the excessively long run times for simulation of such rare events to practical magnitudes.

Variance reduction techniques include geometry splitting and Russian roulette, energy splitting and Russian roulette, exponential transform, implicit capture and weight cutoff, energy weight windows, and next event estimator.

The next event estimator was used for the simpler geometries modeled for the RPF, including the targets, pencil tanks, carbon bed absorber, high-dose waste container, and low-dose waste container. For the hot cell walls, the deep penetration through the thick concrete requires a bit more sophisticated variance reduction technique. Therefore, energy-dependent, mesh-based weight windows were used to accelerate the simulation of particle transport through the hot cell walls.

Tallies were used to score particles when they emerge from the shield material and form the basis for the results reported in any shielding or dose assessment. For the RPF, the tally was recorded as energy-dependent particle flux. To obtain meaningful results, the energy-dependent particle flux was convolved with a response function of interest. The response function used for the NWMI calculations was the International Commission on Radiation Protection (ICRP) 1974 photon flux-to-dose conversion factors.

For the NWMI target analysis, ring detector tallies are placed at the surface, 1 m, 2 m, 3 m, and 4 m from the target material axial midpoint [Proprietary Information]. For the NWMI pencil tank analysis, point-and-ring detector tallies were placed at the tank content axial midpoint, at the surface, and at 1 m, 2 m, 3 m, and 4 m. The response functions for the pencil tank were normalized to the number of batches represented in the model. [Proprietary Information].

For the carbon bed absorber analysis, point detector and ring detector tallies were placed near the surface and at 1 m, 2 m, 3 m, and 4 m from the tank at the axial mid-plane [Proprietary Information]. For the waste container analysis, point detector tallies were placed at the surface and 1 m, 2 m, 3 m, and 4 m from the container content axial midpoint [Proprietary Information]. For the hot cell wall analysis, detector tallies were placed at the source location and distributed along the –X direction at the exterior surface and at distances 1 m, 2 m, 3 m, and 4 m away. In addition, detector tallies were included through the wall at the inside position, the material interface, and at the midpoints of each composite material. Due to the variations in wall thickness, the hot cell wall analysis did not employ dose rate response functions. Instead, direct calculations were made for each case.

4.2.3.4 Geometries

The geometries for each of the five process streams modeled using MCNP.

4.2.3.4.1 Target Geometry

The NWMI target model dimensions are based on reference drawing OSTR-MO-100, "Molybdenum Production Project." Materials employed in the model are shown Table 4-14. Number densities for each material are provided in NWMI-2015-SHIELD-001.

Table 4-14. Target Model Materials

Model material	Master material	Density (g/cm³)
Void	[Proprietary Information]	[Proprietary Information]
Target	[Proprietary Information]	[Proprietary Information]
Cladding	[Proprietary Information]	[Proprietary Information]
End fitting	[Proprietary Information]	[Proprietary Information]
Bottom washer	[Proprietary Information]	[Proprietary Information]
Top washer	[Proprietary Information]	[Proprietary Information]
Ambient	[Proprietary Information]	[Proprietary Information]

Source: NWMI-2015-SHIELD-001, *Radioisotope Production Facility Shielding Analysis*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[Proprietary Information]

4.2.3.4.2 Pencil Tank Geometry

The models for a 5-inch (in.) Schedule 40S pencil tank were developed based on the data shown in Table 4-15. The tank diameter and wall thickness were taken from standard industry American Society of Mechanical Engineers (ASME) references. Other dimensions were assumed based on engineering judgement.

The tank contents were represented [Proprietary Information]. Tank walls are modeled as SS304. Number densities for each material are provided in NWMI-2015-SHIELD-001.

Table 4-15 Pencil Tank Model Data

Description	Reference	Dimension (in.)
Outer diameter	ANSI/ASME 36.19M[a] Schedule 40S	[Proprietary Information]
Tank wall thickness	ANSI/ASME 36.19M[a] Schedule 40S	[Proprietary Information]
Tank height	Assumed	[Proprietary Information]
Floor thickness	Assumed	[Proprietary Information]
Roof thickness	Assumed	[Proprietary Information]
Floor offset	Assumed	[Proprietary Information]
Roof offset	Assumed	[Proprietary Information]

Source: NWMI-2015-SHIELD-001, *Radioisotope Production Facility Shielding Analysis*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[a] ANSI/ASME 36.19M, *Stainless Steel Pipe*, American Society of Mechanical Engineers, 4th Edition, New York, New York, 2015.

4.2.3.4.3 Offgas Carbon Bed Geometry

The geometry for the offgas carbon bed was similar to the pencil tank model, but a nominal [Proprietary Information] Schedule 40S pipe was used instead, and the tank content was granular activated carbon at [Proprietary Information]. The dimensions used for the model are shown in Table 4-16. Number densities for each material are provided in NWMI-2015-SHIELD-001.

Table 4-16 Carbon Bed Model Geometric Parameters

Description	Reference	Dimension (in.)
Outer diameter	ANSI/ASME 36.19M[a] Schedule 40S	[Proprietary Information]
Tank wall thickness	ANSI/ASME 36.19M[a] Schedule 40S	[Proprietary Information]
Tank height	Assumed	[Proprietary Information]
Tank separation	Assumed	[Proprietary Information]
Shield wall thickness	Assumed	[Proprietary Information]

[a] ANSI/ASME 36.19M, *Stainless Steel Pipe, American Society of Mechanical Engineers*, 4th Edition, New York, New York, 2015.

4.2.3.4.4 Waste Container Geometries

Waste container models are developed based on the geometric and material data shown in Table 4-17. The high-dose waste container contents are based on streams W0015 (Hdsolid, high-dose solidified waste). Number densities for each material are provided in NWMI-2015-SHIELD-001. The solidifying agent is assumed to be sodium montmorillonite. For the high-dose waste, the sorbent, water, and sodium nitrite were considered.

Table 4-17. Waste Container Geometric Data

Container	Reference	Outer diameter (ft)	Outer height (ft)	Fill height (ft)	Wall thickness (in.)	Tank materia l	Content volume (L)
High-dose waste	C-003-001456-007,[a] Note 8	5.4583	6.2292	5.8914	0.5	Poly	3785

[a] C-003-001456-007, "Poly HIC CRM Flat Bottom Liner," Rev. 3, Energy*Solutions*, Columbia, South Carolina.

4.2.3.4.5 Hot Cell Wall Geometry

The RPF shield wall model was based on the layout of the dissolution hot cell. The results are not sensitive to the precise hot cell configuration since tallies are taken through the wall at a location directly adjacent to a point source representation of the irradiated target source.

The primary bioshield walls of the dissolution hot cell were modeled as a composite of an inner stainless-steel wall and an outer concrete wall. For the composite wall analysis, windows were not represented in the model, and the tally locations were conservatively placed directly adjacent the source. To evaluate the hot cell window, the primary bioshield wall was replaced with a composite of leaded glass window and air.

The composite wall materials and thicknesses were parameterized in the model, with values varied to determine the required wall composition to meet an external surface dose rate limit of 0.5 mrem/hr.

Materials used in the model are shown in Table 4-18 for the steel/concrete composite wall analysis. For the window analysis, model material "CompWall1" was set to LeadGlass and "CompWall2" was set to Air. Number densities for each material are provided in NWMI-2015-SHIELD-001.

Table 4-18. Material Assignment for Steel/Concrete Composite Wall Model

Model material	Master material	Density (g/cm^3)
Void	Void	[Proprietary Information]
Ambient	Air	[Proprietary Information]
Wall	Concrete	[Proprietary Information]
Window	LeadGlass	[Proprietary Information]
CellWall	SS304	[Proprietary Information]
Ground	Concrete	[Proprietary Information]
Outside	Air	[Proprietary Information]
WindowWell	Air	[Proprietary Information]
CompWall1	CarbonSteel	[Proprietary Information]
CompWall2	Concrete	[Proprietary Information]
Floor	Concrete	[Proprietary Information]

4.2.3.4.6 Expected Dose Equivalent Rates in Air

To understand the hazards associated with the radioactive material inventory, an estimate of the dose equivalent rate was calculated with MCNP, based on the source spectrums generated from ORIGEN-S for each of the five configurations.

4.2.3.4.7 Irradiated Target Estimated Dose Equivalent Rate in Air

Using the initial target source term from MURR and the methodology described above, the dose equivalent rate for a target in air was calculated as a function of time and distance from the target. Table 4-19 and Figure 4-45 present the results of this calculation for a single target. The earliest time after the EOI was chosen to be [Proprietary Information], which is considered the earliest conservable time after EOI that a target shipment could be received by the RPF from a shipment originating from MURR. Substantial shielding will be required to handle the irradiated targets.

Table 4-19. Dose Equivalent Rate from an Irradiated Target as a Function of Time at Various Distances in Air

Time after irradiation	Dose equivalent rate at surface (rem/hr)	Dose equivalent rate at 1 m (rem/hr)	Dose equivalent rate at 2 m (rem/hr)	Dose equivalent rate at 3 m (rem/hr)	Dose equivalent rate at 4m (rem/hr)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[Proprietary Information]

Figure 4-45. Dose Equivalent Rate from an Irradiated Target as a Function of Time

4.2.3.4.8 Recycled Uranium to Target Fabrication Estimated Dose Equivalent Rate in Air

The material received into the target fabrication area will be a purified uranium solution with a concentration of [Proprietary Information]. This time period will allow sufficient time for the [Proprietary Information]. This material will be fed into a 5-in. diameter pencil tank described previously. Results of the estimated dose equivalent rate as a function of time post-EOI and distance in air are given in Table 4-20. There are two primary observations from the results [Proprietary Information].

Table 4-20. Target Fabrication Incoming Process Stream Dose Rates

Time after irradiation (week)	Dose equivalent rate at surface (mrem/hr)	Dose equivalent rate at 1 m (mrem/hr)	Dose equivalent rate at 2 m (mrem/hr)	Dose equivalent rate at 3 m (mrem/hr)	Dose equivalent rate at 4m (mrem/hr)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

4.2.3.4.9 Secondary Carbon Adsorbers Estimated Dose Equivalent Rate in Air

The dose equivalent rate off of the dissolver offgas secondary carbon bed is of interest because its function is to delay (i.e., create decay time) the release of the halogen and noble gases by collecting the offgas effluent over time. Table 4-21 shows the weekly average and cumulative dose equivalent rates for the carbon bed assuming a weekly deposition of offgas. Due to rapid decay of the retained radioisotopes, the cumulative dose rate from the carbon bed soon reaches a limiting value after approximately [Proprietary Information].

Table 4-21. Carbon Bed Model Dose Rate Results

Time after irradiation (weeks)	Average weekly dose equivalent rate (rem/hr)	Cumulative dose equivalent rate (rem/hr)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

4.2.3.4.10 High-Dose Waste Container Estimated Dose Equivalent Rate in Air

Each high-dose waste container will hold high-activity waste generated [Proprietary Information].

Results of the bounding estimated dose equivalent rate from a high-dose waste container as a function of time post-EOI and the distance in air are listed in Table 4-22.

Table 4-22. High-Dose Waste Container Bounding Dose Equivalent Rates

Time after irradiation (weeks)	Dose equivalent rate at surface (rem/hr)	Dose equivalent rate at 1 m (rem/hr)	Dose equivalent rate at 2 m (rem/hr)	Dose equivalent rate at 3 m (rem/hr)	Dose equivalent rate at 4 m (rem/hr)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

4.2.3.5 Estimated Hot Cell Wall Thickness

Based on the source terms identified above, the most important shielding consideration will be the thickness of the primary bioshield wall surrounding the hot cells. While not yet determined, the final composition of the hot cell wall will likely be a combination (composite) of both steel and concrete. For the composite wall analysis, a base case was defined as a [Proprietary Information]. MCNP was then used to estimate the dose equivalent rate on the other side of the wall.

The calculated dose equivalent rate through the composite wall is shown in Figure 4-46.

[Proprietary Information]

Figure 4-46. Dose Equivalent Rate Variation through Base Case 120 Centimeter (4-Foot) Composite Wall

The linearity of the logarithmic transform of dose equivalent rate with thickness exhibited in Figure 4-46 suggests that the dose rate variation can be characterized by determining the exponential coefficients λ_1 and λ_2 describing the dose rate decay through the steel and concrete walls, respectively.

For each region $i = 1,2$, the dose rate variation through region i is modeled as:

$$d(x) = d_{i-1} \exp[-\lambda_i(x - x_{i-1})] \text{ for } x_{i-1} < x \le x_i \quad \text{Equation 4-1}$$

Where

$d_{i-1} = d(x_{i-1}) =$ Dose rate at source-side boundary of region i

$x_0 = 0$ is the inside surface of the composite wall

To determine the exponential coefficients λ_1 and λ_2, a series of three cases was executed with a fixed total wall thickness of [Proprietary Information]. The exponential coefficient λ_1 was then determined by an exponential fit to the calculated dose rate at the extent of the steel wall $d(x_1)$. The fitted value for λ_1 was estimated to be [Proprietary Information].

To determine λ_2, Equation 4-1 is first rearranged as follows:

$$\lambda_2 = \frac{\ln(d_0) - \ln(d_2) - \lambda_1 x_1}{x_2 - x_1} \quad \text{Equation 4-2}$$

An estimate of λ_2 is obtained for each of the three cases, as shown in Table 4-23, and the average of the three is taken as the best estimate.

Table 4-23. Estimation of Coefficient λ_2

x_1	x_2	λ_1	d_0	d_2	λ_2
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Average					[Proprietary Information]

Solving Equation 4-2 for x_1 and setting the through-wall dose rate d_2 to 0.5 mrem/hr, an expression for the required steel wall thickness as a function of the total wall thickness x_2 is obtained:

$$x_1 = \frac{\ln(d_0) - \ln(d_2) - \lambda_2 x_2}{\lambda_1 - \lambda_2} \qquad \text{Equation 4-3}$$

Using Equation 4-3, the required steel thickness to shield the design basis source term for various total wall thicknesses is shown in Table 4-24.

Table 4-24. Required Steel Thickness in Composite Wall for Various Total Wall Thicknesses

Total shield thickness		Steel		Concrete	
(m)	(ft)	(cm)	(in.)	(cm)	(in.)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

For the base case [Proprietary Information], the exterior dose equivalent rates are shown in Table 4-25 for various steel wall thicknesses.

Table 4-25. Exterior Dose Rates for 120 Centimeter (4-Feet) Total Wall Thickness and Various Steel Thicknesses

Steel thickness (cm)	Areal Density (g/cm^2)	Dose equivalent rate at surface (mrem/hr)	Dose equivalent rate at 1 m (mrem/hr)	Dose equivalent rate at 2 m (mrem/hr)	Dose equivalent rate at 3 m (mrem/hr)	Dose equivalent rate at 4 m (mrem/hr)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

While the final hot cell wall thickness and composition has not yet been determined, the results in Table 4-25 indicate that a wall thickness of [Proprietary Information] can accomplish the goal of minimizing the external wall dose rates to 0.5 mrem/hr, significantly below the 5 mrem/hr goal. This also represents the thickness required for the largest source term. Using the same methodology, the shield wall thickness surrounding the smaller source terms described above is anticipated to be proportionally smaller for the final facility design.

4.2.3.6 Estimated Minimum Hot Cell Window Thickness

To analyze the hot cell window thickness needed, the entire hot cell wall was assumed to be made entirely from leaded glass. The wall thickness was varied to determine the required thickness to meet an exterior surface dose rate of 0.5 mrem/hr. Table 4-26 lists the dose rate results for a series of four cases with varying window thicknesses. The results suggest that the required window thickness is [Proprietary Information] with an associated areal density of [Proprietary Information]. If the lead glass composition varies from the composition analyzed here, the same shielding effectiveness can be achieved by ensuring that the window has the same required areal density.

Table 4-26. Estimated Dose Equivalent Rates on the Outside of the Hot Cell Window

Window thickness (cm)	Areal density (g/cm^2)	Dose equivalent rate at surface (mrem/hr)	Dose equivalent rate at 1 m (mrem/hr)	Dose equivalent rate at 2 m (mrem/hr)	Dose equivalent rate at 3 m (mrem/hr)	Dose equivalent rate at 4 m (mrem/hr)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

4.2.4 Calculated Dose Equivalent Rates and Shield Thickness Requirements

The shielding boundary provides shielding for workers and the public during normal operations to reduce worker exposure to an average of 0.5 mrem/hr, or less, in all normally accessible workstations and occupied areas outside of the hot cell. All penetrations will be designed with offset bends or with a labyrinth configuration such that streaming will not occur. In all cases, the shielding thickness required to create a work environment within the limits and parameters found in 10 CFR 20 can be achieved.

4.2.5 Ventilation Systems for the Biological Shield Structure

Summary of Ventilation Systems for the Biological Shield Structure

The ventilation around the biological shield structure will be Zone II/III supply and the Zone I exhaust. The biological shielding will be subjected to ambient temperature conditions. The Zone I exhaust will provide ventilation of the hot cell and confinement of the hot cell atmosphere, and maintain the hot cell at negative pressure. The supply air will maintain the temperature for personnel comfort. The process offgas treatment system will provide confinement of the chemical vapors from the process equipment within the hot cell and treat the radioactive offgases through retention, adsorption, and filtration.

The facility ventilation system, including the Zone I exhaust and the process vessel ventilation, is described in Chapter 9.0, Section 9.1.

4.3 RADIOISOTOPE EXTRACTION SYSTEM

This section describes the radioisotope extraction process from the time irradiated targets enter the RPF through the ^{99}Mo product shipment. The radioisotope extraction processes will include the major systems listed in Table 4-27, which are described in this section.

Table 4-27. Radioisotope Extraction Systems

System name	Section
Irradiated target receipt and disassembly (irradiated target receipt subsystem)	4.3.2
Irradiated target receipt and disassembly (target disassembly subsystem)	4.3.3
Target dissolution	4.3.4
Molybdenum recovery and purification	4.3.5

4.3.1 Extraction Time Cycle

NWMI-2015-RPT-007, *Process Time-Cycle Analysis Report (Part 50 License)*, was developed to evaluate the time-cycle of the radioisotope extraction process. Results of the evaluation are based on the operating logic and activity durations used as inputs. The time-cycle evaluation presented is based on the current inputs for receiving MURR targets. The sequence is described below and summarized in Figure 4-47.

Irradiated target receipt – Irradiated targets are transported between the reactor and RPF in a cask and received at the RPF no sooner than [Proprietary Information]. The weekly receipt of irradiated targets from a reactor is assumed to be transported [Proprietary Information]. The receipt activities from cask receipt to transfer to target disassembly, which are described in detail in Section 4.3.2, [Proprietary Information] of the first transfer cask to avoid delaying target disassembly and dissolution activities.

Target disassembly – Once the targets are transferred to the disassembly hot cells, the targets will be disassembled and the target material collected. The time for disassembly activities, described in Section 4.3.3, will be [Proprietary Information].

Target dissolution – The target dissolution sequence, described in Section 4.3.4, will begin with preparation activities lasting [Proprietary Information] of the target dissolution process will last [Proprietary Information], from the end of target disassembly to the time the solution is transferred to the Mo recovery and purification system. [Proprietary Information].

Mo recovery and purification – The Mo recovery and purification sequence will begin with three ion-exchange separation steps, lasting [Proprietary Information]. A sample of the recovered and purified ^{99}Mo solution will be transferred to a sample container, and the container then transferred to the analytical laboratory for testing, which lasts [Proprietary Information] including transfer time. The transfer of product solution to the product containers is [Proprietary Information]. Loading the product container into the shipping cask and preparing for shipment takes [Proprietary Information].

The activities of the [Proprietary Information]. The relationship and overlap of activities from irradiated target receipt through product shipment is shown in Figure 4-47. [Proprietary Information].

[Proprietary Information]

Figure 4-47. Extraction Time Cycle

4.3.2 Irradiated Target Receipt

Irradiated target receipt will include movement of the cask from the truck, receipt inspection activities, and introduction of the irradiated targets into the target receipt hot cell (H103). The system description also includes content required in NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, Chapter 4.

4.3.2.1 Design Basis

The irradiated target receipt subsystem will receive irradiated target shipping casks and transfer the irradiated targets to the hot cell for disassembly. The design basis for this subsystem is to:

- Receive irradiated targets in casks per the cask certificate of compliance
- Provide the capability to complete gas sampling of the cask
- Provide a bridge crane for irradiated target cask handling
- Provide appropriate space for removal of the impact limiters, etc.
- Provide a transfer system to move the cask and/or targets from the truck port to a hot cell
- Meet ALARA principles during target transfer activities

4.3.2.2 System Description

The irradiated target receipt system description provides information regarding the process, process equipment, SNM and radioactive inventories, and the hazardous chemicals used in the system. The process descriptions (Sections 0 and 4.3.2.2.2) provide a detailed account of the SNM in process during normal operations and provide the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.3.2.2.3 and 4.3.2.2.4. These sections describe the equipment in sufficient detail to provide confidence that the SNM and byproduct material can be controlled throughout the process. A description of the SNM in terms of physical and chemical form, volume in process, required criticality control features, and radioactive inventory in process is provided in Sections 4.3.2.2.5 and 4.3.2.2.6. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.3.2.2.7.

These descriptions provide a detailed account of the SNM in process during the cask receipt activities. The SNM, along with any included fission-product radioactivity, is described in Sections 4.3.2.2.5 and 4.3.2.2.6. Based on this description, these operations can be conducted safely in the NWMI RPF.

4.3.2.2.1 Cask Receipt Process Description

A simplified operational flow diagram for the cask receipt subsystem is shown in Figure 4-48.

[Proprietary Information]

Figure 4-48. Cask Receipt Subsystem Flow Diagram

The subsystem activities will begin with the arrival of the truck and lowboy trailer with the shipping cask containing the irradiated targets. The truck, trailer, and shipping cask will enter the NWMI RPF via an exterior facility high bay door. The truck, trailer, and shipping cask will enter the facility in one of the irradiated target receipt bays (Figure 4-49 and Figure 4-50). The shipping cask will then be documented for material tracking and accountability requirements. Operators will use the truck bay overhead spray wand for any necessary wash-down of the truck, trailer, or shipping cask while located in the irradiated target receipt truck bays. The truck, trailer, and shipping cask will then enter the irradiated target receipt bay via a high bay door.

[Proprietary Information]

Figure 4-49. Irradiated Target Handling Equipment Arrangement Plan View

[Proprietary Information]

Figure 4-50. Irradiated Target Handling Equipment Arrangement Isometric View

The trailer containing the shipping cask will be positioned between impact limiter removal platform 1A (TD-MP-100) and impact limiter removal platform 1B (TD-MP-110), if entering from the irradiated target receipt truck bay A. The trailer containing the shipping cask will be positioned between impact limiter removal platform 2A (TD-MP-120) and impact limiter removal platform 2B (TD-MP-130), if entering from the irradiated target receipt truck bay B. The truck will be disconnected from the trailer and exit the facility via the high bay doors in which it entered. All high bay doors will be verified to be closed before proceeding with the cask unloading activities.

The shipping cask will first be checked for radiological contamination prior to further cask unloading activities. Operators will remove the shipping cask's upper impact limiter using the impact limiter removal platforms (TD-MP-100, TD-MP-110, TD-MP-120, and TD-MP-130) and facility overhead crane (MH-L-100). The upper impact limiter will then be located in the designated impact limiter landing zone and secured. The facility process control and communications system will be used to notify operators in the operating gallery that the BRR shipping cask transfer cart (TD-MC-100) is in position and ready for shipping cask loading. The operators will then use the facility overhead crane (TD-L-100) to lift and locate the shipping cask onto the transfer cart. The powered transfer cart will transfer the shipping cask to the cask preparation airlock.

Before the cask enters the cask preparation airlock, operators will be in position, having entered the airlock through the main entry door. The material transfer cart rail switch will be positioned to direct the cart to the desired BRR shipping cask lift (TD-L-110, TD-L-120) located beneath a target transfer port (TD-TP-210, TD-TP-220). Once the area is prepared, operators will open the airlock entry door. The powered BRR shipping cask transfer cart will move along the cart rails to the park position on the [Proprietary Information] lift. The airlock entry door will then be closed, with the cask in position and ready for preparation for hot cell transfer.

A gas sampling device connected to the cask vent port will analyze the headspace in the cask. Following verification that there is no contamination in the gas sample, the cavity will be vented to the atmosphere to equalize pressure. The cask de-lidding backdraft hood (TD-EN-100) will be used for added protection and remain on throughout the cask lid removal and hot cell docking steps. Hoist rings will be installed in the closure lid, and the lid-retaining screws removed while monitoring for any release of radiation. The closure lid will be removed using the lid hoist (TD-L-130) and placed on the closure lid stand. The cask sealing surface protector, shield plug restraint, and remote handling adapter will then be installed. Once the cask is prepared, operators will use a human-machine interface to raise the cask using the BRR shipping cask lift (TD-L-110, TD-L-120) to the transfer port sealing surface. Position indicators will signal when the cask's face is at the determined seal compression height.

Following the target receipt activities (described in Section 4.3.2.2.2), the transfer cart will move the empty shipping cask to the loading/unloading area. The operators will then use the facility overhead crane (TD-L-100) to lift and locate the shipping cask onto the trailer and replace the cask's upper impact limiter.

The truck will enter the RPF via an exterior facility high bay door in either irradiated target receipt truck bay A or irradiated target receipt truck bay B, depending on which station the trailer and shipping cask are in. Operators will use the truck bay overhead spray wand for any necessary wash-down of the truck while located in the irradiated target receipt truck bays. The truck will then enter the irradiated target receipt bay via a high bay door, connect to the trailer, and exit to the irradiated target receipt truck bay. The shipping cask will then be documented for material tracking and accountability requirements. The truck, trailer, and shipping cask will exit the facility via the high bay doors in which it entered.

4.3.2.2.2 Target Receipt Process Description

When the cask is in position and ready for target transfer into the target receipt hot cell (TD-EN-200), the target transfer port (TD-TP-210, TD-TP-220) will be opened to access the cask shield plug. Using the target receipt hoist (TD-L-200) and the remote handling adapter, the shield plug will be removed and placed on a shield plug stand. Using the target receipt hoist (TD-L-200), the targets will be removed from the cask and placed in the target staging rack. When all targets are removed from the cask and placed in the target staging rack, the cask shield plug will be repositioned in the cask by the target receipt hoist (TD-L-200) and the target transfer port (TD-TP-210, TD-TP-220) will be closed.

When the cask is ready for removal, the BRR shipping cask lift (TD-L-110, TD-L-120) will be lowered. The cask de-lidding backdraft hood (TD-EN-100) will provide added protection while operators survey and decontaminate the cask lid area. The shield plug remote handling adapter, restraint, and sealing surface protector will be removed and decontaminated for reuse. The lid hoist (TD-L-130) will be used to install the cask closure lid, the retaining screws installed and torqued, and the vent port plug installed. The lid area will again be surveyed and decontaminated, as required. The powered [Proprietary Information] transfer cart will move the empty cask out of the airlock to its park position in the cask transfer tunnel, and the airlock door closed.

The above description provides a detailed account of the SNM in process during the target receipt activities. The SNM, along with any included fission-product radioactivity, is described in Sections 4.3.2.2.5 and 4.3.2.2.6. Based on this description, these operations can be conducted safely in this facility.

4.3.2.2.3 Process Equipment Arrangement

The cask preparation airlock, shown in Figure 4-51, will be located under the operating gallery between the shipping cask truck bay and the hot cell. The [Proprietary Information] transfer cart will move the casks into and out of the cask preparation airlock.

[Proprietary Information]

Figure 4-51. Cask Preparation Airlock

The equipment arrangement within the cask preparation airlock is shown in Figure 4-52.

[Proprietary Information]

Figure 4-52. Cask Preparation Airlock Equipment Arrangement

The equipment arrangement within the target receipt hot cell (H102) is shown in Figure 4-53. Casks will be lifted to mate with the target transfer port (TD-TP-210 and TE-TP-220), where the lid hoist (TD-L-310) opens the port. The target receipt hoist (TD-L-200) will remove the irradiated targets from the casks, and targets will be moved by manipulators through the transfer doors to target disassembly hot cells.

4.3.2.2.4 Process Equipment Design

During irradiated target receipt activities, the irradiated target material will remain within the targets, and the targets will remain within the shielded shipping cask. Section 4.4.2.9.3 provides a description of the target. The shipping container license describes the shipping cask.

Auxiliary equipment will be used to remove the cask impact limiters, move the cask, and mate the cask to the port on the hot cell. This equipment is listed in Table 4-28.

[Proprietary Information]

Figure 4-53. Target Receipt Hot Cell Equipment Arrangement

Table 4-28. Irradiated Target Receipt Auxiliary Equipment

Equipment name	Equipment no.
Impact limiter removal platform 1A	TD-MP-100
Impact limiter removal platform 1B	TD-MP-110
Impact limiter removal platform 2A	TD-MP-120
Impact limiter removal platform 2B	TD-MP-130
Facility overhead crane	TD-L-100
[Proprietary Information] transfer cart	TD-MC-100
Cask de-lidding backdraft hood	TD-EN-110
[Proprietary Information] lift	TD-L-110
[Proprietary Information] lift	TD-L-120
Lid hoist	TD-L-130
Target receipt hoist	TD-L-200
Target transfer port	TD-TP-210
Target transfer port	TD-TP-220

[Proprietary Information]

4.3.2.2.5 Special Nuclear Material Description

Special Nuclear Material Inventory

The SNM inventory within the irradiated target receipt system will be determined by the number of targets received by cask shipments in each operating week. The total SNM inventory within the target receipt system will be bounded by the number of targets in the maximum weekly cask shipments. [Proprietary Information].

Table 4-29 summarizes the irradiated target receipt in-process SNM inventory. The target receipt SNM inventory is planned to be [Proprietary Information] (Section 4.3.1). As cask receipt through target disassembly activities are performed, the irradiated target receipt system SNM inventory will be bounded by [Proprietary Information].

Table 4-29. Irradiated Target Receipt In-Process Special Nuclear Material Inventory

Stream	Form	Concentration[a]	SNM mass[a]
Irradiated targets	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U).

LEU = low-enriched uranium.
N/A = not applicable.
SNM = special nuclear material.
[Proprietary Information]

NWMI-2015-CSE-001, *NWMI Preliminary Criticality Safety Evaluation: Irradiated Target Handling and Disassembly*, describes criticality safety evaluations (CSE) of the irradiated target receipt system performed during preliminary design. Normal operations in the irradiated target receipt cell are intended to be unmoderated. Single parameter limits for uranium containing 20 wt% ^{235}U indicate that an unmoderated, but [Proprietary Information] at theoretical density remains subcritical. Licensing documentation for the [Proprietary Information] indicates that a single shipping basket with all positions filled [Proprietary Information]. However, the current double-contingency analysis in NWMI-2015-CSE-001 imposes a limit of [Proprietary Information]. Further evaluation of the irradiated target receipt area criticality controls will be performed and included in the Operating License Application.

Criticality Control Features

Criticality control features are required in this system, as defined in NWMI-2015-CSE-001. This evaluation covers handling of the targets beginning with their removal from their shipping casks. The criticality control features, including passive design features and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, "Engineered Safety Features," Section 6.3. The administrative controls and technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0, "Technical Specifications."

The criticality control features for this subsystem, including passive design features and administrative controls with designators of PDF and AC, respectively, are listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features will include:

- Exclusion of liquid lines (CSE-01-PDF1)
- Geometry requirements of the basket holding wells within the hot cell (CSE-01-PDF2)

The administrative controls will include:

- Limited movement to one irradiated target basket at a time (CSE-01-AC4)
- Limited number of targets that may be in the target receipt hot cell (CSE-01-AC4)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, "Accident Analysis," Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the irradiated target receipt activities.

- IROFS CS-02, "Mass and Batch Handling Limits for Uranium Metal, [Proprietary Information], Targets, and Laboratory Samples outside Process Systems," sets batch limits on samples.
- IROFS CS-03, "Interaction Control Spacing Provided by Administrative Control," defines spacing requirements between irradiated target baskets.
- IROFS CS-04, "Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement," affects the location, spacing, and design of workstations.
- IROFS CS-05, "Container Batch Volume Limit," restricts the volume of the [Proprietary Information].
- IROFS CS-08, "Floor and Sump Geometry Control on Slab Depth, Sump Diameter or Depth for Floor Dikes," controls the geometry of the floor to prevent criticality in the event of spills.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include the following.

- The batch limits in the receipt hot cell are set conservatively low such that the administrative control on spacing can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.
- The effects of a criticality accident are mitigated by the shielding described in Section 4.2.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.3.2.2.6 Radiological Hazards

This section provides details of the radioactive inventory in process. This section also identifies the essential physical and operational features of the irradiated SNM processing system that are required to prevent the release of radioactive material and to maintain radiation levels below applicable radiation exposure limits prescribed in 10 CFR 20 for the protection of workers and public. The analysis in this section is based on information developed during preliminary design. Additional detailed information, including definition of technical specifications, will be developed for the Operating License Application and included in Chapter 14.0.

Radionuclide Inventory

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. NWMI-2014-CALC-014, *Selection of Dominant Target Isotopes for NWMI Material Balances*, identifies the 123 dominant radioisotopes included in the MURR material balance (NWMI-2013-CALC-006). NWMI-2014-CALC-014 provides the basis for using the 123 radioisotopes from the total list of 660 radioisotopes potentially present in irradiated targets. The majority of omitted radioisotopes exist in trace quantities and/or decay swiftly to stable nuclides. The reduced set of 123 radioisotopes consists of those that dominate the radioactivity and decay heat of irradiated targets.

Activities during an operating week that process targets irradiated in the MURR represent the radionuclide inventory as described in Section 4.1. The radionuclide inventory will be based on a [Proprietary Information]. The targets will be received in the target receipt system and staged for transfer to the target disassembly hot cells. Figure 4-54 provides a simplified description of the process streams used to describe the in-process radionuclide inventory.

Figure 4-54. Target Receipt In-Process Radionuclide Inventory Streams

The in-process radionuclide inventory of the irradiated targets is listed in Table 4-30, assuming all [Proprietary Information] could be stored in the target receipt hot cell and neglecting decay that occurs during the time to perform receipt activities.

Table 4-30. Irradiated Target Receipt Radionuclide In-Process Inventory (3 pages)

Item	MURR target processing	Item	MURR target processing
Unit operation	Target receipt	**Unit operation:**	Target receipt
Decay Time after EOI[a]	[Proprietary Information]	**Decay Time after EOI**[a]	[Proprietary Information]
Stream description[b]	Targets	**Stream description**[b]	Targets
Isotopes	**Ci**[c]	**Isotopes**	**Ci**[c]
^{241}Am	[Proprietary Information]	^{239}Pu	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	^{240}Pu	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	^{241}Pu	[Proprietary Information]
^{139}Ba	[Proprietary Information]	^{103m}Rh	[Proprietary Information]
^{140}Ba	[Proprietary Information]	^{105}Rh	[Proprietary Information]
^{141}Ce	[Proprietary Information]	^{106}Rh	[Proprietary Information]
^{143}Ce	[Proprietary Information]	^{106m}Rh	[Proprietary Information]
^{144}Ce	[Proprietary Information]	^{103}Ru	[Proprietary Information]
^{242}Cm	[Proprietary Information]	^{105}Ru	[Proprietary Information]
^{243}Cm	[Proprietary Information]	^{106}Ru	[Proprietary Information]
^{244}Cm	[Proprietary Information]	^{122}Sb	[Proprietary Information]
^{134}Cs	[Proprietary Information]	^{124}Sb	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	^{125}Sb	[Proprietary Information]
^{136}Cs	[Proprietary Information]	^{126}Sb	[Proprietary Information]
^{137}Cs	[Proprietary Information]	^{127}Sb	[Proprietary Information]

Table 4-30. Irradiated Target Receipt Radionuclide In-Process Inventory (3 pages)

Item	MURR target processing	Item	MURR target processing
Unit operation	Target receipt	**Unit operation:**	Target receipt
Decay Time after EOI[a]	[Proprietary Information]	**Decay Time after EOI[a]**	[Proprietary Information]
Stream description[b]	Targets	**Stream description[b]**	Targets
Isotopes	**Ci[c]**	**Isotopes**	**Ci[c]**
^{155}Eu	[Proprietary Information]	^{128}Sb	[Proprietary Information]
^{156}Eu	[Proprietary Information]	^{128m}Sb	[Proprietary Information]
^{157}Eu	[Proprietary Information]	^{129}Sb	[Proprietary Information]
^{129}I	[Proprietary Information]	^{151}Sm	[Proprietary Information]
^{130}I	[Proprietary Information]	^{153}Sm	[Proprietary Information]
^{131}I	[Proprietary Information]	^{156}Sm	[Proprietary Information]
^{132}I	[Proprietary Information]	^{89}Sr	[Proprietary Information]
^{132m}I	[Proprietary Information]	^{90}Sr	[Proprietary Information]
^{133}I	[Proprietary Information]	^{91}Sr	[Proprietary Information]
^{133m}I	[Proprietary Information]	^{92}Sr	[Proprietary Information]
^{134}I	[Proprietary Information]	^{99}Tc	[Proprietary Information]
^{135}I	[Proprietary Information]	^{99m}Tc	[Proprietary Information]
^{83m}Kr	[Proprietary Information]	^{125m}Te	[Proprietary Information]
^{85}Kr	[Proprietary Information]	^{127}Te	[Proprietary Information]
^{85m}Kr	[Proprietary Information]	^{127m}Te	[Proprietary Information]
^{87}Kr	[Proprietary Information]	^{129}Te	[Proprietary Information]
^{88}Kr	[Proprietary Information]	^{129m}Te	[Proprietary Information]
^{140}La	[Proprietary Information]	^{131}Te	[Proprietary Information]
^{141}La	[Proprietary Information]	^{131m}Te	[Proprietary Information]
^{142}La	[Proprietary Information]	^{132}Te	[Proprietary Information]
^{99}Mo	[Proprietary Information]	^{133}Te	[Proprietary Information]
^{95}Nb	[Proprietary Information]	^{133m}Te	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	^{134}Te	[Proprietary Information]
^{96}Nb	[Proprietary Information]	^{231}Th	[Proprietary Information]
^{97}Nb	[Proprietary Information]	234Th	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	^{232}U	[Proprietary Information]
^{147}Nd	[Proprietary Information]	^{234}U	[Proprietary Information]
^{236m}Np	[Proprietary Information]	^{235}U	[Proprietary Information]
^{237}Np	[Proprietary Information]	^{236}U	[Proprietary Information]
^{238}Np	[Proprietary Information]	^{237}U	[Proprietary Information]
^{239}Np	[Proprietary Information]	^{238}U	[Proprietary Information]
^{233}Pa	[Proprietary Information]	^{131m}Xe	[Proprietary Information]

Table 4-30. Irradiated Target Receipt Radionuclide In-Process Inventory (3 pages)

Item	MURR target processing	Item	MURR target processing
Unit operation	Target receipt	**Unit operation:**	Target receipt
Decay Time after EOI[a]	[Proprietary Information]	**Decay Time after EOI**[a]	[Proprietary Information]
Stream description[b]	Targets	**Stream description**[b]	Targets
Isotopes	**Ci**[c]	**Isotopes**	**Ci**[c]
^{234}Pa	[Proprietary Information]	^{133}Xe	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	^{133m}Xe	[Proprietary Information]
^{112}Pd	[Proprietary Information]	^{135}Xe	[Proprietary Information]
^{147}Pm	[Proprietary Information]	^{135m}Xe	[Proprietary Information]
^{148}Pm	[Proprietary Information]	^{89m}Y	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	^{90}Y	[Proprietary Information]
^{149}Pm	[Proprietary Information]	^{90m}Y	[Proprietary Information]
^{150}Pm	[Proprietary Information]	^{91}Y	[Proprietary Information]
^{151}Pm	[Proprietary Information]	^{91m}Y	[Proprietary Information]
^{142}Pr	[Proprietary Information]	^{92}Y	[Proprietary Information]
^{143}Pr	[Proprietary Information]	^{93}Y	[Proprietary Information]
^{144}Pr	[Proprietary Information]	^{93}Zr	[Proprietary Information]
^{144m}Pr	[Proprietary Information]	^{95}Zr	[Proprietary Information]
^{145}Pr	[Proprietary Information]	^{97}Zr	[Proprietary Information]
^{238}Pu	[Proprietary Information]	Total Ci	[Proprietary Information]

[a] In-process inventory based on a [Proprietary Information], neglecting the time required to receive targets in [Proprietary Information].

[b] Figure 4-54 provides a simplified description of the process streams indicated.

[c] In-process inventory based on total of [Proprietary Information], representing the weekly process throughput. Normal operation expected to begin target transfers to target disassembly when the targets become available after receipt from the first shipping cask.

EOI = end of irradiation. MURR = University of Missouri Research Reactor.

Radiological Protection Features

Radiological protection features are designed to prevent the release of radioactive material and to maintain radiation levels below applicable radiation exposure limits prescribed in 10 CFR 20 for the protection of workers and the public. These features include defense-in-depth and engineered safety features. The engineered safety features identified in this section are described in Chapter 6.0, Section 6.2.

The following defense-in-depth features will provide radiological protection to workers and the public.

- Shipment and receipt of radiological material will require approved procedures that implement U.S. Department of Transportation (DOT) requirements.
- The cask lifts and docking ports will be equipped with mechanical or electrical interlocks to ensure cask mating. The cask lifts will have locking bars that prevent lowering of the lift until the bars are removed.

- Alarming radiation monitors will provide continuous monitoring of the dose rate in occupied areas and alarm at an appropriate setpoint above background.
- Temporary shielding may be used to reduce radiation exposure when irradiated target baskets are removed from casks.

Chapter 13.0, Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the target receipt activities and will provide radiological protection to workers and the public:

- Cranes and lifts involved in irradiated target receipt will have enhanced procedures (IROFS FS-01) and additional design and testing requirements (IROFS FS-02). The irradiated target cask lifting fixture (IROFS FS-04) design prevents cask tipping or toppling during a seismic event.
- The high-dose material will be processed inside shielded areas. The hot cell shielding boundary (IROFS RS-04) will provide shielding for workers and the public at all workstations and occupied areas outside of the hot cell. The hot cell liquid confinement boundary (IROFS RS-01), which is credited to prevent releases of liquid, will also prevent the release of the solid target material.
- The cask atmosphere will be sampled before the lid is removed (IROFS RS-12), and a local hood will provide ventilation during the lid removal (IROFS RS-13).

4.3.2.2.7 Chemical Hazards

No chemical reagents will be used for irradiated target receipt, and the chemicals hazards of the irradiated target material will be bounded by the radiological hazards. The features preventing release of radioactive material and limiting radiation exposure will also protect workers and the public from exposure to hazardous chemicals.

4.3.3 Target Disassembly

Target disassembly will include the disassembly of the targets and the retrieval and transfer of the irradiated target material for processing. This system will be fed by irradiated target receipt, as described in Section 4.3.2. This system will feed the target dissolution system by the transfer of recovered irradiated target material through the dissolver 1 hot cell (H105) and dissolver 2 hot cell (H101) isolation door interfaces.

The target disassembly system description provides information regarding the process, process equipment, SNM and radioactive inventories, and the hazardous chemicals used in the system. The process description (Section 4.3.3.1) provides a detailed account of the SNM in process during normal operation and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.3.3.2 and 0. These sections describe the equipment in sufficient detail to provide confidence that SNM and byproduct material can be controlled throughout the process. A description of the SNM in terms of physical and chemical form, volume in process, required criticality control features, and radioactive inventory in process is provided in Sections 4.3.3.4 and 4.3.3.5. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.3.4.6.

4.3.3.1 Process Description

Two target disassembly stations will be provided, each one dedicated to a single dissolver. A maximum of [Proprietary Information] will be disassembled for each dissolver batch. The target material container will be filled with the contents of the targets and then physically transferred to the dissolver and inserted at the start of the dissolution cycle. Individual targets will be transferred from the target receipt hot cell (H103) into either the target disassembly 1 hot cell (H104) or target disassembly 2 hot cell (H102) for processing.

The targets will be disassembled, and the irradiated target material collected and transferred to either dissolver 1 hot cell (H105) or dissolver 2 hot cell (H101).

Using hot cell manipulators, a single target will be passed through the transfer door from the target receipt hot cell (H102) into the target disassembly hot cell (H102, H104). The target and the collection container will be scanned and weighed to meet material control and accountability (MC&A) tracking and verification requirements. The target will be fastened into the target cutting assembly spindle, and the collection container will be moved into position beneath the collection hopper.

The target disassembly subsystem will disassemble targets and collect irradiated target material. The following conditions will be required prior to disassembly.

- Ventilation inside the hot cell is operable.
- The fission gas capture hood is on and functional.
- The irradiated target material collection container is in position under the target cutting assembly collection bin.
- The 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 operator will activate the fission gas capture hood (TD-Z-310, TD-Z-410) and the collection hopper vibrator. Using hot cell manipulators, the target cutting tool will be manually advanced by a hand wheel until the tool pierces the target outer wall. The target spindle will be manually rotated by a hand wheel to complete the outer wall cut. The cutting tool will then be manually advanced until the tool pierces the target inner wall, and the spindle manually rotated to complete the inner wall cut.

The target disassembly station will open the target. Gases released during opening and removal of the target material will flow to the airspace of the target disassembly station enclosure. The vent gas from the enclosure will discharge at a controlled rate in a separate line to the dissolver offgas system equipment.

The target disassembly station will be sealed to minimize leakage. This station will be maintained at a lower pressure than the hot cell to ensure that the fission product gases from any leaks do not flow into the hot cell airspace. The empty target hardware will be retained inside the disassembly enclosure until outgassing of fission product gases is sufficiently complete. The empty target hardware will then be transferred through an airlock into a waste receptacle.

The hot cell manipulators will be used to release each target piece from the spindle, upend it with the open end in the collection hopper, and tap it against the side of the hopper a number of times until it appears that no more irradiated target material remains inside. The hardware pieces will then be placed on the scale for verification that all irradiated target material has been recovered. The collection container will be placed on the scale for verification that all irradiated target material has been collected in the container. The waste drum transfer port (TD-TP-300, TD-TP-400) will be opened, and the empty target hardware pieces will be placed in the waste drum for transfer to the waste handling system. The collection container lid will be installed, and the container placed in the target dissolution system transfer drawer.

The following equipment will be used in target disassembly 1 or 2:

- Target disassembly hoist (TD-L-300) or target disassembly hoist (TD-L-400)
- Waste drum transfer port (TD-TP-300) or waste drum transfer port (TD-TP-400)
- Target cutting assembly (TD-Z-300) or target cutting assembly (TD-Z-400)
- Fission gas capture hood (TD-Z-310) or fission gas capture hood (TD-Z-410)

The need for MC&A equipment has been identified, but has not been defined. Additional detailed information will be provided in the Operating License Application.

The above description provides a detailed account of the SNM in process during the target disassembly activities. The SNM, along with any included fission-product radioactivity, is described in Section 4.3.3.4. Based on this description, these operations can be conducted safely in this facility.

4.3.3.2 Process Equipment Arrangement

The equipment arrangement within the target disassembly hot cell (H102, H104) is shown in Figure 4-55. Irradiated targets will be received through the transfer door by manipulator. One-by-one, targets will be loaded into the target cutting assembly (TD-Z-300, TD-Z-400) under the fission gas capture hood (TD-Z-310, TD-Z-410). The targets will be cut, and the target material collected in a container. The target material collection container will then be transferred to the target dissolution hot cells.

[Proprietary Information]

Figure 4-55. Target Disassembly Hot Cells Equipment Arrangement

4.3.3.3 Process Equipment Design

During target disassembly activities, the irradiated target material will be transferred from the target to the target material collection container. Section 4.4.2.9.3 provides a description of the target. Auxiliary equipment supporting target disassembly, including the cutting assembly, fission gas capture hood, and handling equipment, is listed in Table 4-31.

Table 4-31. Target Disassembly Auxiliary Equipment

Equipment name	Equipment no.
Target cutting assembly	TD-Z-300
Fission gas capture hood	TD-Z-310
Target disassembly hoist	TD-L-300
Waste drum transfer port	TD-TP-300
Target cutting assembly	TD-Z-400
Fission gas capture hood	TD-Z-410
Target disassembly hoist	TD-L-400
Waste drum transfer port	TD-TP-400

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. The process description identifies the control strategy for normal operations, which sets requirements for the process monitoring and control equipment, and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information of the process monitoring and control equipment will be developed for the Operating License Application.

4.3.3.4 Special Nuclear Material Description

Special Nuclear Material Inventory

The SNM inventory within the irradiated target disassembly system will be determined by the number of targets transferred from the target receipt hot cell for disassembly to prepare a dissolver basket. Targets will be transferred [Proprietary Information] between the receipt and disassembly hot cells. The total SNM inventory within the target disassembly system will be bounded by the number of targets in the maximum dissolver charge. [Proprietary Information].

Each irradiated target is designed to [Proprietary Information].

Table 4-32 summarizes the in-process SNM inventory for an individual target disassembly cell. The target disassembly SNM inventory is planned to be zero during a majority of the RPF operating week (Section 4.3.1). Two disassembly hot cells will be available in the RPF and both hot cells could contain an in-process inventory at the same time. During disassembly activities, the maximum disassembly cell in-process SNM inventory will vary from [Proprietary Information], depending on the target reactor source in a particular operating week.

Table 4-32. Individual Irradiated Target Disassembly Hot Cell In-Process Special Nuclear Material Inventory

Stream	Form	Concentration[a]	SNM mass[a]
Irradiated targets	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at $\leq$ 19.95 wt% ^{235}U).

[b] SNM in-process inventory of an individual disassembly hot cell. Two disassembly hot cells are available and both cells may contain SNM inventory at the same time.

^{235}U = uranium-235.
^{238}U = uranium-238.
LEU = low-enriched uranium.
N/A = not applicable.
SNM = special nuclear material.
U = uranium
[Proprietary Information]

NWMI-2015-CSE-001 describes CSEs of the target disassembly system performed during preliminary design. Normal operations in the target disassembly cell are intended to be unmoderated. Single parameter limits for uranium containing 20 wt% ^{235}U indicate that an unmoderated, but ideally shaped and reflected [Proprietary Information] remains subcritical. However, the current double contingency analysis in NWMI-2015-CSE-001 imposes a limit of [Proprietary Information] on the disassembly hot cell inventory, combined with ensuring that no liquid lines exist in the disassembly hot cell as a criticality safety control.

Current criticality safety controls are based on single parameter limits under flooded conditions. The single parameter limit for an ideally reflected and moderated sphere [Proprietary Information]. The single parameter volume limit for a homogeneous [Proprietary Information]. Further evaluation of the target disassembly hot cell criticality controls will be performed and included in the Operating License Application.

Criticality Control Features

Criticality control features are required in this system, as defined in NWMI-2015-CSE-001. This evaluation covers handling of the targets, beginning with removal from the shipping casks. These features, including passive design features and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. Technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0.

The criticality control features for this subsystem will include the passive design features and administrative controls with designators of PDF and AC, respectively, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features will include:

- Exclusion of liquid lines (CSE-01-PDF1)
- Geometry requirements of the basket holding wells within the hot cell (CSE-01-PDF2)
- Inline HEPA filter installed in the gas capture hood (CSE-01-PDF3)

The administrative controls will include:

- Limited number of targets that may be in the target disassembly hot cells (CSE-01-AC3)
- Volume limit of the container that collects [Proprietary Information] during disassembly (CSE-01-AC4)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the irradiated target receipt activities.

- IROFS CS-02 sets batch limits on samples.
- IROFS CS-04 affects location, spacing, and design of workstations.
- IROFS CS-05 restricts the volume of the [Proprietary Information] collection container.
- IROFS CS-08 controls the geometry of the floor to prevent criticality in the event of spills.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features include:

- The batch limits in the disassembly hot cell will be set conservatively low such that the administrative control on spacing can sustain multiple upsets.
- The criticality alarm system will provide criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.
- The effects of a criticality accident will be mitigated by the shielding described in Section 4.2.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.3.3.5 Radiological Hazards

This section provides details of the radioactive inventory in process and identifies the essential physical and operational features of the irradiated SNM processing system that are required to prevent the release of radioactive material and to maintain radiation levels below applicable radiation exposure limits prescribed in 10 CFR 20 for the protection of workers and the public.

The analysis in this section is based on information developed during preliminary design. Additional detailed information, including definition of technical specifications, will be developed for the Operating License Application and included in Chapter 14.0.

Radionuclide Inventory

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. NWMI-2014-CALC-014 identifies the 123 dominant radioisotopes included in the MURR material balance (NWMI-2013-CALC-006). NWMI-2014-CALC-014 provides the basis for using the 123 radioisotopes from the 660 radioisotopes potentially present in irradiated targets. The majority of omitted radioisotopes exist in trace quantities and/or decay swiftly to stable nuclides. The reduced set of 123 radioisotopes consists of those that dominate the radioactivity and decay heat of irradiated targets.

[Proprietary Information]

Figure 4-56. Target Disassembly In-Process Radionuclide Inventory Streams

Activities during an operating week that process targets irradiated in the MURR represent the radionuclide inventory as described in Section 4.1. The radionuclide inventory will be based on a weekly throughput of [Proprietary Information]. Targets will be [Proprietary Information] receipt to the target disassembly hot cells. During MURR target processing, four LEU targets will be collected as a dissolver charge in a disassembly hot cell and transferred to one of the dissolver hot cells for processing. Figure 4-56 provides a simplified description of process streams used to describe the in-process radionuclide inventory. The radionuclide inventory will be split among the three streams (disassembly offgas, target cladding, and dissolver charge) in the target disassembly hot cell.

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. The in-process radionuclide inventory passing through target disassembly activities during an operating week is listed in Table 4-33 based on a total of eight MURR targets, neglecting decay that will occur during the time to perform target receipt and disassembly activities.

Table 4-33. Target Disassembly In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Target disassembly	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	Targets cladding	Disassembly offgas	Dissolver charge
Isotopes	**Ci**[c]	**Ci**[c]	**Ci**[c]
^{241}Am	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{139}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{242}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{243}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{244}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{155}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{157}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{130}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{83m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-33. Target Disassembly In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Target disassembly	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	Targets cladding	Disassembly offgas	Dissolver charge
Isotopes	Ci[c]	Ci[c]	Ci[c]
^{85m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{87}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{88}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Mo	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{96}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Nd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236m}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{233}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{112}Pd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{149}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{150}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144m}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{145}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-33. Target Disassembly In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Target disassembly	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	Targets cladding	Disassembly offgas	Dissolver charge
Isotopes	Ci[c]	Ci[c]	Ci[c]
^{238}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{240}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{241}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{122}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{124}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{126}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128m}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{153}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99m}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-33. Target Disassembly In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation	Target disassembly		
Decay time after EOI[a]	[Proprietary Information]		
Stream description[b]	Targets cladding	Disassembly offgas	Dissolver charge
Isotopes	**Ci**[c]	**Ci**[c]	**Ci**[c]
^{131m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{231}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
234Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{232}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{235}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Total Ci	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] In-process inventory based [Proprietary Information], neglecting time required to receive and disassemble targets.

[b] Figure 4-56 provides a simplified description of the process streams.

[c] In-process inventory based [Proprietary Information], representing the weekly process throughput. Normal operation expected to prepare a dissolver charge [Proprietary Information] such that the in-process inventory of an individual target disassembly cell is described by one-half the listed radionuclide inventory.

EOI = end of irradiation.
MURR = University of Missouri Research Reactor.

The radionuclide inventory of target transfers from target receipt is listed in Table 4-30, recognizing that a target enters a disassembly hot cell one at a time. Based on preparing a dissolver charge containing [Proprietary Information], the in-process inventory of an individual target disassembly hot cell is described by one-half the radionuclide inventory listed in Table 4-33.

Radiological Protection Features

Radiological protection features are designed to prevent the release of radioactive material and to maintain radiation levels below applicable radiation exposure limits prescribed in 10 CFR 20 for the protection of workers and the public. These features include defense-in-depth and engineered safety features. The engineered safety features identified in this section are described in Chapter 6.0, Section 6.2.

The following defense-in-depth features will provide radiological protection to workers and the public:

- The workspaces within the target disassembly hot cells are designed to contain spilled material.
- Alarming radiation monitors will provide continuous monitoring of the dose rate in occupied areas and alarm at an appropriate setpoint above background.

Chapter 13.0, Section 13.2, provides a description of the IROFS. The following IROFS will be applicable to the target disassembly activities and will provide radiological protection to workers and the public:

- The high-dose material will be processed inside shielded areas. The hot cell shielding boundary (IROFS RS-04) will provide shielding for workers and the public at workstations and occupied areas outside of the hot cell. The hot cell liquid confinement boundary (IROFS RS-01), which is credited to prevent releases of liquid, will also prevent the release of the solid target material.
- Radioactive gases will flow to target dissolution offgas treatment, which is part of the hot cell secondary confinement boundary (IROFS RS-03).

4.3.3.6 Chemical Hazards

No chemical reagents will be used for target disassembly, and the chemicals hazards of the target disassembly process will be bounded by the radiological hazards. The features preventing release of radioactive material and limiting radiation exposure will also protect workers and the public from exposure to hazardous chemicals.

4.3.4 Irradiated Target Dissolution System

The target dissolution system description provides information regarding the process, process equipment, SNM and radioactive inventories, and the hazardous chemicals used in the system. The process description (Section 4.3.4.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.3.4.2 and 4.3.4.3. These sections describe the equipment in sufficient detail to provide confidence that the SNM and byproduct material can be controlled throughout the process. A description of the SNM in terms of physical and chemical form, volume in process, required criticality control features, and radioactive inventory in process is provided in Sections 4.3.4.4 and 4.3.4.5. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.3.4.6.

4.3.4.1 Process Description

The target dissolution system will begin with the receipt of irradiated target material from disassembled targets that is passed to one of the target dissolution hot cells. The target dissolution system will then dissolve the target material, treat the offgas, and transfer the concentrated uranyl nitrate solution from the dissolver hot cells to feed tank 1A and feed tank 1B (MR-TK-100 and MR-TK-200) in the Mo recovery and purification system. Any solid waste generated in the target dissolution system will feed the waste handling system through the dissolver waste drum ports (DS-TP-100 and DS-TP-200) where the solid waste drums are transferred.

The target dissolution process will be operated in a batch mode. The targets will be disassembled one at a time, and the irradiated LEU target material will be 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 dissolved, and the resulting solution transferred to the separations step.

Dissolution Process Description

The function of the dissolution process is to dissolve the irradiated target material to uranyl nitrate so the ^{99}Mo can be extracted from the solution.

Figure 4-57 provides a summary of the major process flows for the target dissolution process steps. The irradiated targets will be opened, and the contained LEU target material removed and placed in collection containers. Using hot cell manipulators, a single container will be passed through the transfer door from one of the target disassembly hot cells into the corresponding dissolver hot cell. The dissolver basket will be positioned and fastened into the dissolver basket filler (DS-Z-100). The target material container will then be manipulated to transfer the irradiated target material from the container into the dissolver basket.

[Proprietary Information]

Figure 4-57. Simplified Target Dissolution Flow Diagram

The container will then be scanned and weighed to verify that all irradiated target material has been transferred per the MC&A requirements. The hot cell manipulator will be used to return the empty collection container into the dissolver 1 hot cell isolation door for transfer back to the target disassembly 1 hot cell (H104). The LEU collection container transfer activities and dissolver basket filling operations will be repeated as required for the quantity of collection containers in the specified dissolver batch.

Detailed design of the dissolver baskets and associated handling mechanisms is yet to be developed. Preliminary analysis indicates that the dissolver baskets will have an [Proprietary Information]. When handling the fixture and bottom support plate, the overall height of a dissolver basket is expected to be between [Proprietary Information]. The dissolver baskets will be made of a screen material that is open on top. Stainless steel or other corrosion-resistant metal is assumed to be the primary material of construction for the dissolver baskets. Each dissolver basket will hold the irradiated LEU target material for a full dissolver batch.

The dissolver design includes a valve arrangement allowing placement and removal of a dissolver basket. To initiate dissolution, the operator will open the valve assembly, and the dissolver hoist will lift a dissolver basket from the filling station and lower it into the dissolver (DS-D-100/DS-D-200). Markings on the hoist cable will indicate when the basket is at the proper position, and the hoist hook will be disengaged from the basket and raised out of the dissolver and valve assembly. Concentrated nitric acid will be added to submerge the irradiated target material and heated to near-boiling temperatures (about 100 to 120 degrees Celsius [°C]). The heat-up rate will be controlled to prevent excessive foaming. The [Proprietary Information]:

[Proprietary Information]

The mass balance calculations in NWMI-2013-CALC-002, *Overall Summary Material Balance – OSU Target Batch*, and NWMI-2013-CALC-006 provide detailed descriptions of the feed and product streams. The initial concentration of the nitric acid for the dissolution batch is [Proprietary Information] (NWMI-2013-CALC-013, *Irradiated Target Dissolution System Equipment Sizing*). Based on these concentrations and a [Proprietary Information].

Dissolution with nitric acid will produce nitrogen oxide gases (NO_x) and evolve gaseous fission products. The offgas treatment is described in the following section. In addition to the gaseous fission products, the intense radiation field in the dissolver will generate hydrogen and oxygen gas in the dissolver due to radiolysis of water. A sweep gas during dissolution will limit the concentration of flammable gases to less than 25 percent of the lower flammability limit.

When dissolution is complete, the uranyl nitrate solution will be cooled enough to allow pumping and will then be transferred to the Mo recovery and purification system. The solution will be passed through a strainer during the transfer to remove residual suspended solids.

After the uranyl nitrate system is transferred to the Mo recovery and purification system, the dissolver valve assembly will be opened for dissolver basket removal. The dissolver hoist hook will be lowered down through the valve assembly and into the dissolver until markings on the hoist cable indicate that the hook is at the proper position. The hoist hook will be engaged with the basket and raised out of the dissolver and valve assembly, and the basket will be placed in the drying area within the hot cell.

Nitrogen or air will be used to purge the dissolver at the end of dissolution. This process will reduce the concentration of radioactive gases in the dissolver to minimize the risk of release into the cell airspace when the dissolver entry valves are opened to allow fresh target material to be added for the next batch. Between dissolver batches, the dissolver and offgas system will be filled with nitrogen or air to prevent buildup of flammable hydrogen gas mixtures. Continuous sweep gas flow is not expected to be required for hydrogen mitigation during these periods.

Dissolver Offgas Process Description

The dissolver offgas will consist of NO_x, nitric acid vapors, water vapor, and gaseous fission products (iodine [I], Xe, and Kr). The first step in offgas treatment will be removing the NO_x and nitric acid vapors, followed by treatment of the gaseous fission products. The gaseous fission products from the offgas treatment will be mixed with the offgas from the target disassembly activities. Iodine will be absorbed from the offgas stream by the iodine removal unit (IRU). The release of other gaseous fission products will be delayed by adsorption beds to allow sufficient decay. The following subsystems will comprise the dissolver offgas treatment process:

- NO_x treatment 1
- NO_x treatment 2
- Primary fission gas treatment
- Secondary fission gas treatment
- Waste collection

NO_x Treatment Description

The NO_x treatment subsystem will remove NO, nitrogen dioxide (NO_2), HNO_3, water vapor, and a portion of the iodine from the dissolver offgas. Removal of these components will substantially reduce the total volume of the gas stream and provide a composition suitable for use in the downstream fission gas retention equipment. The NO_x treatment design is based on minimizing total net gas flow from the dissolver and offgas system to minimize impacts to the required fission gas retention equipment size.

Two trains will be provided for NO_x treatment, one dedicated to each dissolver (DS-D-100/DS-D-200) where the condensers (DS-E-130/DS-E-230) are mounted above the dissolvers. The downstream equipment for control of fission product gases will be shared between the two dissolver systems. Gas components removed by this system will include nitrogen oxides (NO and NO_2), and carbon dioxide (CO_2) gases plus water (H_2O) and HNO_3 vapors.

To facilitate the dissolution and offgas treatment processes, a small amount of air or oxygen will be added to the dissolver. A portion of the oxygen will react with the dissolver solution to reduce acid consumption and reduce NO_x generation. The balance of the oxygen will mix with the evolved gases and continue to react with nitric oxide (NO) in the downstream process steps.

Secondary reactions between NO_x gas species, water, nitric and nitrous acids, and oxygen will take place by the reactions shown in Equation 4-4 and Equation 4-5. The production of nitric acid will reduce the amount of nitric acid initially required. The NO_2 produced will be more readily reacted and absorbed by scrubbing solutions.

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO \qquad \text{Equation 4-4}$$

$$2NO + O_2 \rightarrow 2NO_2 \qquad \text{Equation 4-5}$$

From the dissolver, the offgas will flow to the dissolver offgas condenser (DS-E-130 or DS-E-230). In the condenser, the stream will be cooled, condensing water and nitric acid vapors. NO_2 will be absorbed into the condensate, producing additional HNO_3 and NO, while oxygen will react with NO present in the offgas producing additional NO_2. The condensed nitric acid stream from the condenser will drain back to the dissolver. The recycled acid will reduce the amount of acid needed in the initial dissolver charge.

Vent gas from the dissolver offgas condenser will flow to a primary caustic scrubber (DS-C-310 or DS-C-410), which will remove most of the remaining NO_x by reaction with a sodium hydroxide (NaOH) solution to produce a sodium nitrate/nitrite solution. [Proprietary Information] may be added to the scrubber solution if needed to improve NO_x removal. Any CO_2 in the condenser vent stream will also be removed by reaction with NaOH, producing sodium carbonate. Reaction of oxygen and NO will continue in the primary caustic scrubber, further reducing the NO concentration. The primary caustic scrubber will also be expected to remove a substantial fraction of radioiodine present in the offgas stream.

In the primary caustic scrubber, the gas/liquid contact will be performed in a vertical column. As an initial step, scrubbing solution will be injected into the gas stream via a venturi scrubber or spray nozzle. The mixture will then flow into the bottom of the column, where the gas and liquid separate. The gas will flow upward through the column packing, and the liquid will collect in a reservoir at the bottom of the column. Cooling water flowing through a cooling coil or jacket will remove the heat generated by the reactions. Additional scrubbing solution will be added at the top of the column and flow downward through the packing, where it will contact the up-flowing gas stream to remove additional NO_x. At the bottom of the column, the liquid will collect in a reservoir. The gas will exit through a pipe at the top of the column.

From the primary caustic scrubber (DS-C-310/DS-C-410), the gas will flow to a NO_x oxidizer (DS-C-340 or DS-C-440), where it will be contacted with a liquid oxidant solution to convert the remaining NO to NO_2. A number of reagents may be considered for the liquid oxidant, including sodium hypochlorite, hydrogen peroxide, potassium permanganate, sodium percarbonate, and sodium persulfate. Sodium hypochlorite is used commercially for this purpose, but is undesirable for this application due to potential corrosion problems related to the added chloride. In the current analysis, [Proprietary Information] will be the assumed oxidation agent.

The gas will flow from the NO_x oxidizer to a NO_x absorber (DS-C-370 or DS-C-470), where it will be contacted with a solution of [Proprietary Information to remove the remaining NO_2. Treated gas from the NO_x absorber will flow to the fission gas retention equipment.

During upset conditions when the offgas treatment loses vacuum, a pressure relief confinement tank (DS-TK-500) will contain the offgas until the gas treatment equipment is operational. A pressure relief valve connected to the NO_x absorber will evacuate the dissolver offgas during loss of vacuum. The pressure relief confinement tank will normally be maintained under vacuum. Further detail on the pressure relief confinement tank is provided in Chapter 6.0.

Fission Gas Retention Process Description

Irradiated target material will have a high content of short-lived radioisotopes of iodine and noble gases (Xe and Kr). These isotopes will be released as gases during the dissolution process. The high radioactivity and mobility of these isotopes will require stringent measures be taken to control their movement and release. The primary functions of the fission gas retention equipment will be to remove radioiodine from the gas stream and to delay release of the noble gases (Xe and Kr) sufficiently to allow release to the stack. The fission gas retention equipment will also provide primary confinement of the gases to prevent their release within the facility.

Emissions modeling has not been finalized; however, preliminary estimates suggest that the required overall decontamination factor for iodine could be on the order of [Proprietary Information]. Several sequential iodine removal steps will be included in the overall dissolver offgas treatment process to achieve the required iodine removal. Each step is an important component of the overall approach but is not required to perform the full iodine control function.

The dissolver and NO_x treatment systems are expected to retain [Proprietary Information of the iodine from the target material. Each IRU (DS-SB-600A/B/C) is expected to retain [Proprietary Information] of the iodine in its inlet gas stream, and the primary adsorbers (DS-SB-620A/B/C) and iodine guard beds (DS-SB-640A/B/C) are expected to retain [Proprietary Information] of the iodine in their inlet gas streams. The combined iodine decontamination factor of these units is expected to well exceed [Proprietary Information]. As part of the overall approach, a key function of the IRUs will be to reduce the iodine content sufficiently so that the radiation dose rate and heat generation from absorbed iodine does not significantly reduce the performance or life expectancy of the downstream primary adsorbers. The primary adsorbers and iodine guard beds will then remove the remaining traces of iodine that are not removed by the IRUs. A radiation detector will be placed on or downstream of each iodine guard bed to verify that the iodine has been adequately removed. To increase sensitivity, the radiation detector may use a solid iodine sorbent to collect residual iodine in the vent gas, coupled with a radiation detector that will monitor for any significant buildup of radiation dose rate on the sorbent material.

Within the offgas treatment systems, the IRUs and the secondary adsorbers will be the primary unit operations responsible for retaining the iodine and fission product noble gases. The configuration of this offgas equipment will be three trains operating in parallel. Vent gas from the NO_x absorbers will flow to IRUs (DS-SB-600A/B/C). The IRUs will absorb iodine [Proprietary Information]. Remaining traces of iodine in the IRU vent gas will be removed in the downstream primary adsorber and iodine guard beds (DS-SB-640A/B/C). Buildup of radiation dose rates in the iodine guard beds may be used as an indication that the IRU sorbent bed needs to be replaced.

From the IRUs, the gas stream will flow to gas dryers (DS-E-610A/B/C) and primary adsorbers (DS-SB-620A/B/C). The gas dryers will reduce water vapor content of the gas to improve performance of the downstream sorbent beds.

For radioactive noble gases, the overall process concept is to delay the gas release so that decay will reduce the radioisotope content sufficiently to allow the decayed noble gases to be safely discharged to the stack. Preliminary information suggests that xenon-133 (^{133}Xe) is the isotope that will drive the required delay time, and that a delay time for ^{133}Xe of about [Proprietary Information] is expected to be sufficient.

Two sequential noble gas retention steps will be included in the overall dissolver offgas treatment process. The primary adsorbers are expected to provide a moderate delay for xenon, on the [Proprietary Information]. From the primary adsorbers, the gas will flow through an iodine guard bed, particulate filter, vacuum receiver tank, vacuum pump, and then to secondary adsorbers. The secondary adsorbers (DS-SB-730A/B/C) will provide an extended delay of xenon, on the order of [Proprietary Information]. The primary and secondary adsorbers will also adsorb and delay release of krypton. However, the delay time for krypton is much shorter, only [Proprietary Information] of that for xenon. The secondary adsorbers will provide some additional iodine retention but are not credited as part of the iodine control approach. Vacuum receiver tanks (DS-TK-700A/B), located between the primary and secondary adsorbers, will act as buffer tanks for the vacuum system to reduce the cycling and peak capacity requirement for the vacuum pumps.

Waste Collection

During normal process operations, liquid wastes will be generated by the primary caustic scrubbers, NO_x oxidizers and absorbers, and gas dryers. Liquid wastes will be collected in waste collection and sampling tanks (DS-TK-800/DS-TK-820). Additional liquid wastes will be generated by maintenance operations, such as tank and line flushes. Waste volume estimates have not yet been developed.

The above description provides a detailed account of the SNM in process during the target dissolution activities. The SNM, along with any included fission-product radioactivity, is described in Sections 4.3.4.4 and 4.3.4.5. Based on this description, these operations can be conducted safely in the RPF.

4.3.4.2 Process Equipment Arrangement

The target dissolution 1 and target dissolution 2 subsystems will be located along the rows of the processing hot cells within the RPF. The NO_x treatment 1, No_x treatment 2, pressure relief, primary fission gas treatment, and waste collection subsystems will be located in the tank hot cell. The subsystem locations are shown in Figure 4-17.

The dissolver 1 hot cell (H104) and dissolver 2 hot cell (H101) location within the rows of the processing hot cells is shown in Figure 4-58. Irradiated target material will be transferred from the target disassembly hot cells to the dissolver hot cells via manipulators. Following dissolution, the uranyl nitrate solution will be transferred from the dissolver hot cells to the Mo recovery hot cell.

[Proprietary Information]

Figure 4-58. Dissolver Hot Cell Locations

The equipment arrangement within the dissolver 1 hot cell (H104) is shown in Figure 4-59. Irradiated target material in containers will be brought in through the dissolver hot cell isolation door and loaded into dissolver baskets at the filler (DS-Z-100). The basket will be lifted by the hoist (DS-L-100) and lowered through the valve assembly into the dissolver (DS-D-100). During dissolution, the reflux condenser (DS-E-130) will cool the offgas and return water and nitric acid to the dissolvers. The primary caustic scrubber (DS-C-310) will be the first step of the offgas treatment.

[Proprietary Information]

Figure 4-59. Dissolver Hot Cell Equipment Arrangement (Typical of Dissolver 1 Hot Cell and Dissolver 2 Hot Cell)

The remainder of the offgas treatment equipment will be located in the tank hot cell, as shown in Figure 4-60. The gas from the primary caustic scrubbers will flow to NO_x treatment 1 or NO_x treatment 2 and then to the primary fission gas treatment equipment. Liquid waste from the offgas treatment equipment will be pumped to the waste collection equipment.

[Proprietary Information]

Figure 4-60. Target Dissolution System Tank Hot Cell Equipment Arrangement

The secondary fission gas treatment equipment will be located on the second floor with local shielding, as shown in Figure 4-61.

[Proprietary Information]

Figure 4-61. Target Dissolution System Mezzanine Equipment Arrangement

4.3.4.3 Process Equipment Design

A common vessel geometry has been assumed for vessels that may contain significant quantities of fissile material. This approach provides a geometrically favorable configuration for criticality control when process solutions may contain significant quantities of uranium with enrichments up to 20 wt% ^{235}U. The assumed geometry is based on use of vessel elements ("risers") with [Proprietary Information] apart from other solution-containing vessel risers (center-to-center). The actual diameter and spacing requirements will be better defined by vessel sizing analysis. Multiple interconnected risers will be used to provide the overall capacity required for a specific vessel.

The assumed geometry requirement influences the configuration of the dissolvers and offgas treatment columns and liquid waste tanks. For each dissolver, there will be two vertical risers with the required spacing between risers. Each dissolver will include a vertically oriented condenser that sits on top of one of the risers. Circulation will be induced by an agitator. Offgas from each dissolver condenser will flow directly to dedicated offgas treatment equipment that will include a primary caustic scrubber, NO_x oxidizer, and NO_x absorber. IRUs, gas dryers, and adsorber systems will be shared between the two dissolver systems and treat gases from the dissolution and target evacuation steps. Pending formal analysis, the geometrically favorable configuration requirements are assumed to apply to the dissolvers, condensers, primary caustic scrubbers, NO_x oxidizers, NO_x absorbers, and waste collection and sampling tanks. The geometrically favorable configuration requirements are assumed to not apply to the IRUs, gas dryers, and downstream offgas treatment equipment.

Details for design parameters of the processing equipment, including normal operating conditions, are summarized in Table 4-34.

Table 4-34. Irradiated Target Dissolution Process Equipment

Equipment name	Equipment no.	Nominal tank diameter cm (in.)	Individual tank capacity	Tank material	Operating range	
					Temperature °C (°F)[a]	Pressure
Dissolver	DS-D-100/200	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Dissolver reflux condenser	DS-E-130/230	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
NO_x treatment (primary caustic scrubber, NO_x oxidizer, and NO_x absorber	DS-C-310/340/370 DS-C-410/440/470	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Iodine removal unit	DS-SB-600A/B/C	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Gas dryer	DS-E-610A/B/C	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Primary absorber	DS-SB-620A/B/C	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Iodine guard bed	DS-SB-640A/B/C	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Secondary absorber	DS-SB-730A/B/C	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Vacuum receiver tank	DS-TK-700A/B	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Waste collection and sampling tanks	DS-TK-800/820	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Pressure relief confinement tank	DS-TK-500	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]

N/A = not applicable.
NO_x = nitrogen oxide.
SS = stainless steel.
TBD = to be determined.

The primary caustic scrubber, NO_x oxidizer, and NO_x absorber will each be nominal [Proprietary Information] vertical columns with internal packing, baffles, and/or trays to facilitate contact of offgas with the scrubbing and oxidation solutions. The solutions will be recirculated through each column using a mechanical pump to maintain adequate liquid downflow. The bottom of each column will be a liquid reservoir that holds accumulated scrubber solution.

The IRUs will consist of a sorption bed that uses a [Proprietary Information]. The gas dryers will each have a vertical pipe heat exchanger [Proprietary Information]. The heat exchanger will be cooled with chilled glycol solution.

The primary and secondary adsorbers will consist of carbon-filled columns made from nominal [Proprietary Information] pipe segments.

In addition to the process equipment, auxiliary equipment will be used for material handling, pumping, and waste handling. This equipment is listed in Table 4-35.

Table 4-35. Target Dissolution Auxiliary Equipment

Equipment name	Equipment no.
Dissolver agitator	DS-A-100/200
Dissolver offgas pipe cooler	DS-E-140/240
Dissolver hoist	DS-L-100/200
Dissolver basket filler	DS-Z-100/200
Dissolver waste drum port	DS-TP-100/200
Venturi eductor	DS-ED-300/400
NO_x treatment solution pumps	DS-P-330/360/390 (A/B) DS-P-430/460/490 (A/B)
Pressure relief tank pump	DS-P-510
Fission gas treatment filters	DS-F-630A/B/C
Vacuum pump	DS-P-710A/B
Waste collection and sampling tanks	DS-TK-800/820
Waste tank pumps	DS-P-810/830

NO_x = nitrogen oxide.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. The process descriptions identify the control strategy for normal operations, which will set requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information of the process monitoring and control equipment will be developed for the Operating License Application.

4.3.4.4 Special Nuclear Material Description

This section provides a summary of the maximum amounts of SNM and the chemical and physical forms of SNM used in the process. Any required criticality control features that are designed into the process systems and components are also identified. Criticality control features provided will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

Special Nuclear Material Inventory

The SNM inventory within the irradiated target dissolution system will be determined by the mass of uranium in a dissolver charge that has been transferred into the dissolver hot cell from the target disassembly hot cell. Irradiated LEU target material will be moved into the dissolver hot cells in a container. The transfer container contents will be poured into a dissolver basket or inserted directly into the dissolver. The dissolver basket contents will be dissolved in nitric acid, and the resulting aqueous solution of uranyl nitrate will be transferred to the Mo recovery and purification system for further processing. The total SNM inventory within the target dissolver system will be bounded by the number of targets in the maximum dissolver charge. [Proprietary Information]. The target dissolution system SNM inventory will be reduced when targets from MURR are being processed [Proprietary Information].

Table 4-36 summarizes the in-process SNM inventory for an individual target dissolution cell. The target dissolution SNM inventory is [Proprietary Information] (Section 4.3.1). Two dissolution hot cells will be available in the RPF, and both hot cells could contain an in-process inventory at the same time. During dissolution activities, the maximum dissolution cell in-process SNM inventory will vary [Proprietary Information], depending on the target reactor source in a particular operating week. The dissolution system will produce uranium solution in the dissolver with a maximum concentration of approximately [Proprietary Information]. Dilution water will be added to a dissolver at the end of [Proprietary Information] such that initial solution transfers to the ^{99}Mo recovery feed tank range from approximately [Proprietary Information]. Initial dissolver solution transfers will be followed by a dissolver vessel and transfer line water flush volume ranging from [Proprietary Information]. The design is based on producing [Proprietary Information] in the downstream tank ^{99}Mo recovery feed tank after dilution with flush water.

Table 4-36. Individual Target Dissolution Hot Cell In-Process Special Nuclear Material Inventory

Stream	Form	Concentration[a]	SNM mass[a]
Dissolver 1 or dissolver 2 (DS-D-100, DS-D-200)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U).

[b] Dissolution reaction changes chemical form from [Proprietary Information] to aqueous uranyl nitrate solution.

[c] SNM in-process inventory of an individual dissolver hot cell. Two dissolver hot cells are available, and both cells could contain SNM inventory at the same time.

^{235}U = uranium-235.
^{238}U = uranium-238.
LEU = low enriched uranium.
SNM = special nuclear material.
U = uranium.
[Proprietary Information]

Nuclear criticality evaluations performed in NWMI-2015-CRITCALC-002, *Irradiated Target Low-Enriched Uranium Material Dissolution*, indicate that the target dissolution system vessels remain subcritical under normal and abnormal conditions when all vessels contain solution at a concentration of 750 g U/L after dissolution. NWMI-2015-CSE-002, *NWMI Preliminary Criticality Safety Evaluation: Irradiated Low-Enriched Uranium Target Material Dissolution*, describes CSEs of the target dissolution system. The current double-contingency analysis in NWMI-2015-CSE-002 imposes [Proprietary Information] on the dissolution hot cell inventory as a criticality safety control.

Current criticality safety controls are based on single parameter limits under flooded conditions. The single parameter limit for [Proprietary Information]. Further evaluation of the target dissolution hot cell criticality controls will be performed and included in the Operating License Application.

Criticality Control Features

Criticality control features are required in this system, as defined in NWMI-2015-CSE-002. These features, including passive design and active engineered features, allow for adherence to the double-contingency principle. This section applies the criticality control features that are discussed in Chapter 6.0, Section 6.3.

The criticality control features for this subsystem will include the passive design and active engineered features with designators of PDF and AEF, respectively, listed below. The passive design features will include geometric constraints of the floor, process equipment, workstations, and ventilation system. Active engineered features will include the requirement of continuous ventilation. Chapter 6.0 provides detailed descriptions of the following criticality control features.

- For the case of a liquid leak, the floor will be criticality-safe (CSE-02-PDF1), and the floor will have a minimum area to preclude collection of leaked fissile solution at high concentration to an unfavorable depth (CSE-02-PDF4).
- The geometry of the process equipment will be inherently criticality-safe (CSE-02-PDF2 and CSE-02-PDF3) and will maintain a subcritical geometry during and after a facility DBE (CSE-02-PDF5 and CSE-02-PDF6). Dissolver design and operability of the ventilation system will preclude pressurization of the process vessels (CSE-02-AFE-1).
- For the case of liquid leaks to secondary systems, a safe-geometry secondary system barrier will be provided between the process vessels and the unfavorable-geometry supply systems (CSE-02-PDF7 and CSE-02-PDF8).

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the target dissolution activities.

- IROFS CS-02 sets batch limits on samples.
- IROFS CS-04 affects location, spacing, and design of workstations.
- IROFS CS-05 restricts the volume of [Proprietary Information] collection container.
- IROFS CS-07, "Pencil Tank Geometry Control on Fixed Interaction Spacing of Individual Tanks," defines maximum tank diameters and minimum spacing between process equipment, which is applicable to the dissolvers, reflux condenser, and the primary caustic scrubber.
- IROFS CS-08 controls the geometry of the floor to prevent criticality in the event of spills.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include the following.

- Tanks are vented and unpressurized during normal operations, and corrosion resistance is a design requirement. Level is monitored on all tanks and indicated to the operator to reduce the likelihood of overflow.
- The batch limits in the dissolution hot cell are set conservatively low such that the administrative control on spacing can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.
- The effects of a criticality accident are mitigated by the shielding described in Section 4.2.

The criticality control features provided throughout the target dissolution process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.3.4.5 Radiological Hazards

This section provides details of the radioactive inventory in process and identifies the essential physical and operational features of the irradiated SNM processing system that are required to prevent the release of radioactive material and to maintain radiation levels below applicable radiation exposure limits prescribed in 10 CFR20 for the protection of workers and the public. The analysis in this section is based on information developed during preliminary design. Additional detailed information, including definition of technical specifications, will be developed for the Operating License Application and described in Chapter 14.0.

Radionuclide Inventory

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. NWMI-2014-CALC-014 identifies the 123 dominant radioisotopes included in the MURR material balance (NWMI-2013-CALC-006). NWMI-2014-CALC-014 provides the basis for using the 123 radioisotopes from the total list of 660 radioisotopes potentially present in irradiated targets. The majority of omitted radioisotopes exist in trace quantities and/or decay swiftly to stable nuclides. The reduced set of 123 radioisotopes consists of those that dominate the radioactivity and decay heat of irradiated targets.

Activities during an operating week that process targets irradiated in the MURR represent the radionuclide inventory as described in Section 4.1. The radionuclide inventory will be based on a [Proprietary Information]. During MURR target processing, LEU from [Proprietary Information] will be collected as a dissolver charge in a disassembly hot cell and transferred to one of the dissolver hot cells for processing. Figure 4-62 provides a simplified description of process streams used to describe the in-process radionuclide inventory. The radionuclide inventory will be split among three streams (dissolver offgas, filter solids, and dissolver solution) in the target dissolution hot cell. Dissolver offgas will be gases generated during the dissolution reaction that leave the dissolver condenser. Filter solids represent undissolved material that will be removed from the dissolver solution as it is transferred out of a dissolver hot cell.

[Proprietary Information]

Figure 4-62. Target Dissolution In-Process Radionuclide Inventory Streams

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. The in-process radionuclide inventory passing through target dissolution activities during an operating week is listed in Table 4-37 based on [Proprietary Information], neglecting decay that will occur during the time to perform target receipt, disassembly, and dissolution activities. The radionuclide inventory of dissolver charge transfers from target disassembly is summarized in Table 4-33. Based on preparing a dissolver charge containing [Proprietary Information], the in-process inventory of an individual target dissolution hot cell is described by [Proprietary Information]listed in Table 4-37.

Table 4-37. Target Dissolution In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Target dissolution	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	Dissolver offgas	Dissolver solution	Filter solids
Isotopes	**Ci**[c]	**Ci**[c]	**Ci**[c]
^{241}Am	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{139}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{242}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{243}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{244}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{155}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{157}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{130}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{83m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{87}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{88}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-37. Target Dissolution In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Target dissolution	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	Dissolver offgas	Dissolver solution	Filter solids
Isotopes	Ci [c]	Ci [c]	Ci [c]
^{141}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Mo	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{96}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Nd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236m}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{233}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{112}Pd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{149}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{150}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144m}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{145}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{240}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{241}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-37. Target Dissolution In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Target dissolution	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	Dissolver offgas	Dissolver solution	Filter solids
Isotopes	**Ci**[c]	**Ci**[c]	**Ci**[c]
^{103m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{122}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{124}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{126}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128m}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{153}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99m}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-37. Target Dissolution In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Target dissolution	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	Dissolver offgas	Dissolver solution	Filter solids
Isotopes	**Ci** [c]	**Ci** [c]	**Ci** [c]
^{133}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{231}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{232}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{235}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Total Ci	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] In-process inventory based on [Proprietary Information], neglecting time required to receive, disassemble, and dissolve targets.

[b] Figure 4-62 provides a simplified description of the process streams.

[c] In-process inventory based [Proprietary Information], representing the weekly process throughput. Normal operation expected to prepare a dissolver charge containing [Proprietary Information] such that the in-process inventory of an individual target dissolution cell is described by [Proprietary Information]

EOI = end of irradiation. MURR = University of Missouri Research Reactor.

Dissolver offgas will be treated by the dissolver offgas system to control radionuclide emissions. The dissolver offgas system includes two groups of unit operations: NO_x scrubbers and fission gas treatment. Radionuclides in the dissolver offgas stream listed in Table 4-37 will enter the NO_x scrubbers, where NO_x is removed and the radionuclide inventory is split into two streams (scrubbed gas, and waste), as shown in Figure 4-63. The maximum in-process radionuclide inventory of the target dissolution offgas streams is listed in Table 4-38.

[Proprietary Information]

Figure 4-63. Nitrogen Oxide Scrubbers In-Process Radionuclide Inventory Streams

Table 4-38. Nitrogen Oxide Scrubbers In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing	
Unit operation	NO_x scrubbers	
Decay Time after EOI[a]	[Proprietary Information]	
Stream description[b]	Scrubbed gas	Scrubber waste
Isotopes	**Ci**[c]	**Ci**[c]
^{241}Am	[Proprietary Information]	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	[Proprietary Information]
^{139}Ba	[Proprietary Information]	[Proprietary Information]
^{140}Ba	[Proprietary Information]	[Proprietary Information]
^{141}Ce	[Proprietary Information]	[Proprietary Information]
^{143}Ce	[Proprietary Information]	[Proprietary Information]
^{144}Ce	[Proprietary Information]	[Proprietary Information]
^{242}Cm	[Proprietary Information]	[Proprietary Information]
^{243}Cm	[Proprietary Information]	[Proprietary Information]
^{244}Cm	[Proprietary Information]	[Proprietary Information]
^{134}Cs	[Proprietary Information]	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	[Proprietary Information]
^{136}Cs	[Proprietary Information]	[Proprietary Information]
^{137}Cs	[Proprietary Information]	[Proprietary Information]
^{155}Eu	[Proprietary Information]	[Proprietary Information]
^{156}Eu	[Proprietary Information]	[Proprietary Information]
^{157}Eu	[Proprietary Information]	[Proprietary Information]
^{129}I	[Proprietary Information]	[Proprietary Information]
^{130}I	[Proprietary Information]	[Proprietary Information]
^{131}I	[Proprietary Information]	[Proprietary Information]
^{132}I	[Proprietary Information]	[Proprietary Information]
^{132m}I	[Proprietary Information]	[Proprietary Information]
^{133}I	[Proprietary Information]	[Proprietary Information]
^{133m}I	[Proprietary Information]	[Proprietary Information]
^{134}I	[Proprietary Information]	[Proprietary Information]
^{135}I	[Proprietary Information]	[Proprietary Information]

Table 4-38. Nitrogen Oxide Scrubbers In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing	
Unit operation	NO_x scrubbers	
Decay Time after EOI[a]	[Proprietary Information]	
Stream description[b]	Scrubbed gas	Scrubber waste
Isotopes	**Ci**[c]	**Ci**[c]
^{83m}Kr	[Proprietary Information]	[Proprietary Information]
^{85}Kr	[Proprietary Information]	[Proprietary Information]
^{85m}Kr	[Proprietary Information]	[Proprietary Information]
^{87}Kr	[Proprietary Information]	[Proprietary Information]
^{88}Kr	[Proprietary Information]	[Proprietary Information]
^{140}La	[Proprietary Information]	[Proprietary Information]
^{141}La	[Proprietary Information]	[Proprietary Information]
^{142}La	[Proprietary Information]	[Proprietary Information]
^{99}Mo	[Proprietary Information]	[Proprietary Information]
^{95}Nb	[Proprietary Information]	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	[Proprietary Information]
^{96}Nb	[Proprietary Information]	[Proprietary Information]
^{97}Nb	[Proprietary Information]	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	[Proprietary Information]
^{147}Nd	[Proprietary Information]	[Proprietary Information]
^{236m}Np	[Proprietary Information]	[Proprietary Information]
^{237}Np	[Proprietary Information]	[Proprietary Information]
^{238}Np	[Proprietary Information]	[Proprietary Information]
^{239}Np	[Proprietary Information]	[Proprietary Information]
^{233}Pa	[Proprietary Information]	[Proprietary Information]
^{234}Pa	[Proprietary Information]	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	[Proprietary Information]
^{112}Pd	[Proprietary Information]	[Proprietary Information]
^{147}Pm	[Proprietary Information]	[Proprietary Information]
^{148}Pm	[Proprietary Information]	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	[Proprietary Information]
^{149}Pm	[Proprietary Information]	[Proprietary Information]
^{150}Pm	[Proprietary Information]	[Proprietary Information]
^{151}Pm	[Proprietary Information]	[Proprietary Information]
^{142}Pr	[Proprietary Information]	[Proprietary Information]
^{143}Pr	[Proprietary Information]	[Proprietary Information]
^{144}Pr	[Proprietary Information]	[Proprietary Information]
^{144m}Pr	[Proprietary Information]	[Proprietary Information]
^{145}Pr	[Proprietary Information]	[Proprietary Information]
^{238}Pu	[Proprietary Information]	[Proprietary Information]
^{239}Pu	[Proprietary Information]	[Proprietary Information]
^{240}Pu	[Proprietary Information]	[Proprietary Information]
^{241}Pu	[Proprietary Information]	[Proprietary Information]

Table 4-38. Nitrogen Oxide Scrubbers In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing	
Unit operation	NO_x scrubbers	
Decay Time after EOI[a]	[Proprietary Information]	
Stream description[b]	Scrubbed gas	Scrubber waste
Isotopes	Ci[c]	Ci[c]
^{103m}Rh	[Proprietary Information]	[Proprietary Information]
^{105}Rh	[Proprietary Information]	[Proprietary Information]
^{106}Rh	[Proprietary Information]	[Proprietary Information]
^{106m}Rh	[Proprietary Information]	[Proprietary Information]
^{103}Ru	[Proprietary Information]	[Proprietary Information]
^{105}Ru	[Proprietary Information]	[Proprietary Information]
^{106}Ru	[Proprietary Information]	[Proprietary Information]
^{122}Sb	[Proprietary Information]	[Proprietary Information]
^{124}Sb	[Proprietary Information]	[Proprietary Information]
^{125}Sb	[Proprietary Information]	[Proprietary Information]
^{126}Sb	[Proprietary Information]	[Proprietary Information]
^{127}Sb	[Proprietary Information]	[Proprietary Information]
^{128}Sb	[Proprietary Information]	[Proprietary Information]
^{128m}Sb	[Proprietary Information]	[Proprietary Information]
^{129}Sb	[Proprietary Information]	[Proprietary Information]
^{151}Sm	[Proprietary Information]	[Proprietary Information]
^{153}Sm	[Proprietary Information]	[Proprietary Information]
^{156}Sm	[Proprietary Information]	[Proprietary Information]
^{89}Sr	[Proprietary Information]	[Proprietary Information]
^{90}Sr	[Proprietary Information]	[Proprietary Information]
^{91}Sr	[Proprietary Information]	[Proprietary Information]
^{92}Sr	[Proprietary Information]	[Proprietary Information]
^{99}Tc	[Proprietary Information]	[Proprietary Information]
^{99m}Tc	[Proprietary Information]	[Proprietary Information]
^{125m}Te	[Proprietary Information]	[Proprietary Information]
^{127}Te	[Proprietary Information]	[Proprietary Information]
^{127m}Te	[Proprietary Information]	[Proprietary Information]
^{129}Te	[Proprietary Information]	[Proprietary Information]
^{129m}Te	[Proprietary Information]	[Proprietary Information]
^{131}Te	[Proprietary Information]	[Proprietary Information]
^{131m}Te	[Proprietary Information]	[Proprietary Information]
^{132}Te	[Proprietary Information]	[Proprietary Information]
^{133}Te	[Proprietary Information]	[Proprietary Information]
^{133m}Te	[Proprietary Information]	[Proprietary Information]
^{134}Te	[Proprietary Information]	[Proprietary Information]
^{231}Th	[Proprietary Information]	[Proprietary Information]
234Th	[Proprietary Information]	[Proprietary Information]
^{232}U	[Proprietary Information]	[Proprietary Information]

Table 4-38. Nitrogen Oxide Scrubbers In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing	
Unit operation	NO_x scrubbers	
Decay Time after EOI[a]	[Proprietary Information]	
Stream description[b]	Scrubbed gas	Scrubber waste
Isotopes	**Ci**[c]	**Ci**[c]
^{234}U	[Proprietary Information]	[Proprietary Information]
^{235}U	[Proprietary Information]	[Proprietary Information]
^{236}U	[Proprietary Information]	[Proprietary Information]
^{237}U	[Proprietary Information]	[Proprietary Information]
^{238}U	[Proprietary Information]	[Proprietary Information]
^{131m}Xe	[Proprietary Information]	[Proprietary Information]
^{133}Xe	[Proprietary Information]	[Proprietary Information]
^{133m}Xe	[Proprietary Information]	[Proprietary Information]
^{135}Xe	[Proprietary Information]	[Proprietary Information]
^{135m}Xe	[Proprietary Information]	[Proprietary Information]
^{89m}Y	[Proprietary Information]	[Proprietary Information]
^{90}Y	[Proprietary Information]	[Proprietary Information]
^{90m}Y	[Proprietary Information]	[Proprietary Information]
^{91}Y	[Proprietary Information]	[Proprietary Information]
^{91m}Y	[Proprietary Information]	[Proprietary Information]
^{92}Y	[Proprietary Information]	[Proprietary Information]
^{93}Y	[Proprietary Information]	[Proprietary Information]
^{93}Zr	[Proprietary Information]	[Proprietary Information]
^{95}Zr	[Proprietary Information]	[Proprietary Information]
^{97}Zr	[Proprietary Information]	[Proprietary Information]
Total Ci	[Proprietary Information]	[Proprietary Information]

[a] In-process inventory based on [Proprietary Information], neglecting time required to receive, disassemble, and dissolve targets.

[b] Figure 4-63 provides a simplified description of the process streams.

[c] In-process inventory based on [Proprietary Information], representing the weekly process throughput. Normal operation expected to prepare a dissolver charge containing [Proprietary Information] such that the in-process inventory of an individual target dissolution offgas system is described by one-half the listed radionuclide inventory.

EOI = end of irradiation.
MURR = University of Missouri Research Reactor.
NO_x = nitrogen oxide.

[Proprietary Information]

Figure 4-64. Fission Gas Treatment In-Process Radionuclide Inventory Streams

Scrubbed gas from the NO_x scrubbers and disassembly offgas will be passed through the fission gas treatment unit operations prior to release via the process vessel ventilation system. Figure 4-64 provides a simplified description of process streams used to describe the in-process radionuclide inventory. The in-process radionuclide inventory entering the fission gas treatment unit operations includes the disassembly offgas stream in Table 4-33 and the scrubbed gas stream in Table 4-38.

The fission gas treatment system will remove iodine isotopes from gas passing through the system and delay the release of Kr and Xe isotopes to reduce the activity in offgas emission by decay. Table 4-39 describes the radionuclides in treated target dissolution offgas. Isotopes of Kr will be reduced by a holdup of [Proprietary Information] and Xe isotopes will be reduced by a [Proprietary Information]. Iodine is captured on solid materials in the IRUs. The total in-process inventory of captured radionuclides and isotopes delayed for decay vary as radionuclides from one processing week decay as additional material is captured during subsequent operating weeks. Bounding estimates for the in-process inventory of iodine, Kr, and Xe isotopes are estimated in NWMI-2013-CALC-011. The bounding estimates produce a total equilibrium in-process inventory on fission gas treatment equipment of [Proprietary Information] for all iodine isotopes, [Proprietary Information] for all Kr isotopes, and [Proprietary Information] for all Xe isotopes.

Table 4-39. Fission Gas Treatment In-Process Radionuclide Inventory (3 pages)

Item	MURR target processing	Item	MURR target processing
Unit operation:	Fission gas treatment	**Unit operation:**	Fission gas treatment
Decay time after EOI[a]	[Proprietary Information]	**Decay time after EOI:**	[Proprietary Information]
Stream description[b]	Treated target dissolution offgas	**Stream description:**	Treated target dissolution offgas
Isotopes	**Ci**[c]	**Isotopes**	**Ci**[c]
^{241}Am	[Proprietary Information]	^{239}Pu	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	^{240}Pu	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	^{241}Pu	[Proprietary Information]
^{139}Ba	[Proprietary Information]	^{103m}Rh	[Proprietary Information]
^{140}Ba	[Proprietary Information]	^{105}Rh	[Proprietary Information]
^{141}Ce	[Proprietary Information]	^{106}Rh	[Proprietary Information]
^{143}Ce	[Proprietary Information]	^{106m}Rh	[Proprietary Information]
^{144}Ce	[Proprietary Information]	^{103}Ru	[Proprietary Information]
^{242}Cm	[Proprietary Information]	^{105}Ru	[Proprietary Information]
^{243}Cm	[Proprietary Information]	^{106}Ru	[Proprietary Information]
^{244}Cm	[Proprietary Information]	^{122}Sb	[Proprietary Information]
^{134}Cs	[Proprietary Information]	^{124}Sb	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	^{125}Sb	[Proprietary Information]
^{136}Cs	[Proprietary Information]	^{126}Sb	[Proprietary Information]
^{137}Cs	[Proprietary Information]	^{127}Sb	[Proprietary Information]
^{155}Eu	[Proprietary Information]	^{128}Sb	[Proprietary Information]
^{156}Eu	[Proprietary Information]	^{128m}Sb	[Proprietary Information]
^{157}Eu	[Proprietary Information]	^{129}Sb	[Proprietary Information]
^{129}I	[Proprietary Information]	^{151}Sm	[Proprietary Information]
^{130}I	[Proprietary Information]	^{153}Sm	[Proprietary Information]
^{131}I	[Proprietary Information]	^{156}Sm	[Proprietary Information]
^{132}I	[Proprietary Information]	^{89}Sr	[Proprietary Information]
^{132m}I	[Proprietary Information]	^{90}Sr	[Proprietary Information]
^{133}I	[Proprietary Information]	^{91}Sr	[Proprietary Information]
^{133m}I	[Proprietary Information]	^{92}Sr	[Proprietary Information]
^{134}I	[Proprietary Information]	^{99}Tc	[Proprietary Information]
^{135}I	[Proprietary Information]	^{99m}Tc	[Proprietary Information]
^{83m}Kr [d]	[Proprietary Information]	^{125m}Te	[Proprietary Information]
^{85}Kr [d]	[Proprietary Information]	^{127}Te	[Proprietary Information]
^{85m}Kr [d]	[Proprietary Information]	^{127m}Te	[Proprietary Information]
^{87}Kr [d]	[Proprietary Information]	^{129}Te	[Proprietary Information]

Table 4-39. Fission Gas Treatment In-Process Radionuclide Inventory (3 pages)

Item	MURR target processing	Item	MURR target processing
Unit operation:	Fission gas treatment	**Unit operation:**	Fission gas treatment
Decay time after EOI[a]	[Proprietary Information]	**Decay time after EOI:**	[Proprietary Information]
Stream description[b]	Treated target dissolution offgas	**Stream description:**	Treated target dissolution offgas
Isotopes	**Ci**[c]	**Isotopes**	**Ci**[c]
^{88}Kr [d]	[Proprietary Information]	^{129m}Te	[Proprietary Information]
^{140}La	[Proprietary Information]	^{131}Te	[Proprietary Information]
^{141}La	[Proprietary Information]	^{131m}Te	[Proprietary Information]
^{142}La	[Proprietary Information]	^{132}Te	[Proprietary Information]
^{99}Mo	[Proprietary Information]	^{133}Te	[Proprietary Information]
^{95}Nb	[Proprietary Information]	^{133m}Te	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	^{134}Te	[Proprietary Information]
^{96}Nb	[Proprietary Information]	^{231}Th	[Proprietary Information]
^{97}Nb	[Proprietary Information]	^{234}Th	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	^{232}U	[Proprietary Information]
^{147}Nd	[Proprietary Information]	^{234}U	[Proprietary Information]
^{236m}Np	[Proprietary Information]	^{235}U	[Proprietary Information]
^{237}Np	[Proprietary Information]	^{236}U	[Proprietary Information]
^{238}Np	[Proprietary Information]	^{237}U	[Proprietary Information]
^{239}Np	[Proprietary Information]	^{238}U	[Proprietary Information]
^{233}Pa	[Proprietary Information]	^{131m}Xe [d]	[Proprietary Information]
^{234}Pa	[Proprietary Information]	^{133}Xe [d]	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	^{133m}Xe [d]	[Proprietary Information]
^{112}Pd	[Proprietary Information]	^{135}Xe [d]	[Proprietary Information]
^{147}Pm	[Proprietary Information]	^{135m}Xe [d]	[Proprietary Information]
^{148}Pm	[Proprietary Information]	^{89m}Y	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	^{90}Y	[Proprietary Information]
^{149}Pm	[Proprietary Information]	^{90m}Y	[Proprietary Information]
^{150}Pm	[Proprietary Information]	^{91}Y	[Proprietary Information]
^{151}Pm	[Proprietary Information]	^{91m}Y	[Proprietary Information]
^{142}Pr	[Proprietary Information]	^{92}Y	[Proprietary Information]
^{143}Pr	[Proprietary Information]	^{93}Y	[Proprietary Information]
^{144}Pr	[Proprietary Information]	^{93}Zr	[Proprietary Information]
^{144m}Pr	[Proprietary Information]	^{95}Zr	[Proprietary Information]
^{145}Pr	[Proprietary Information]	^{97}Zr	[Proprietary Information]
^{238}Pu	[Proprietary Information]	Total Ci	[Proprietary Information]

[a] In-process inventory based on [Proprietary Information], neglecting time to receive, disassemble, and dissolve targets.

[b] Figure 4-64 provides a simplified description of the process streams.

[c] In-process inventory based on [Proprietary Information], representing the weekly process throughput. Normal operation expected to prepare a dissolver charge containing [Proprietary Information] such that the in-process inventory of an individual target dissolution offgas system is described by one-half the listed radionuclide inventory.

[d] Fission gas treatment system based on noble gas holdup for decay. System provides [Proprietary Information] of Kr isotopes and [Proprietary Information] for Xe isotopes.

EOI = end of irradiation.
Kr = krypton.
MURR = University of Missouri Research Reactor.
Xe = xenon.

Radiological Protection Features

Radiological protection features are designed to prevent the release of radioactive material and to maintain radiation levels below the applicable radiation exposure limits prescribed in 10 CFR 20 for the protection of workers and the public. These features include defense-in-depth and engineered safety features. The engineered safety features identified in this section are described in Chapter 6.0, Section 6.2.

The following defense-in-depth features will provide radiological protection to workers and the public.

- Target dissolution processes operate at or slightly below atmospheric pressure, or solutions are pumped between tanks that are at atmospheric pressure to reduce the likelihood of a system breach at high pressure.
- The process equipment is designed for high reliability with materials that minimize corrosion rates associated with the processed solutions.
- Alarming radiation monitors provide continuous monitoring of dose rate in occupied areas and alarm at an appropriate setpoint above background.

Chapter 13.0, Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the target dissolution activities and will provide radiological protection to workers and the public:

- The high-dose material and solution is processed inside shielded areas. The hot cell shielding boundary (IROFS RS-04) provides shielding for workers and the public at workstations and occupied areas outside of the hot cell. The hot cell liquid confinement boundary (IROFS RS-01) prevents releases of liquid.
- Radioactive gases flow to target dissolution offgas treatment, which is part of the hot cell secondary confinement boundary (IROFS RS-03).

4.3.4.6 Chemical Hazards

This section provides a summary of the maximum amounts of chemicals used in the process and the associated chemical hazards. Any required chemical protection provisions designed into the process systems and components are also identified.

Chemical Inventory

Chemicals used for the dissolution and offgas treatment processes will include oxygen gas, nitric acid, NaOH, Na_2SO_3, and hydrogen peroxide solutions. Estimated quantities are listed in Table 4-40.

Table 4-40. Chemical Inventory for the Target Dissolution Area

Chemical	OSU batch	MURR batch	Annual quantity
20% (6.1 M) NaOH	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
5% NaOH + 5% Na_2SO_3 solution	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Hydrogen peroxide (30%)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Nitric acid (10 M)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Nitrogen gas	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Oxygen gas	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Note: This table does not include the special nuclear material identified in Table 4-36.

MURR = University of Missouri Research Reactor.
Na_2SO_3 = sodium sulfite.
NaOH = sodium hydroxide.
OSU = Oregon State University.

Chemical Protection Provisions

The chemical hazards for target dissolution system are described in Chapter 9.0. Chemicals hazards within the system are bounded by the radiological hazards. The features preventing release of radioactive material and limiting radiation exposure will also protect workers and the public from exposure to hazardous chemicals.

4.3.5 Molybdenum Recovery and Purification System

The Mo recovery and purification system description provides information regarding the process, process equipment, SNM and radioactive inventories, and the hazardous chemicals used in the system. The process description (Section 4.3.5.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.3.5.2 and 4.3.5.3. These sections describe the equipment in sufficient detail to provide confidence that SNM and byproduct material can be controlled throughout the process. A description of the SNM in terms of physical and chemical form, volume in process, required criticality control features, and radioactive inventory in process is provided in Sections 4.3.5.4 and 4.3.5.5. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.3.5.6.

4.3.5.1 Process Description

The overall function of the Mo recovery and purification system is to extract ^{99}Mo from uranyl nitrate solution, remove impurities from the ^{99}Mo solution, and package the solution in shipping containers and casks. The target dissolution system will provide the uranyl nitrate solution with ^{99}Mo, and the U recovery and recycle system will receive the uranyl nitrate solution after the ^{99}Mo has been extracted.

The Mo recovery and purification flow diagram, Figure 4-65, illustrates the basic process steps and diagrams the relationships between the five subsystems of the Mo recovery and purification system:

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

[Proprietary Information]

Figure 4-65. Simplified Molybdenum Recovery and Purification Process Flow Diagram

Primary Ion Exchange

The first set of IX columns (MR-IX-125 and MR-IX-165) will [Proprietary Information], which will retain molybdenum from an acidic solution while allowing other species to pass through. Other species that will be retained to some extent [Proprietary Information].

The feed tanks (MR-TK-100 and MR-TK-140) for the primary IX subsystem will be located in the tank hot cell (H014), and the primary IX columns will be located in the Mo recovery hot cell (H106).

The column operation will consist of pumping a sequence of solutions through the IX media (summarized in Table 4-41). Column effluents will be routed to different vessels during a process cycle, depending on the processing step. The column operations will include the following.

- **Loading cycle** – Uranyl nitrate solution with ^{99}Mo will be pumped to the columns from the feed tanks to retain ^{99}Mo from the solution. [Proprietary Information]. Column effluent during the loading cycle will be routed to the U recovery and recycle system.
- **Pre-elution rinse cycle** – To ensure that the ^{99}Mo in the solution has had a chance to load onto the column, a water rinse solution will be pumped from the chemical addition hood (MR-EN-110) through the column after the loading cycle. Effluent from the column will be routed to the waste handling system.

Table 4-41. Typical Ion Exchange Column Cycle

Cycle	Column feed solution	Flow (cm/min)	Volume (BV)
Loading	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Pre-elution rinse	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Elution	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Regeneration	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

BV = bed volume
HNO_3 = nitric acid.
NaOH = sodium hydroxide.

- **Elution cycle** – Once the pre-elution rinse cycle is complete, the column feed will be switched to a solution containing [Proprietary Information]. This solution will be pumped from the chemical addition hood (MR-EN-110). Molybdenum will be eluted off the column, and the effluent from the column will be routed to the Mo purification feed tank #2 (MR-TK-200).
- **Regeneration step cycle** – Restoring the column to a nitric acid condition will be done by rinsing the column with a [Proprietary Information]. Column effluent will be directed to the waste handling system.

Secondary Ion Exchange

The eluate from the primary IX column will be adjusted with [Proprietary Information] will be fed by the operator via the chemical addition hood (MR-EN-110) to the feed tank 2 (MR-TK-200) located in the Mo recovery hot cell (H106). The [Proprietary Information] state so that it does not adsorb to the secondary IX column (MR-IX-225).

The second product recovery and purification IX column will be a [Proprietary Information] form prior to use. The column operation will consist of pumping a sequence of solutions (listed in Table 4-42) through the IX media. Column effluents will be routed to different vessels during a process cycle, depending on the processing step. The column operations will include the following.

Table 4-42. Strong Basic Anion Exchange Column Cycle

Cycle	Column feed solution	Flow (cm/min)	Volume (BV)
Loading	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Pre-elution rinse	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Elution	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Regeneration (first)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Regeneration (second)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Preconditioning	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

BV = bed volume

- **Loading cycle** – Mo solution will be fed to the column during the loading cycle to retain the Mo from the solution. The material will adsorb [Proprietary Information] of the incoming Mo, along with only a trace of the [Proprietary Information] noted earlier. Column effluent during the loading cycle will be routed to the waste handling system.
- **Pre-elution rinse cycle** – To ensure that all the Mo in the solution has had a chance to load onto the column, a water rinse solution will be routed to the column after the loading cycle. Effluent from the column will be routed to the waste handling system.
- **Elution cycle** – Once the pre-elution rinse cycle is complete, the column feed will be switched to a solution containing [Proprietary Information]. The Mo will be eluted off the column, and the effluent from the column will be routed to the Mo purification feed tank #3 (MR-TK-300) located in the Mo purification hot cell (H107).
- **Regeneration first step** – Restoring the column to a phosphate form will begin with [Proprietary Information]. This step will displace the nitrate ions in the column with nitrite ions. Column effluent will be directed to the waste handling system.
- **Regeneration second step** – The second step will displace nitrite ions by rinsing the column with a [Proprietary Information]. Column effluent will be directed to the waste handling system.
- **Preconditioning step** – To ensure the [Proprietary Information] will be pumped through the column. Column effluent will be directed to the waste handling system.

The chemical rinses for the secondary IX column will be fed from the chemical addition hood (MR-EN-110).

The waste streams from the IX columns will accumulate in the waste collection tank (MR-TK-340). Sampling will verify the absence of fissile material prior to being pumped to the large-geometry waste handling system.

Tertiary Ion Exchange

Beginning with the collection of the eluate from the secondary IX column, the tertiary IX activities will take place within the Mo purification hot cell (H107), where special considerations for the aseptic handling of the Mo product will be applied. Air purified to U.S. Pharmacopeial Convention (USP) standards, along with chemicals that have this level of purity, will be used to ensure the integrity of the Mo product.

The eluate from the secondary IX media will require [Proprietary Information]. The third IX media will [Proprietary Information] and the column (MR-IX-325) will be operated as described for the primary IX column. The exception is that during the loading cycle, the effluent will be directed to the waste handling subsystem. The volume of feed material to this column will be much smaller than the liquid feed to the first or second column. The eluate from this column will be the molybdate product, which will flow to the product tank (MR-TK-400).

Molybdenum Product

Once the ^{99}Mo product solution is eluted, a small amount of bleach solution will be added and samples taken for verification of product specifications, which are listed in Table 4-43. The product from one [Proprietary Information] with a small amount of [Proprietary Information] added. This product will have an instantaneous ^{99}Mo content as high as [Proprietary Information], depending on the time between the EOI and the molybdenum recovery.

Table 4-43. Purified Molybdenum Product Specification

Item	Lantheus requirement	Mallinckrodt requirements
Chemical form[a]	[Proprietary Information]	[Proprietary Information]
Specific activity	[Proprietary Information]	[Proprietary Information]
Concentration[b]	[Proprietary Information]	[Proprietary Information]
Radiopurity[c,d]	[Proprietary Information]	[Proprietary Information]
Gamma	[Proprietary Information]	[Proprietary Information]
Other gammas (excluding ^{99m}Tc)	[Proprietary Information]	[Proprietary Information]
Beta	[Proprietary Information]	[Proprietary Information]
Alpha	[Proprietary Information]	[Proprietary Information]

Source: NWMI-2013-049, *Process System Functional Specification*, Rev. C, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[a] Product is normally stabilized by addition [Proprietary Information].

[b] Activity and concentration specifications are at buyer's calibration time.

[c] Radiopurity specifications are at 72 hr after buyer's official receipt time.

[d] Assay accuracy of material delivered will be ±5% of labeled value.

[e] Based on vendor's calibration date.

Na_2MoO_4 = sodium molybdate.
NaOCl = sodium hypochlorite.
NaOH = sodium hydroxide.

The operators will fill and weigh the ^{99}Mo product via the product holder/scale (MR-Z-420) from the product tank. Using hot cell manipulators, the operator will fill the designated product vessels and transfer the product vessel containing the ^{99}Mo product to the capping unit (MR-Z-430). The ^{99}Mo product vessel will then be capped, sealed, and prepared for transfer to the product and sample hot cell (H108) via an isolation door.

Using hot cell manipulators, a single container will be passed through the transfer door from the Mo purification hot cell (H107) into the product and sample hot cell (H108). Once the shipping cask is in position, the operator may safely open the product transfer port (MR-TP-400) entry door. Using hot cell manipulators, the operator will load the shipping cask with the packaged ^{99}Mo product.

4.3.5.2 Process Equipment Arrangement

The Mo recovery hot cell, Mo purification hot cell, and product and sample hot cell location will be within the rows of the processing hot cells shown in Figure 4-66.

[Proprietary Information]

Figure 4-66. Molybdenum Product Hot Cell Equipment Arrangement

The equipment arrangement within the Mo recovery hot cell is shown in Figure 4-67. The uranyl nitrate solution will be pumped into the hot cell to one of the IX columns (MR-IX-125 or MR-IX-165). The eluate from these columns will collect in the feed tank 2 (MR-TK-200) and will then be pumped to IX column 2 (MR-IX-225). The chiller (MR-Z-130) will maintain constant temperatures in the IX columns. The eluate from IX column 2 (MR-IX-225) will flow to feed tank 3 (MR-TK-300) in the Mo purification hot cell (H107).

[Proprietary Information]

Figure 4-67. Molybdenum Recovery Hot Cell Equipment Arrangement

The equipment arrangement within the Mo purification exchange hot cell is shown in Figure 4-68. Molybdenum solution will be collected in feed tank 3 (MR-TK-300) and will then be pumped through IX column 3 (MR-IX-325). The product will collect in the product tank (MR-TK-400), where final adjustments will be made. The operator will fill and weigh product containers on the product holder/scale (MR-Z-420) and seal the container with the capping unit (MR-Z-430). Product containers will be transferred by manipulators through the isolation door to the product and sample hot cell (H108).

[Proprietary Information]

Figure 4-68. Molybdenum Purification Hot Cell Equipment Arrangement

The arrangement of the product and sample hot cell equipment is shown in Figure 4-69. Product and sample containers will be transferred by manipulator into the hot cell. These containers will be loaded into their respective transfer carts by the product and sample hoist (MR-L-400) through the transfer ports.

[Proprietary Information]

Figure 4-69. Product and Sample Hot Cell Equipment Arrangement

The tanks feeding the uranyl nitrate solution (MR-TK-100 and MR-TK-140), the tank collecting the post-extraction uranyl nitrate solution (MR-TK-180), and the tank collecting the IX waste streams (MR-TK-340) will be located in the tank hot cell (H014A), as shown in Figure 4-70.

[Proprietary Information]

Figure 4-70. Molybdenum Feed Tank Hot Cell Equipment Arrangement

4.3.5.3 Process Equipment Design

The process equipment basis is described in the process description (Section 4.3.5.1) and located in the equipment arrangement (Section 4.3.5.2). Details for design parameters of the processing equipment, including normal operating conditions, are listed in Table 4-44. The auxiliary equipment, which includes chemical feed equipment, chillers, and handling equipment, is listed in Table 4-45.

Table 4-44. Molybdenum Recovery and Purification Process Equipment

Equipment name	Equipment no.	Individual tank capacity	Criticality-safe by geometry	Tank material	Operating conditions	
					Temperature °C	Pressure atm
Feed tank 1A	MR-TK-100	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
IX column 1A feed pump	MR-P-120	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
IX column 1A	MR-IX-125	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Feed tank 1B	MR-TK-140	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
IX column 1B feed pump	MR-P-150	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
IX column 1B	MR-IX-165	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
U solution collection tank	MR-TK-180	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
U solution tank pump	MR-P-190	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
Feed tank 2	MR-TK-200	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
IX column 2 feed pump	MR-P-210	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
IX column 2	MR-IX-225	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Feed tank 3	MR-TK-300	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
IX column 3 feed pump	MR-P-310	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
IX column 3	MR-IX-325	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Waste collection tank	MR-TK-340	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Waste collection tank pump	MR-P-350	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
Product tank	MR-TK-400	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Product tank pump	MR-P-410	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]

IX = ion exchange.
N/A = not applicable.
SS = stainless steel.
TBD = to be determined.
U = uranium.

Table 4-45. Molybdenum Recovery and Purification Auxiliary Equipment

Equipment name	Equipment no.	Equipment name	Equipment no.
Chemical addition hood	MR-EN-110	IX column 3 filter	MR-F-320
IX column 1 chemical pump	MR-P-115/155	Chiller 3	MR-Z-330
IX column 1 filter	MR-F-120/160	Product holder/scale	MR-Z-420
Chiller 1	MR-Z-130/170	Capping unit	MR-Z-430
IX column 2 chemical pump	MR-P-215	Product and sample hot cell	MR-EN-400
IX column 2 filter	MR-F-220	Product transfer port	MR-TP-400
Chiller 2	MR-Z-230	Sample transfer port	MR-TP-410
Mo purification hot cell	MR-EN-300	Product and sample hoist	MR-L-400
IX column 3 chemical pump	MR-P-315		

IX = ion exchange.
Mo = molybdenum.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. The process description identifies the control strategy for normal operations, which sets the requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information on the process monitoring and control equipment will be developed for the Operating License Application.

4.3.5.4 Special Nuclear Material Description

This section provides a summary of the maximum amounts of SNM and the chemical and physical forms of SNM used in the process. Any required criticality control features that are designed into the process systems and components are also identified. Criticality control features provided will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

Special Nuclear Material Inventory

The SNM inventory within the Mo recovery and purification system will be determined by the uranium in dissolver solution transfers into the IX column 1A/1B feed tanks (MR-TK-100 and MR-TK-140). Dissolver solution in the feed tanks will be passed through IX columns 1A and 1B (MR-IX-125 and MR-IX-165). During the IX column 1A/1B loading cycles, essentially all uranium will remain in the column effluent that is transferred to the U solution collection tank (MR-TK-180) and on to the impure U collection tanks in the U recovery and recycle system. IX column 1A/1B eluate transferred to feed tank 2 (MR-TK-200) and other column effluents transferred to the Mo system waste collection tank (MR-TK-340) will contain only trace quantities of uranium. The IX product and waste streams from IX column 2 (MR-IX-225) and IX column 3 (MR-IX-325) will also contain only trace uranium quantities.

Individual irradiated target dissolver solution transfers to the IX column 1A/1B feed tanks are described in Section 4.3.4.4 and are summarized as follows:

- During OSTR target processing:
  - [Proprietary Information]
  - [Proprietary Information]
  - [Proprietary Information]
  - [Proprietary Information]
- During MURR target processing:
  - [Proprietary Information]
  - [Proprietary Information]
  - [Proprietary Information]

[Proprietary Information] Table 4-46 summarizes the in-process SNM inventory for Mo recovery and purification SNM vessels containing the dominant uranium inventory. The Mo recovery and purification system SNM inventory is planned to be [Proprietary Information] (Section 4.3.1). Based on the alternative transfer sequences from target dissolution, the solution concentration in [Proprietary Information], after the initial dissolver solution transfer.

The uranium concentration will range from [Proprietary Information] (MR-TK-180) based on the solution concentration range after combination of dissolver solution and flush water. Waste collected in MR-TK-340 will contain only trace uranium quantities. All vessels associated with IX column 2 (MR-IX-225) and IX column 3 (MR-IX-325) operation will contain solutions with trace quantities of uranium and have been excluded from Table 4-46.

Table 4-46. Molybdenum Recovery and Purification System In-Process Special Nuclear Material Inventory

Stream	Form	Concentration	SNM mass[a]
Feed tank 1A – (MR-TK-100)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Feed tank 1B – (MR-TK-140)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U solution collection tank (MR-TK-180)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Mo system waste collection tank (MR-TK-340)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Mo system ion exchange vessels (MR-IX-125/165)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U)

[b] Aqueous solution of uranyl nitrate.

[c] Used as a transfer tank for feed tank solutions after ion exchange column processing. The SNM in-process inventory is described by the contents of a single feed tank during normal operation. Inventory is limited to solution in two of the three tanks MR-TK-100, MR-TK-14, and MR-TK-180.

[d] Aqueous solution with trace quantities of uranium ions that may be present in a variety of chemical forms.

[e] Based on two ion exchange columns, each with volume of 0.15 L.

^{235}U	= uranium-235.	Mo	= molybdenum.
^{238}U	= uranium-238.	SNM	= special nuclear material.
LEU	= low-enriched uranium.	U	= uranium.

Feed tank 1A and feed tank 1B were sized to contain solution from [Proprietary Information]. Therefore, the maximum inventory of each feed tank is described by solution from dissolution of [Proprietary Information]. Logistics to minimize the time for preparation of a ^{99}Mo product batch during MURR target processing may result in [Proprietary Information].

The U solution collection tank (MR-TK-180) will be used to support SNM-bearing solution transfers to the U recovery and recycle system impure U collection tanks and will be generated by processing material from a feed tank through IX column 1A or IX column 1B. Therefore, the bounding in-process SNM ^{99}Mo system inventory is described by the contents of the two feed tanks during normal operation.

Nuclear criticality evaluations performed in NWMI-2015-CRITCALC-006, *Tank Hot Cell*, indicate that the Mo recovery and purification system vessels located in the tank hot cell (MR-TK-100, MR-TK-140, MR-TK-180, and MR-TK-340) remain subcritical under normal and abnormal conditions when all vessels contain solution at a [Proprietary Information]. NWMI-2015-CSE-003, *NWMI Preliminary Criticality Safety Evaluation: Molybdenum-99 Product Recovery*, describes CSEs of the Mo recovery and purification system. The current double-contingency analysis in NWMI-2015-CSE-003 imposes a limit of [Proprietary Information] IX feed tank (MR-TK-100 and MR-TK-140) as a criticality safety control. Current criticality safety controls are based on single parameter limits under flooded conditions. Further evaluation of the Mo recovery and purification system criticality controls will be performed and included in the Operating License Application.

Criticality Control Features

Criticality control features are required in the Mo recovery and purification system, as defined in NWMI-2015-CSE-003. These features, including passive design and active engineered features, allow for adherence to the double-contingency principle. This section applies the criticality control features that are discussed in Chapter 6.0, Section 6.3.

The criticality control features for this subsystem will include the passive design and active engineered features with designators of PDF and AEF, respectively, listed below. The passive design features will include geometric constraints of the floor, process equipment, workstations, and ventilation system. The active engineered features will include the requirement of continuous ventilation. The passive design features affect the design of process equipment, ventilation piping, and the room floor. Chapter 6.0 provides detailed descriptions of the following criticality control features.

- For the case of a liquid leak, the floor will be criticality-safe (CSE-03-PDF1), and the floor will have a minimum area to preclude collection of leaked fissile solution at high concentration to an unfavorable depth (CSE-03-PDF2).
- The geometry of the process equipment will be inherently criticality safe (CSE-03-PDF3 and CSE-03-PDF4) and will maintain a subcritical geometry during and after a facility DBE (CSE-03-PDF5 and CSE-03-PDF9). The dissolver design and operability of the ventilation system will preclude pressurization of the process vessels (CSE-03-AFE-1).
- The molybdenum IX column volume will be limited, and the installation of support vessels will provide a safe geometry for criticality safety (CSE-03-PDF6, CSE-03-PDF7, and CSE-03-PDF8).
- The internal volume for the molybdenum local chiller will be limited (CSE-03-PDF10).
- For the case of liquid leaks to secondary systems, a safe-geometry secondary system barrier will be provided between the process vessels and the unfavorable-geometry supply systems (CSE-03-PDF11 and CSE-03-PDF12).

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the Mo recovery and purification activities.

- IROFS CS-02 sets batch limits on samples.
- IROFS CS-04 affects location, spacing, and design of workstations.
- IROFS CS-07 defines maximum tank diameters and minimum spacing between process equipment, which is applicable to the feed tanks, IX columns, and waste collection tanks.
- IROFS CS-08 controls the geometry of the floor to prevent criticality in the event of spills.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include the following.

- Tanks are vented and unpressurized during normal operations, and corrosion resistance is a design requirement. Level is monitored on all tanks and indicated to the operator to reduce the likelihood of overflow.
- Under normal conditions, the product samples have no fissile material, and therefore criticality is not feasible.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.
- The effects of a criticality accident are mitigated by the shielding described in Section 4.2.

The criticality control features provided throughout the Mo recovery and purification system will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.3.5.5 Radiological Hazards

Radionuclide Inventory

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. NWMI-2014-CALC-014 identifies the 123 dominant radioisotopes included in the MURR material balance (NWMI-2013-CALC-006). NWMI-2014-CALC-014 provides the basis for using the 123 radioisotopes from the total list of 660 radioisotopes potentially present in irradiated targets. The majority of omitted radioisotopes exist in trace quantities and/or decay swiftly to stable nuclides. The reduced set of 123 radioisotopes consists of those that dominate the radioactivity and decay heat of irradiated targets.

Activities during an operating week that process targets irradiated in the MURR represent the radionuclide inventory as described in Section 4.1. The radionuclide inventory will be based on a weekly throughput of [Proprietary Information] will be produced as dissolver solution in a dissolution hot cell and transferred to one of the two Mo recovery and purification system IX feed tanks located in the tank hot cell. Figure 4-71 provides a simplified description of process streams used to describe the in-process radionuclide inventory. The radionuclide inventory will be split among the three streams (Mo product, impure U, and Mo IX waste) in the Mo recovery and purification system hot cells.

[Proprietary Information]

Figure 4-71. Molybdenum Recovery and Purification In-Process Radionuclide Inventory Streams

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. The in-process radionuclide inventory passing through Mo recovery and purification activities during an operating week is listed in Table 4-46 based on a total of [Proprietary Information]. Normal operation will store large solution volumes in the tank hot cell. Therefore, the in-process inventory of the Mo recovery and purification hot cells includes a small fraction of the impure U and Mo IX waste streams, combined with the total Mo product stream. The in-process inventory is based on [Proprietary Information] to receive, disassemble, and dissolve targets for transfer to the first stage Mo IX feed tank and describes the generation of impure U. [Proprietary Information] of process time is required to complete recovery and purification activities for the Mo product. The allocations produce decay times ranging from [Proprietary Information] when combined with a minimum receipt target decay of [Proprietary Information] after EOI. The radionuclide inventory of dissolver solution transfers into the IX feed tanks is listed in Table 4-37.

Table 4-47. Molybdenum Recovery and Purification In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Mo recovery and purification	
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	Impure U	Mo product	Mo IX waste
Isotopes	Ci[c]	Ci[c]	Ci[c]
^{241}Am	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{139}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{242}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{243}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{244}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{155}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{157}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{130}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{83m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{87}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{88}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-47. Molybdenum Recovery and Purification In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Mo recovery and purification	
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	Impure U	Mo product	Mo IX waste
Isotopes	Ci [c]	Ci [c]	Ci [c]
^{141}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Mo	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{96}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Nd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236m}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{233}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{112}Pd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{149}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{150}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144m}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{145}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{240}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{241}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-47. Molybdenum Recovery and Purification In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation	Mo recovery and purification		
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	Impure U	Mo product	Mo IX waste
Isotopes	Ci [c]	Ci [c]	Ci [c]
^{106}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{122}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{124}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{126}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128m}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{153}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99m}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{231}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-47. Molybdenum Recovery and Purification In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation		Mo recovery and purification	
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	Impure U	Mo product	Mo IX waste
Isotopes	**Ci [c]**	**Ci [c]**	**Ci [c]**
^{234}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{232}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{235}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Total Ci	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] In-process inventory based on decay time ranging from [Proprietary Information], disassemble, and dissolve targets for transfer to the first stage Mo IX feed tank and describe the generation of impure U. An [Proprietary Information] of process time is allowed to complete recovery and purification activities to describe the Mo product and Mo IX waste generated. The allocations produce decay times ranging from [Proprietary Information] when combined with a minimum receipt target decay of [Proprietary Information].

[b] Figure 4-71 provides a simplified description of the process streams.

[c] In-process inventory based [Proprietary Information], representing the [Proprietary Information] throughput. Normal operation stores large solution volumes in the tank hot cell. Therefore, the in-process inventory of Mo recovery and purification hot cells is described by a small fraction of the impure U and Mo IX waste streams, combined with the total Mo product stream.

EOI = end of irradiation.
IX = ion exchange.
Mo = molybdenum.
MURR = University of Missouri Research Reactor.
U = uranium.

Radiological Protection Measures

Radiological protection features are designed to prevent the release of radioactive material and to maintain radiation levels below the applicable radiation exposure limits prescribed in 10 CFR 20 for the protection of workers and the public. These features include defense-in-depth and engineered safety features. The engineering safety features are identified in this section and described in Chapter 6.0, Section 6.2.

The following defense-in-depth features will provide radiological protection to workers and the public.

- Most solution process equipment operates at or slightly below atmospheric pressure or solutions are pumped between tanks that are at atmospheric pressure to reduce the likelihood of system breach at high pressure.
- The process equipment is designed for high reliability with materials that minimize corrosion rates associated with the processed solutions.
- Alarming radiation monitors provide continuous monitoring of the dose rate in occupied areas and alarm at an appropriate setpoint above background.

Chapter 13.0, Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the Mo recovery and purification activities and will provide radiological protection to workers and the public:

- The high-dose material and solution is processed inside shielded areas. The hot cell shielding boundary (IROFS RS-04) provides shielding for workers and the public at workstations and occupied areas outside of the hot cell. The hot cell liquid confinement boundary (IROFS RS-01) prevents releases of liquid.
- Radioactive gases flow to the target dissolution offgas treatment, which is part of the hot cell secondary confinement boundary (IROFS RS-03).

4.3.5.6 Chemical Hazards

This section provides a summary of the maximum amounts of chemicals used in the process and the associated chemical hazards. Any required chemical protection provisions that are designed into the process systems and components are also identified.

Chemical Inventory

Table 4-48 provides a summary of the supply chemicals required for Mo recovery and purification system unit operations based on the material balances. These chemicals will be managed through the laboratory chemical supply rather than bulk supply. Most of the additions will be in small batch bottles pumped into the Mo recovery hot cell and Mo purification hot cell via a glovebox with a high-purity air supply.

Higher purity chemicals will be needed, including USP-grade for some of the caustic and wash water used with the final IX column, plus the [Proprietary Information] added to the final product.

Table 4-48. Chemical Inventory for the Molybdenum Recovery and Purification Area

Chemical	OSU cycle (L)	MURR cycle (L)	Annual (L)[a]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Note: This table does not include the special nuclear material identified in Table 4-46.

[a] Computed as eight OSU campaigns of 30 targets, and 44 MURR campaigns of eight targets per year.

[Proprietary Information]
[Proprietary Information]
IX = ion exchange.
Mo = molybdenum.
MURR = University of Missouri Research Reactor.
[Proprietary Information]
[Proprietary Information]
[Proprietary Information]
[Proprietary Information]
OSU = Oregon State University.
[Proprietary Information]

Chemical Protection Provisions

The chemical hazards for the Mo recovery and purification system are described in Chapter 9.0. Chemicals hazards within the system are bounded by the radiological hazards. The features preventing release of radioactive material and limiting radiation exposure will also protect workers and the public from exposure to hazardous chemicals.

4.4 SPECIAL NUCLEAR MATERIAL PROCESSING AND STORAGE

This section describes the processing components and procedures involved in handling, processing and storing SNM beyond the radioisotope extraction process. Section 4.4.1 describes the processing of irradiated LEU, which comprises the U recovery and recycle system. The product of the U recovery and recycle system will be recycled LEU with doses low enough to be directly handled without shielding. Section 4.4.2 describes the processing of the fresh and recycled LEU, which comprises the target fabrication system. The product of the target fabrication system will be new targets.

4.4.1 Processing of Irradiated Special Nuclear Material

The U recovery and recycle system description provides information regarding the SNM processing time cycle, process, process equipment, SNM and radioactive inventories, and the hazardous chemicals used in the system. The SNM processing time-cycle identifies the functions for lag storage for feed storage and product solutions described in Section 4.3.1. The process description (Section 4.4.1.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 0 and 4.4.1.3. These sections describe the equipment in sufficient detail to provide confidence that the SNM and byproduct material can be controlled throughout the process. The description of SNM in terms of physical and chemical form, volume in process, required criticality control features, and radioactive inventory in process is provided in Sections 4.4.1.4 and 4.4.1.5. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.4.1.6.

Figure 4-72 provides an overview of the U recovery and recycle process. Uranium-bearing raffinate from the Mo recovery and purification system is processed by the U recovery and recycle system.

[Proprietary Information]

Figure 4-72. Uranium Recovery and Recycle Process Functions

The U recovery and recycle process will include three weeks of lag storage for feed solution and 13 weeks of lag storage for product solutions. The lag storage will have three main functions:

- Minimize the potential for uranium processing to delay Mo recovery and purification operations
- [Proprietary Information]
- Control the content of ^{237}U in solutions transferred between the uranium recycle and target fabrication systems

Depending on the source reactor of a target batch, the uranium processing will be performed in as many as [Proprietary Information]. For example, if OSU is the source reactor [Proprietary Information]. In contrast, if MURR is the source [Proprietary Information].

Two cycles of uranium purification will be included to separate uranium from unwanted fission products via ion exchange. The first cycle will separate the bulk of the fission product contaminant mass from the uranium product. Product will exit the IX column as a dilute uranium stream that is concentrated to control the stored volume of process solutions. Uranium from the first cycle will be purified by a nearly identical second-cycle system to reduce fission product contaminants to satisfy product criteria. Each IX 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.

Supporting systems will include interface tanks between the uranium process and waste handling vessels. These interface vessels will be required to monitor solutions that are transferred between process systems using different criticality control philosophies. The support systems will also include a uranium rework vessel for returning solutions to the second uranium cycle feed tank. Rework material will primarily originate from out-of-specification product when processing uranium from irradiated targets, but also could be obtained periodically from solution generated in the target fabrication system.

4.4.1.1 Process Description

Figure 4-73 provides an overview of the U recovery and recycle process.

[Proprietary Information]

Figure 4-73. Uranium Recovery and Recycle Overview

The process was divided into the following five major subsystems for design development:

- **Impure U lag storage** – An important feature of the RPF is to minimize the time that solutions containing ^{99}Mo are held up in the system equipment due to the short half-life of the primary product. The impure U lag storage process will consist of a group of solution storage vessels used to minimize the potential for the U recovery and recycle process to delay upstream processing activities in the target dissolution and Mo purification systems.
- **First-cycle uranium recovery** – This subsystem represents a group of unit operations that separate the bulk of the fission product contaminant mass from the uranium product. IX columns will be used as the primary contaminant separation unit operation. The IX column operation will be supported by tanks for storage of intermediate process solutions and a concentrator or condenser to control the volume of uranium product solutions.
- **Second-cycle uranium recycle** – This subsystem represents a group of unit operations that provide the final separation of fission product contaminants from the uranium product and is similar to the first-cycle uranium recovery system. Fission product separation will be performed using an IX column as the separation unit operation. The IX column operation will be supported by tanks for storage of intermediate process solutions and a concentrator or condenser to control the volume of uranium product solutions.
- **Product uranium lag storage** – This subsystem consists of a group of solution storage vessels included to minimize the potential for the U recovery and recycle process to delay upstream processing activities in the target dissolution and Mo purification systems. Delays will be minimized by providing storage for uranium product such that target fabrication delays have minimal impact on operating the U recovery and recycle system, with the impure U lag storage tanks available to receive solutions from the Mo purification system.
- **Other support** – This subsystem consists of a group of storage vessels that interface with other facility systems. The capabilities will include vessels to interface between the IX columns and liquid waste handling system supporting routine process waste transfers, and between the IX columns and solid waste handling system supporting periodic resin bed replacement.

The system is sized to purify [Proprietary Information] for recycle to the target fabrication system. The goal operating time is to complete the weekly process load in [Proprietary Information]. Equipment sizing is based on processing feed solution from [Proprietary Information]. Throughput turn-down associated with [Proprietary Information] from the MURR reactor will be accomplished by processing fewer sub-batches [Proprietary Information] in the U recovery and recycle system equipment during a particular operating week.

A simplified process flow diagram for the U recovery and recycle system, indicating the major process equipment, is shown in Figure 4-74. The material balances are presented for two uranium processing cases [Proprietary Information]. During operations, the system is designed to process uranium from a maximum of [Proprietary Information]. Uranium lag storage capacity has been included at the front and back end of the system to support a batch operating concept.

[Proprietary Information]

Figure 4-74. Simplified Uranium Recovery and Recycle Process Flow Diagram

Impure Uranium Collection (UR-TK-100/120/140/160)

Feed to the U recovery and recycle system will consist of uranium-bearing solutions generated by the first cycle of the Mo purification system, which will be accumulated in the impure U collection tanks. These vessels will provide a lag storage capability between the Mo purification and the uranium system equipment. The uranium-bearing solution has a nominal composition of approximately [Proprietary Information] when processing targets from MURR based on the material balance described in NWMI-2013-CALC-006. The uranium-bearing solution concentration is increased to approximately [Proprietary Information] when processing targets from the OSU reactor to reduce the solution volume stored by the impure U collection tanks.

Solution will be pumped from the Mo purification system feed tank through the IX beds to the impure U collection tanks. Tank capacity, when combined with the first-cycle uranium recovery IX feed tank, will be sized to contain feed solution lag storage such that uranium processed has been decayed at least [Proprietary Information].

The vessel contents will be maintained at a nominal temperature of [Proprietary Information] by cooling jackets while residing in the lag storage tanks. Radiolytic decay is considered the primary heat source of solutions stored in these vessels, and the solution will be maintained at the IX media operating temperature to reduce evaporation during the decay storage time. Storage temperature control will also minimize the time required for temperature adjustment when preparing a feed batch for the IX system.

No system-specific offgas treatment will be provided for this vessel. However, the potential exists for iodine-131 (^{131}I) to evolve in offgas from this vessel, and the vent system supporting the vessel is assumed to require treatment to control the iodine emissions.

Primary Ion Exchange

The primary IX subsystem will separate the bulk of the fission product contaminant mass from the uranium product.

IX Feed Tank #1 (UR-TK-200)

The IX feed tank will be used to prepare feed batches for the first-cycle uranium recovery system by adjusting the composition of solution fed in batches to IX column #1 to initiate separation of uranium from fission products. Solution from the impure U collection tanks will be adjusted to a composition of [Proprietary Information]. In addition, reductant will be added to each feed batch, converting fission [Proprietary Information]. The valence state adjustment will reduce the affinity of the IX media for plutonium by addition of a combination of [Proprietary Information]. Evaluation of the kinetics indicates that the reduction reaction is essentially complete in [Proprietary Information]. Holding reductant is added at a ratio of [Proprietary Information].

No system-specific offgas treatment will be provided for this vessel. However, the potential exists for ^{131}I to evolve in offgas from this vessel, and the vent system supporting the vessel is assumed to require treatment to control iodine emissions.

IX Column #1 (UR-IX-240/260)

The [Proprietary Information] was used in the preliminary design to describe the characteristics of a uranium purification media. [Proprietary Information]. The vendor information indicates that the material is generally produced to support analytical chemistry sample preparation. An industrial-scale material, with equivalent properties, is expected to be identified for the IX material used within the RPF. Discussion with the vendor indicates that [Proprietary Information]. A working capacity [Proprietary Information] has been used as the basis for column sizing (NWMI-2013-CALC-009, *Uranium Purification System Equipment Sizing*).

The uranium recovery column operation will consist of processing a sequence of solutions through the IX media. Column effluents will be routed to different vessels during a process cycle, depending on the ions present in the effluent. The column cycle operations are summarized as follows:

- **Loading cycle** – Adjusted solution from the IX feed tanks will be fed to the uranium recovery column during the loading cycle to capture uranium in the liquid phase on the IX media, allowing contaminants (e.g., fission products and plutonium) to pass through the column. [Proprietary Information]. Column effluent during the loading cycle will contain a small fraction of the feed uranium and most of the contaminants. The column effluent will be routed to the IX waste collection tanks during the loading cycle, and the composition is projected to [Proprietary Information].
- **Pre-elution rinse cycle** – Once the loading cycle is complete, the uranium recovery column feed will be switched to a solution containing [Proprietary Information] to flush residual loading cycle feed solution from the column liquid holdup. Effluent from the uranium recovery column will be routed to the IX waste collection tanks during the pre-elution rinse cycle because liquid holdup in the column is considered a solution with potential contaminants at the end of the loading cycle. The effluent composition is projected to be [Proprietary Information].

- **Elution cycle** – Once the pre-elution rinse cycle is complete, the uranium recovery column feed will be switched to a solution [Proprietary Information] from the media to the liquid phase passing through the column. Effluent from the uranium recovery column will be routed to the uranium concentrator feed tank #1 during the elution cycle. The selected eluent volume will be sufficient to flush any desorbed [Proprietary Information] from the column liquid holdup by the time the elution cycle is complete. The effluent solution (eluate) has a nominal composition of [Proprietary Information].
- **Regeneration cycle** – The regeneration cycle will prepare the uranium recovery media to perform a new loading cycle by replacing the liquid phase with a solution composition similar to the adjusted impure uranium feed solution. The column feed will be switched to a solution containing [Proprietary Information], which will be used to displace any residual liquid holdup that may be present at approximately [Proprietary Information]. Effluent from the uranium recovery column will be routed to the IX waste collection tanks during this cycle, and the effluent composition can be characterized as a solution that is on the order of [Proprietary Information].

Separation of the uranium system from the other major processes will provide the flexibility to select a column size to support the operation. NWMI-2013-CALC-009 performed a sensitivity study of column size versus the number of uranium batches purified in a week of operation. Therefore, column sizing could be viewed as a tradeoff between the complexity of processing more IX feed batches with the cost of maintaining a larger resin inventory in the facility. While not formally optimized, the sizing comparison selected a column size based on processing the uranium throughput in [Proprietary Information]. This allows a total [Proprietary Information] for processing each feed batch to complete the uranium processing in a total operating period of [Proprietary Information].

Table 4-49 provides a summary of the uranium recovery column cycles, including the volume processed, liquid phase flow rate, and time required to complete each cycle. The flows and volumes are based on a two-column system, operating in parallel, with a [Proprietary Information]. The two-column system was selected to achieve the required throughput using columns that satisfy geometrically favorable dimensions for criticality control. Pressure drop across a resin bed at the indicated flow rates is currently predicted to range from approximately [Proprietary Information].

Table 4-49. First-Cycle Uranium Recovery Ion Exchange Column Cycle Summary

Cycle	Fluid	Flow ($gal/min/ft^2$)	Dimensionless volume	Flow (L/hr)	Volume (L)	Time (hr)
Loading	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Pre-elution rinse	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Elution	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Regeneration	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Note: Volumes and flow rates for a single process batch use two columns operating in parallel with a [Proprietary Information] in each column. This information is provided for a single column in the two parallel column system. The recycled uranium is processed in [Proprietary Information] during an individual week of operation.

BV = bed volume. [Proprietary Information]
CV = column volume. [Proprietary Information]

Resin performance data provided by the vendor is at [Proprietary Information] which is used for the column operating conditions. Temperature control is provided for column feed streams and not on the IX column itself (no cooling jacket on column). Decay heat was evaluated as the primary heat load in the column during operation, and an adiabatic heat balance included in NWMI-2013-CALC-009 indicated that column cooling would not be required under normal operating conditions.

Primary Concentration

The primary concentration subsystem will receive solution from the primary IX subsystem during the elution cycle and concentrate the uranium such that is suitable for adjustment to the feed composition required as input to the secondary IX subsystem.

U Concentrator Feed Tank #1 (UR-TK-300)

Uranium-bearing solutions in column effluents during the elution cycle will be concentrated when generated to control the stored volume of process solutions. Eluant from IX column #1 will be routed to the U concentrator feed tank #1. This vessel will provide an interface between the column and concentrator that allows control of the concentrator feed rate. The capability to add water to the concentrator feed tank will be provided for control of the concentrate acid concentration. No system-specific offgas treatment will be provided for this vessel.

Uranium Concentrator/Condenser #1 (UR-Z-320)

The uranium concentrator/condenser #1 will be included in the first-cycle uranium system to reduce the volume of uranium-bearing solution that must be stored within the hot cell vessels. Uranium-bearing solution for purification will originate from elution of IX column #1, and the solution composition will be approximately [Proprietary Information]. The dilute solution will be concentrated using a thermosiphon concentrator that operates in a near-continuous operating mode based on natural convection for agitation during operation. The concentrator will be operated at approximately [Proprietary Information]. Under these operating conditions, nitric acid in the concentrate is predicted to be at [Proprietary Information]. The concentrate will be transferred to the uranium IX feed adjustment tanks in the second-cycle uranium recycle system.

Overhead vapors from the concentrator will be routed to a condenser that is currently modeled as a simple total condenser operating [Proprietary Information]. Condensate from the condenser is predicted to be characterized as a nitric acid solution with concentration of approximately [Proprietary Information]. No system-specific offgas treatment will be provided for this vessel.

Typical concentrator designs include a de-entrainment section to minimize carryover of uranium-bearing concentrate droplets to the overheads. A nominal superficial velocity of [Proprietary Information] at the concentrator operating conditions, assuming a [Proprietary Information] vessel for criticality control, is used to define the maximum eluent concentration rate. The selected column batch size was found to not be constrained by the de-entrainment section diameter.

Condensate Tanks #1 (UR-TK-340/360/370)

Condensate will consist of solutions that are approximately [Proprietary Information] and will enter the condensate tanks at approximately [Proprietary Information]. No system-specific offgas treatment will be provided for these vessels.

Condensate tank #1 will provide an interface point for monitoring condensate generated by uranium concentrator/condenser #1 prior to transfer to the liquid waste handling system. Equipment in the uranium system will be of geometrically favorable design for criticality control, while it is anticipated that the waste handling system equipment will use an alternate criticality control philosophy (e.g., mass control). The condensate tanks will provide a location for verifying that solutions comply with waste handling criticality control requirements using detectors, as shown in Figure 4-75.

[Proprietary Information]

Source: Figure 7-7 of NWMI-2013-CALC-009, *Uranium Purification System Equipment Sizing*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2013.

Figure 4-75. Condensate Tank #1 Configuration Concept

Condensate generated by eluate concentration represents a relatively large solution volume that would require an extensive commitment of process floor space if monitoring was performed by a collection, sampling, and transfer control approach. Therefore, an online monitoring concept is proposed for condensate transfers to the liquid waste handling system. Uranium in condensate (from concentrator foaming, or other off-normal conditions) was considered the component of interest for criticality control.

Continuous monitoring of the uranium concentration in condensate sample tank #1A will be provided by a sample loop to a uranium concentration detector (e.g., fluorimeter). Circulation to the detector will be operated at flow rates that allow sample tanks to approximate a continuous, stirred tank flow pattern. The detector on Tank #1A will control the routing of transfers out of condensate sample tank #1B. Solution transfers out of condensate sample tank #1B will be routed to waste handling, as long as condensate uranium concentrations comply with criticality control requirements.

A plug flow delay vessel was included between condensate sample tanks 1A and 1B to provide a minimum time of 10 min between detecting an upset uranium concentration and the observed uranium concentration reaching the diversion point. Diversion is expected to be accomplished by operation of a three-way valve such that the 10-min delay time could be considered conservative.

The plug flow delay vessel will provide a response time for the control system to divert solution away from transfers to waste handling prior to uranium reaching the waste handling transfer line. A high uranium concentration reading will result in diverting the condensate back to the concentrator feed tank and will stop the column elution. Operation in this recycle mode will continue until the off-normal conditions causing the high uranium condensate concentrations are corrected.

Condensate sample tank #1B will support recovery from an off-normal event, and the uranium monitor at this vessel will not be used during routine concentrator operation. The condensate sample tank #1B monitor will be used to determine that an upset has cleared from the delay vessel system, and condensate is allowed to be rerouted back to the waste system tanks after an upset.

Secondary Ion Exchange

The secondary IX subsystem will provide the final separation of fission product contaminants such that uranium-bearing solution complies with requirements for acceptance by the target fabrication system.

Uranium IX Feed Adjustment Tanks (UR-TK-400/420)

Concentrate from uranium concentrator/condenser #1 will be collected in one of two tanks that are used to alternate between collecting concentrate and feeding to IX column #2. After collecting a batch of concentrate, the solution will be prepared for feeding the IX column by adding a reductant to modify the valence state of plutonium remaining in the solution. The reductant is based on addition [Proprietary Information]. No system-specific offgas treatment will provided for these vessels.

A majority of radionuclides will be separated from the uranium-bearing solution by IX column #1. Radiolytic decay heat will not be significant in this vessel; however, a cooling jacket will be required to control temperature at the IX media operating temperature of [Proprietary Information] as chemical adjustments are performed.

IX Column #2 (UR-IX-460/480)

The dominant component composition of feed to IX column #2 will be similar to the feed composition of IX column #1 and has been assumed to be similar for the preliminary design description. The [Proprietary Information] will also be used for IX column #2, with a uranium loading of approximately [Proprietary Information] during the loading cycle.

The column operation will be similar to IX column #1 and will consist of a sequence of solutions that passes through the IX media. Column effluents will be routed to different vessels during a process cycle, depending on the ions present in the effluent.

The column cycle operations are summarized as follows.

- **Loading cycle** – Adjusted solution from the uranium IX feed adjustment tanks will be fed to the uranium recycle column during the loading cycle to capture uranium in the liquid phase on the IX media, allowing contaminants (fission products and plutonium) to pass through the column. Column effluent during the loading cycle will contain a small fraction the feed uranium and most of the feed contaminants. The column effluent will be routed to the IX waste collection tanks during the loading cycle, and the composition is projected to contain [Proprietary Information].
- **Pre-elution rinse cycle** – Once the loading cycle is complete, the uranium recycle column feed will be switched to a solution containing [Proprietary Information] to flush residual loading cycle feed solution from the column liquid holdup. Effluent from the uranium recycle column will be routed to the IX waste collection tanks during the pre-elution rinse cycle, as liquid holdup in the column is considered a solution with potential contaminants at the end of the loading cycle. The effluent composition is projected to be [Proprietary Information].

- **Elution cycle** – Once the pre-elution rinse cycle is complete, the uranium recycle column feed will be switched to a solution containing [Proprietary Information] passing through the column. Effluent from the uranium recycle column will be routed to the uranium concentrator feed tank #2 during the elution cycle. The selected eluent volume will be sufficient to flush any [Proprietary Information] from the column liquid holdup by the time the elution cycle is complete. The effluent solution (eluate) will have a nominal composition of [Proprietary Information].
- **Regeneration cycle** – The regeneration cycle will prepare the uranium media for performing a new loading cycle by replacing the liquid phase with a solution composition similar to the adjusted impure uranium feed solution. The column feed will be switched to a solution containing [Proprietary Information], which will be used to displace any residual liquid holdup that may be present at [Proprietary Information]. Effluent from the uranium recycle column will be routed to the IX waste collection tanks during this cycle, and the effluent composition can be characterized as a solution that is on the order of [Proprietary Information].

Column sizing for IX column #2 was assumed to be identical to IX column #1, based on processing [Proprietary Information]. This sizing was considered appropriate for preliminary design because the dominant component feed composition is similar to the IX column #1 feed composition. Therefore, Table 4-49 also provides a summary of the uranium recycle column cycles, including the volume processed, liquid phase flow rate, and time required to complete each cycle. The flows and volumes are based on a two-column system, operating in parallel, with a resin bed volume [Proprietary Information].

The column operating temperature will be [Proprietary Information]. Temperature control will be provided for column feed streams and not on the IX column itself (no cooling jacket on column).

Secondary Concentration

The secondary concentration subsystem will receive solution from the secondary IX subsystem during the elution cycle and concentrate the uranium such that is suitable for transfer to the uranium recycle subsystem.

U Concentrator Feed Tank #2 (UR-TK-500)

Uranium-bearing solutions in column effluents during the elution cycle will be concentrated, as the solutions are generated to control the stored volume of process solutions. Eluant from IX column #2 will be routed to the U concentrator feed tank #2. This vessel will provide an interface between the column and concentrator that will allow control of the concentrator feed rate. The capability to add water to the concentrator feed tank will be provided for control of the concentrate acid concentration. No system-specific offgas treatment will be provided for this vessel.

Uranium Concentrator/Condenser #2 (UR-Z-530)

Uranium concentrator/condenser #2 will be similar to uranium concentrator/condenser #1 and will be included in the second-cycle uranium system to reduce the volume of uranium-bearing solution that must be stored within the hot cell vessels. Uranium-bearing solution for purification will originate from elution of IX column #2, and the solution composition will be [Proprietary Information]. The dilute solution will be concentrated using a thermosiphon concentrator that operates in a near-continuous operating mode based on natural convection for agitation during operation. The concentrator will be operated at approximately [Proprietary Information]. The concentrate will be transferred to the recycled uranium collection and adjustment tanks.

Overhead vapors from the concentrator will be routed to a condenser that is currently modeled as a simple total condenser operating at [Proprietary Information]. Condensate from the condenser is predicted to be characterized as a nitric acid solution with concentration of [Proprietary Information]. No system-specific offgas treatment will be provided for this vessel.

Typical concentrator designs include a de-entrainment section to minimize carryover of uranium-bearing concentrate droplets to the overheads. A nominal superficial velocity of [Proprietary Information] at the concentrator operating conditions, assuming a [Proprietary Information] diameter vessel for criticality control, is used to define the maximum eluent concentration rate. The selected column batch size was found to not be constrained by de-entrainment section diameter.

Condensate Tanks #2 (UR-TK-540/560/570)

Condensate tanks #2 will provide an interface point for monitoring condensate generated by uranium concentrator/condenser #2 prior to transfer to the liquid waste handling system. The function of these vessels is identical to that of condensate tanks #1. No system-specific offgas treatment will be provided for these vessels.

Recycled Uranium Collection Tanks (UR-TK-600 and UR-TK-620)

The recycled uranium collection tanks will provide a lag storage capability between the uranium recycle and target fabrication system equipment. The solution entering the vessels will originate as concentrate from uranium concentrator/condenser #2. The solution will have a nominal composition ranging from [Proprietary Information].

Two individual tanks will be provided for recycled uranium product collection. The recycled uranium collection tanks will perform the following functions.

- **Concentrate receiver tank** – This receiver tank will accumulate recycled uranium batches generated by uranium concentrator #2. The tank will provide holdup of the uranium solution as it is generated by the concentrator to create solution batches that can be periodically transferred to a vessel that can be sampled to confirm compliance with product specifications.
- **Product sample tank** – This sample tank will be used to verify that the recycled uranium complies with product specifications. The tank will provide a vessel for sampling an accumulated batch of concentrate from uranium concentrator #2. The sample vessel will provide a location for the sampler installation and holdup time for the uranium product batch sample to be analyzed. The vessel will also enable the diversion of the sampled solution to a rework tank if sample analysis indicates that the product batch does not comply with product specifications.

A nominal temperature of [Proprietary Information] is currently specified for solution stored in the recycled uranium collection tanks, and cooling jackets are included to cool concentrate stored in the product sample and recycle uranium transfer send tanks. No system-specific offgas treatment will be provided for this vessel.

Uranium Rework Tank (UR-TK-660)

The uranium rework tank will provide the capability to divert out-of-specification recycled uranium, detected in the product sample tank, to be accumulated and returned to one of the two uranium feed batch adjustment tanks. The solution will then be processed by transfer to the uranium IX adjustment tanks in the second-cycle uranium system and prepared to be feed to IX column #2. No system-specific offgas treatment will be provided for this vessel.

Uranium Decay and Accountability Tanks (UR-TK-700 and UR-TK-720)

NWMI-2014-RPT-005, *Uranium Recovery and Recycle Process Evaluation Decisions*, recommends that transfers of uranium product from the uranium system be delayed to allow for decay of [Proprietary Information] to transfer to the target fabrication system. The recycled uranium should be greater than or equal to an [Proprietary Information] for radiation exposure to be reduced to a level that allows contact operation and maintenance in the target fabrication systems. The uranium decay holdup tanks will provide storage [Proprietary Information].

The uranium decay holdup tanks will consist of [Proprietary Information] that are supported by a manifold system that will allow filling and emptying of individual tanks. The tank group capacity is estimated to provide the required holdup time for a system that processes the uranium throughput of [Proprietary Information].

The uranium decay holdup tanks will be co-located with a recycled uranium transfer send tank, which will provide the capability to perform accountability measurements of uranium crossing a facility licensing boundary. The transfer send tank will provide a vessel for performing measurement of the uranium mass that is transferred between the uranium and target fabrication systems. The uranium mass measurement will need to emphasize techniques that provide an uncertainty conforming to accountability requirements. Sample analyses will focus only on the uranium and nitric acid concentration of product solution. Multiple samples and tank level instruments may be needed to reduce measurement uncertainty. In addition, the temperature of process solutions during sampling, tank level measurements, and sample analysis may need to be controlled.

Spent Ion Exchange Resin

Resin Replacement Vessels (UR-TK-820/850)

Resin beds are anticipated to periodically require replacement, as most resins gradually degrade due to exposure to both chemicals and radiation. The degradation reduces the resin uranium capacity and reduces the loading cycle volume (decreasing the process throughput rate) or decreases the effectiveness of uranium separation from unwanted fission products. The frequency of resin bed replacement must be determined based on testing. Resin replacement will likely be required after experiencing an absorbed dose on the order of [Proprietary Information].

The resin replacement vessels will support removal of spent resin from an IX column and addition of fresh resin to a column after spent resin has been removed. The resin replacement vessels have been evaluated as a combination of tanks located inside and outside the hot cell to clarify the flow of material during the resin replacement activity. The current concept for resin replacement vessels includes spent resin collection tanks and a transfer liquid storage tank located inside the hot cell. Fresh resin makeup tanks will be located outside the hot cell.

There will be a total of [Proprietary Information] in the RPF: [Proprietary Information]. Resin replacement activities will be performed during time periods when the uranium system is not attempting to process uranium solutions. The frequency of resin replacement is not yet established. The higher dose rates to resin beds in the first uranium cycle are anticipated to require more frequent replacement than the second uranium cycle resin beds.

The spent resin collection tanks will be provided to support removal of spent resin from the IX columns and sampling resin prior to transfer of resin to the waste handling system for disposal. The spent resin collection tanks are designed with geometrically favorable dimensions to control the potential for criticality. Sampling or monitoring of the spent resin uranium content will be required prior to transfer to the waste handling system, where vessels are not expected to be designed to dimensions that control criticality by geometry. Two spent resin collection tanks will be provided so that the two IX columns in a uranium cycle can be replaced to allow resumption of uranium processing without waiting to complete spent resin sampling or monitoring and then transfer to the waste handling system. The spent resin collection tank operation will be supported by a resin transfer liquid tank to manage liquids in the resin slurry during transfers.

The fresh resin makeup tanks will be provided to support preparation of fresh resin for addition to an IX column after spent resin has been removed. The fresh resin makeup tanks will be located outside the hot cell and will not contain materials that have been contacted with uranium or fission products. Therefore, the vessels are not designed using dimensions to control the potential for criticality. One fresh resin makeup tank per column is currently identified as a method for minimizing the potential for double-batching resin in a single column.

The above description provides a detailed account of the SNM in process during the target disassembly activities. The SNM, along with any included fission-product radioactivity, is described in Section 4.4.1.3. Based on this description, these operations can be conducted safely in this facility.

4.4.1.2 Process Equipment Arrangement

The U recovery and recycle system equipment arrangement within the tank hot cell is shown in Figure 4-76.

[Proprietary Information]

Figure 4-76. Tank Hot Cell Equipment Arrangement

4.4.1.3 Process Equipment Design

A common vessel geometry has been assumed for each vessel in the U recovery and recycle system based on dimensions that provide geometrically favorable designs for criticality control when process solutions contain uranium at 20 wt% ^{235}U. The assumed geometry is based on a [Proprietary Information].

Detailed design calculations were not developed for equipment as part of the preliminary design. However, a description of the following major uranium processing equipment pieces can be developed from past experience with similar types of facilities. The major equipment for the uranium processing system will consist of tanks, IX columns, and concentrators.

[Proprietary Information]

Note: Pencil tank height varied based on tank capacity requirements.

Figure 4-77. Alternative Pencil Tank Diameters for Equipment Sizing

Tanks will represent a dominant vessel used as equipment in the uranium system. Two different tank types have been assumed as equipment in the preliminary design: (1) uncooled tank configuration, and (2) cooled tank configuration. An example of an individual pencil tank for the alternative configurations is shown on Figure 4-77. Both tank alternatives are intended to satisfy criticality requirements for a geometrically favorable design. The uncooled tank will be constructed from [Proprietary Information] Schedule 40 pipe lengths as the primary tank wall. A cooled tank will be constructed from [Proprietary Information] Schedule 40 pipe lengths as the primary tank wall, combined with a cooling jacket fabricated from [Proprietary Information] Schedule 40 pipe. The cooled tank configuration will provide geometry control for the uranium-bearing solutions under unexpected accident conditions, where process liquid leaks into the cooling jacket due to corrosion or other vessel failure mechanism.

A major difference between the two tank configurations is the capacity of the alternatives to store process liquid. The uncooled tank configuration will have a capacity of [Proprietary Information] of primary vessel length, while the cooled tank configuration will have a capacity of [Proprietary Information].

Figure 4-78 is a conceptual sketch of an IX column for uranium purification. The vessel is currently envisioned as based on a [Proprietary Information] diameter cylindrical geometry for criticality control, with the IX media supported on a screen to form a resin bed. An upper screen will be included in the column to restrain the resin within a fixed portion of the column. Inlet and outlet piping connections will communicate with the resin section of the column to allow periodic bed replacement using slurry transfer of the resin. The current concept is based on providing a configuration with two of the columns shown in Figure 4-78 that operate in parallel for each of the IX cycles.

[Proprietary Information]

Figure 4-78. Conceptual Ion Exchange Column for Uranium Purification

Liquid phase will pass through the column in a down-flow such that feed for a particular column cycle will enter at the top of the column and cycle effluents will leave the column from the bottom. The column is anticipated to include a rupture disk-type safety pressure relief assembly as part of the column design. Pressure-relief capabilities will typically be required when using organic resins in a nitric acid system.

Figure 4-79 is a conceptual sketch of a typical concentrator for uranium-bearing solutions where uranium must be controlled by a geometrically favorable design. The configuration shown in Figure 4-79 is based on a natural convection thermosiphon arrangement, but could be configured as a forced convection equipment piece. Dilute feed will enter the concentrator near the bottom and circulate through the reboiler. The reboiler will heat the solution and partially evaporate the feed liquid. Vapor will migrate up the concentrator vessel, through a demister, and will then be condensed. Feed liquid will continue to circulate through the reboiler until the solution reaches a goal density. For the conceptual sketch, concentrate overflows from a mid-point position of the concentrator to a receiver vessel.

[Proprietary Information]

Source: Figure 2 [modified] of ORNL/TM-5518, *Design and Test of a Thermosiphon Evaporator for Acid-Deficient Uranyl Nitrate*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, November, 1976.

Figure 4-79. Conceptual Uranium Concentrator Vessel

Table 4-50 provides a summary description of the U recovery and recycle process equipment.

Table 4-50. Uranium Recovery and Recycle Process Equipment (2 pages)

Equipment name	Equipment no.	Nominal tank diameter (in.)	Individual tank capacity	Tank material	Operating range	
					Temperature °C (°F)[a]	Pressure atm (lb/in^{2}a)[b]
Impure U collection tanks	UR-TK-100/120/140/160	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
IX feed tank #1	UR-TK-200	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
IX column 1A and IX column 1B	UR-IX-240/260	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Concentrator 1 feed tank	UR-TK-300	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Concentrator 1	UR-Z-320	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Condenser 1	UR-Z-320	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Concentrate cooler 1	UR-Z-320	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Sample tank #1A	UR-TK-340	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Plug flow delay vessel	UR-TK-360	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Sample tank #1B	UR-TK-370	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium feed batch adjustment tanks	UR-TK-400/420	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium recycle exchange column #2	UR-IX-460/480	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Concentrator 2 feed tank	UR-TK-500	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Concentrator 2	UR-Z-520	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Condenser #2	UR-Z-520	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Concentrate cooler #2	UR-Z-520	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Sample tank #2A	UR-TK-540	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Plug flow delay vessel	UR-TK-560	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Sample tank #2B	UR-TK-570	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Concentrate receiver tank	UR-TK-600	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Product sample tank	UR-TK-620	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium rework tank	UR-TK-660	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium decay holdup tanks[c]	UR-TK-700[c]	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium product transfer send tank	UR-TK-720	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]

Table 4-50. Uranium Recovery and Recycle Process Equipment (2 pages)

Equipment name	Equipment no.	Nominal tank diameter (in.)	Individual tank capacity	Tank material	Operating range	
					Temperature °C (°F)[a]	Pressure atm (lb/in²a)[b]
Spent resin collection tanks	UR-TK-820	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Resin transfer liquid tank	UR-TK-850	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium IX waste collection tanks	UR-TK-900/920	[Proprietary Information]	[Proprietary Information]	304L SS	[Proprietary Information]	[Proprietary Information]

[a] Temperature range estimated for process solutions. The nominal operating temperature of IX system-related solutions is [Proprietary Information] based on controlling resin operating conditions. The nominal operating temperature of the concentrator systems includes transition to an operating temperature of [Proprietary Information], operating the concentrator at [Proprietary Information], and operating the condenser at [Proprietary Information]. Condenser cooling water supply is assumed to be at [Proprietary Information].

[b] Atmospheric pressure, as controlled by the vessel ventilation system to maintain a negative vessel pressure relative to the vessel enclosure (normally hot cell enclosure for these vessels).

[c] Uranium decay holdup tanks [Proprietary Information], labeled UR-TK-700A through UR-TK-700R.

IX = ion exchange.
SS = stainless steel.
U = uranium.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. The process description in Section 4.4.1.1 identifies the control strategy for normal operations, which sets requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional details of the process monitoring and control equipment will be developed for the Operating License Application.

4.4.1.4 Special Nuclear Material Description

This section provides a summary of the maximum amounts of SNM and the chemical and physical forms of SNM used in the process. This section also describes required criticality control features that are designed into the process systems and components. The criticality control features will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes. All SNM discussed in this section is not be considered waste and will be returned to the U recovery and recycle system, purified, and reused.

Special Nuclear Material Inventory

The U recovery and recycle system SNM inventory will be dominated by [Proprietary Information]. After holdup in the impure U collection tanks, the stored uranium solution will be processed by the IX system in multiple small batches that are collected in the U decay tanks. The U decay tanks will provide an additional [Proprietary Information] prior to transfer to the target fabrication system. [Proprietary Information] will control worker exposure during target fabrication operations.

Table 4-51 summarizes the U recovery and recycle SNM design basis inventory. Uranium solution concentrations vary from less than [Proprietary Information], depending on the process activities supported by a particular vessel and the reactor source for targets in a particular operating week. Nuclear criticality evaluations performed in Atkins-NS-DAC-NMI-14-006 indicate that the U recovery and recycle system vessels remain subcritical under normal and abnormal conditions when all vessels contain solution at a concentration of [Proprietary Information].

Table 4-51. Uranium Recovery and Recycle In-Process Special Nuclear Material Inventory (2 pages)

Stream	Form	Concentration[a]	Volume	SNM mass[a]
Impure U collection tanks – UR-TK-100A/B, 120A/B, 140A/B, 160A/B	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
IX feed tank 1 – UR-TK-200[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Concentrator 1 feed tank – UR-TK-300[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Concentrator 1 holdup – UR-Z-320[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Condensate sample tank 1A – UR-TK-340[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Condensate delay tank 1 – UR-TK-360[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Condensate sample tank 1B – UR-TK-370[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
IX feed tank 2A – UR-TK-400[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
IX feed tank 2B – UR-TK-420[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Concentrator 2 feed tank – UR-TK-500[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Concentrator 2 holdup – UR-Z-520[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Condensate sample tank 2A – UR-TK-540[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Condensate delay tank 2 – UR-TK-560[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Condensate sample tank 2B – UR-TK-570[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Concentrate receiver tank – UR-TK-600[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Product sample tank – UR-TK-620[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U rework tank – UR-TK-660[b]	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U decay tanks ([Proprietary Information]) UR-TK-700A to R	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U product transfer send tank – UR-TK-720	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Spent resin collection tank A – UR-TK-820A	Spent resin in water	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Spent resin collection tank B – UR-TK-820B	Spent resin in water	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Resin transfer liquid tank – UR-TK-850	Resin transfer water	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-51. Uranium Recovery and Recycle In-Process Special Nuclear Material Inventory (2 pages)

Stream	Form	Concentration[a]	Volume	SNM mass[a]
IX waste collection tank 1 – UR-TK-900	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
IX waste collection tank 2 – UR-TK-920	Liquid uranyl nitrate	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U).

[b] Solution moves from impure uranium collection tanks, through the uranium process vessels, to the U decay tanks during a processing week.

[c] Concentrator equipment not currently designed. Holdup volume approximated [Proprietary Information].

[d] Condensate currently estimated to contain trace quantities of uranium [Proprietary Information].

[e] Uranium concentration varies depending on targets being processed [Proprietary Information].

[f] Resin is eluted prior to disposal as spent resin. Disposal stream slurry projected to contain [Proprietary Information]. No data are currently available to predict eluted resin or transfer liquid uranium content, but expected to contain trace uranium quantities.

[g] IX waste currently estimated to contain trace quantities of uranium at an average [Proprietary Information].

IX	= ion exchange.	OSU	= Oregon State University.
LEU	= low-enriched uranium.	SNM	= special nuclear material.
MURR	= University of Missouri Research Reactor.	U	= uranium.

[Proprietary Information]

Uranium solution collected for decay storage in the impure U collection tanks will be processed as multiple smaller batches through the IX separation system. The nominal weekly process throughput will range from [Proprietary Information]. The IX system is sized to process solution in batches containing approximately [Proprietary Information], which will be prepared from impure U collection tank transfers in UR-TK-200. The U recovery and recycle system equipment design is based [Proprietary Information].

Uranium from the feed tank batch will be collected on the first-cycle IX columns and eluted to UR-TK-300 for feed to concentrator UR-Z-320, while alternating concentrate collection between UR-TK-400 and UR-TK-420. Uranium-bearing eluate will pass through the concentrator feed tank (UR-TK-300) to concentrator UR-Z-320, which is not intended as a major uranium collection point during normal operation, but can hold up to [Proprietary Information]. While not finalized, the current concentrator design (UR-Z-320) is based on a natural convection thermosiphon configuration with the potential to hold up to approximately [Proprietary Information] under normal operating conditions. Condensate vessels (UR-TK-340, UR-TK-360, and UR-TK-370) are expected to contain trace quantities of uranium during normal operation.

Uranium concentrate from UR-Z-320 will be collected in the second-cycle IX feed tanks (UR-TK-400 or UR-TK-420) using a batch size of approximately [Proprietary Information], collected on the second-cycle IX columns, and eluted to UR-TK-500 for feed to concentrator UR-Z-520. As with the first uranium cycle, UR-TK-500 is not intended as a major uranium collection point during normal operation, but can hold up [Proprietary Information].

Based on the current concentrator design, UR-Z-520 has the potential to hold between [Proprietary Information], depending on the planned normal operating conditions. Concentrate from UR-Z-520 will be collected in the concentrate receiver UR-TK-600 from multiple IX batches for transfer to the product sample tank (UR-TK-620). The concentrate receiver and product sample tanks will be capable of holding up to [Proprietary Information]. During normal operation, one transfer per week of [Proprietary Information] is projected to occur between UR-TK-600, UR-TK-620, and the U decay tanks (UR-TK-700A to R) [Proprietary Information].

The uranium rework tank (UR-TK-660) will be empty during normal operation, but has the capacity to contain [Proprietary Information].

[Proprietary Information]

The uranium product transfer send tank (UR-TK-720) will support accountability measurements between the U recovery and recycle system and target fabrication system. The tank will normally be empty when not supporting transfers between the two systems, but will have the capability to contain approximately [Proprietary Information].

The spent resin collection tanks (UR-TK-820A/B) and resin transfer liquid tank (UR-TK-850) will be used to support replacement of the IX resin columns in the U recovery and recycle system. The IX columns will be eluted to remove uranium from the media prior to replacement. However, trace uranium quantities are anticipated to remain after column elution. Estimates of residual uranium in spent resin and transfer liquid will be completed for inclusion in the Operating License Application.

Waste solution generated by the U recovery and recycle system is estimated to contain small quantities of uranium, which is characterized as a concentration of [Proprietary Information]. Multiple waste batches will be generated during IX column operation. The uranium inventory of each waste batch is estimated to average [Proprietary Information].

Criticality Control Features

Criticality control features are required in this system, as defined in NWMI-2015-CSE-008, *NWMI Preliminary Criticality Safety Evaluation: Hot Cell Uranium Purification*. These features, including passive design and active engineered features, allow for adherence to the double-contingency principle. This section applies the criticality control features that are discussed in Chapter 6.0, Section 6.3.

The criticality control features for this subsystem will include passive design and active engineered features, which are listed below. The passive design features will include geometric constraints of the floor, process equipment, workstations, and ventilation system. The active engineered features will include the requirement of continuous ventilation. Chapter 6.0 provides detailed descriptions of the criticality control features.

The following passive design features affect the design of process equipment, ventilation piping, and the room floor.

- For the case of a liquid leak, the floor will be criticality-safe (CSE-08-PDF1), the floor of the hot cell will be sealed against chemical penetration (CSE-08-PDF2), and the floor sumps will have a favorable geometry of shallow depth or small diameter (CSE-08-PDF8).
- The geometry of the process equipment will be inherently criticality safe (CSE-08-PDF3 and CSE-08-PDF5) and maintain a subcritical geometry during and after a facility DBE (CSE-08-PDF4).
- For the case of liquid leaks to secondary systems, a safe-geometry secondary system barrier will be provided between the process vessels and the unfavorable-geometry supply systems (CSE-08-PDF6 and CSE-08-PDF7).
- The uranium IX column volume will provide for safe geometry and incorporate a pressure-relief mechanism (CSE-08-PDF9).
- Local vent headers will incorporate design features for a criticality-safe geometry (CSE-08-PDF10).
- Backflow of tank solution into the gas system will be prevented (CSE-08-PDF11).
- Backflow of uranium solution to the unfavorable geometry vessels of the chemical makeup systems will be prevented (CSE-08-PDF12).
- Overpressurization of the uranium process vessels will be prevented (CSE-08-AFE1).

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the U recovery and recycle system activities.

- The process equipment is designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including: (1) outside diameter of process equipment and piping (IROFS CS-06), and (2) fixed spacing between process equipment with fissile solution (IROFS CS-07).
- The floor geometry and use of floor dikes are controlled to prevent criticality in the event of spills (IROFS CS-08).
- Chemical and water supplies are potential sources for backflow of fissile solution to the large geometry of the chemical supply system or demineralized water system. To prevent backflow, solutions are provided through an anti-siphon device that separates the supply from the process equipment (IROFS CS-18).
- Fissile solution that may overflow into the ventilation header is discharged to the floor local overflow drains (IROFS CS-13) or by condensing pots on the ventilation lines (IROFS CS-12).
- In the event of a heat exchanger internal failure, where fissile solution enters the heating or cooling loop, the secondary chilled water and steam loops are inherently criticality-safe by geometry with detection to notify operators of the upset (IROFS CS-10).
- Condensate from the uranium concentrators is monitored actively with isolation to prevent condensate from entering the large-geometry waste handling system (IROFS CS-14). Independent monitoring and isolation provides redundant accident prevention (IROFS CS-15).
- Batch limits are applied, by means of container sizes, to samples taken for analysis (IROFS CS-02).
- Where fissile material is piped through facility walls, double-wall piping that drains to criticality-safe geometry prevents fissile leakage from accumulating in an unfavorable geometry (IROFS CS-09).

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include the following.

- Tanks are vented and unpressurized during normal operations, and corrosion resistance is a design requirement. Level is monitored on all tanks and indicated to the operator to reduce the likelihood of overflow.
- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.
- The effects of a criticality accident are mitigated by the shielding described in Section 4.2.

The criticality control features provided throughout the U recovery and recycle system will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.1.5 Radiological Hazards

Radionuclide Inventory

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes. NWMI-2014-CALC-014 identifies the 123 dominant radioisotopes included in the MURR material balance (NWMI-2013-CALC-006). NWMI-2014-CALC-014 provides the basis for using the 123 radioisotopes from the total list of 660 radioisotopes potentially present in irradiated targets. The majority of omitted radioisotopes exist in trace quantities and/or decay swiftly to stable nuclides. The reduced set of 123 radioisotopes consists of those that dominate the radioactivity and decay heat of irradiated targets.

Activities during an operating week that process targets irradiated in the MURR represent the radionuclide inventory as described in Section 4.1. The radionuclide inventory will be based on a weekly throughput of [Proprietary Information]. The in-process radionuclide inventory of the U recovery and recycle system will be dominated by solution lag storage in the impure U collection tanks. During MURR target processing, [Proprietary Information] will be stored after the ^{99}Mo has been extracted by the Mo recovery and purification system. The solution will be stored in an impure U collection tank such that all feed will be at a decay time [Proprietary Information] after EOI when processed by the U recovery and recycle IX equipment.

Figure 4-80 is a simplified flow diagram illustrating the impure U collection tanks in-process radionuclide inventory. Four separate tanks will be provided to obtain the required decay time period. One tank will receive solution transfer from the Mo recovery and purification system and provide storage for a decay period of [Proprietary Information]. A second tank will provide storage of material from the prior operating week for a decay period of [Proprietary Information], while a third tank will provide storage for a decay period of [Proprietary Information]. A fourth tank will store material that has been decayed to [Proprietary Information], from which feed batches will be drawn for the uranium IX system.

[Proprietary Information]

Figure 4-80. Impure Uranium Collection Tanks In-Process Radionuclide Inventory Streams

A breakdown of the radionuclide inventory is extracted from NWMI-2013-CALC-006 using the reduced set of 123 radioisotopes as recommended in NWMI-2014-CALC-014. The impure U collection tank in-process inventory is described by Table 4-52.

Table 4-52. Impure Uranium Collection Tanks In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing				
Unit operation	Impure U collection tanks				
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Isotopes	**Ci**[c]	**Ci**[c]	**Ci**[c]	**Ci**[c]	**Total Ci**
^{241}Am	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{139}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{242}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{243}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{244}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{155}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{157}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{130}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-52. Impure Uranium Collection Tanks In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing				
Unit operation	Impure U collection tanks				
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Isotopes	**Ci [c]**	**Ci [c]**	**Ci [c]**	**Ci [c]**	**Total Ci**
^{132}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{83m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{87}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{88}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Mo	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{96}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Nd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236m}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{233}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{112}Pd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{149}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{150}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-52. Impure Uranium Collection Tanks In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing				
Unit operation	Impure U collection tanks				
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Isotopes	**Ci [c]**	**Ci [c]**	**Ci [c]**	**Ci [c]**	**Total Ci**
^{143}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144m}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{145}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{240}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{241}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{122}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{124}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{126}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128m}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{153}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99m}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-52. Impure Uranium Collection Tanks In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing				
Unit operation	Impure U collection tanks				
Decay time after EOI[a]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Stream description[b]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Isotopes	**Ci[c]**	**Ci[c]**	**Ci[c]**	**Ci[c]**	**Total Ci**
^{129m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{231}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{232}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{235}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Total Ci	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] In-process inventory of each storage tank based on indicated decay times.

[b] Figure 4-80 provides a simplified description of the process streams.

[c] In-process inventory based on processing of [Proprietary Information] per operating week.

EOI = end of irradiation.
U = uranium.
MURR = University of Missouri Research Reactor.

Solution designated as decayed impure U in Table 4-52 will be withdrawn in multiple batches for processing through the U recovery and recycle separation systems. Figure 4-81 is a simplified flow diagram illustrating the in-process radionuclide inventory of separations provided by IX and concentrator equipment as feed solution passes through the system. The radionuclide inventory will be split among the three streams (U condensate, recycled U, and U IX waste) by the separation system. All material in-process will be [Proprietary Information] by storage in the impure U collection tanks. The maximum radioactive inventory will be based on a weekly throughput of [Proprietary Information]. The separation system in-process inventory is shown in Table 4-53.

[Proprietary Information]

Figure 4-81. Uranium Recovery and Recycle In-Process Radionuclide Inventory Streams

Table 4-53. Uranium Recovery and Recycle In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation:		U recovery and recycle	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	U condensate	Recycled U	U IX waste
Isotopes	Ci [c]	Ci [c]	Ci [c]
^{241}Am	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137m}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{139}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}Ba	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Ce	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{242}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{243}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{244}Cm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134m}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{136}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{137}Cs	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{155}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{157}Eu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{130}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-53. Uranium Recovery and Recycle In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation:		U recovery and recycle	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	U condensate	Recycled U	U IX waste
Isotopes	**Ci**[c]	**Ci**[c]	**Ci**[c]
^{132}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}I	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{83m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{85m}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{87}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{88}Kr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{140}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{141}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}La	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Mo	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{96}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97m}Nb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Nd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236m}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Np	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{233}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234m}Pa	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{112}Pd	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{147}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{148m}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{149}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{150}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Pm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{142}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{143}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{144}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-53. Uranium Recovery and Recycle In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation:		U recovery and recycle	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	U condensate	Recycled U	U IX waste
Isotopes	**Ci**[c]	**Ci**[c]	**Ci**[c]
^{144m}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{145}Pr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{239}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{240}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{241}Pu	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106m}Rh	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{103}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{105}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{106}Ru	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{122}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{124}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{126}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{128m}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Sb	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{151}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{153}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{156}Sm	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Sr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{99m}Tc	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{125m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{127m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{129m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{132}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Table 4-53. Uranium Recovery and Recycle In-Process Radionuclide Inventory (4 pages)

Item	MURR target processing		
Unit operation:		U recovery and recycle	
Decay time after EOI[a]		[Proprietary Information]	
Stream description[b]	U condensate	Recycled U	U IX waste
Isotopes	**Ci** [c]	**Ci** [c]	**Ci** [c]
^{133}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{134}Te	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{231}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}Th	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{232}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{234}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{235}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{236}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{237}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{238}U	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{131m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{133m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{135m}Xe	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{89m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{90m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{91m}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{92}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Y	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{93}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{95}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
^{97}Zr	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Total Ci	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] In-process inventory based on decay time [Proprietary Information].

[b] Figure 4-81 provides a simplified description of the process streams.

[c] In-process inventory based on total [Proprietary Information], representing the weekly process throughput.

EOI = end of irradiation.
MURR = University of Missouri Research Reactor.
U = uranium.

The weekly process throughput described by recycled U in Table 4-53 will be stored in U decay tanks prior to transfer to the target fabrication system. The U decay tanks will function similar to the impure U collection tanks described above, [Proprietary Information]. Similar to the impure U collection system, the U decay storage system will provide 13 positions for solution storage plus a position to support transfers to target fabrication [Proprietary Information]. The total activity of uranium solution produced during an operating week will decrease from [Proprietary Information].

Radioisotope inventory changes will be dominated by the [Proprietary Information]. The total activity of weekly solution transfers to target fabrication at the end of the decay period will be dominated by uranium isotopes and includes:

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

A simplified bounding estimate of the radionuclide in-process inventory of U decay tanks can be obtained from [Proprietary Information] the radionuclide listing for the recycled U stream shown in Table 4-53, recognizing that the recycled U composition does not reflect the radionuclide inventory transferred into the target fabrication system.

Radiological Protection Features

Radiological protection features are designed to prevent the release of radioactive material and to maintain radiation levels below applicable radiation exposure limits prescribed in 10 CFR 20 for the protection of workers and the public. These features include defense-in-depth and engineered safety features. The engineered safety features identified in this section are described in Chapter 6.0, Section 6.2.

The following defense-in-depth features will provide radiological protection to workers and the public.

- Most U recovery and recycle process equipment operates at or slightly below atmospheric pressure or solutions are pumped between tanks that are at atmospheric pressure to reduce the likelihood of system breach at high pressure.
- The process equipment is designed for high reliability with materials that minimize corrosion rates associated with the processed solutions.
- Alarming radiation monitors provide continuous monitoring of the dose rate in occupied areas and alarm at an appropriate setpoint above background.

The following engineered safety features, listed below as IROFS and described in Chapter 13.0, will provide radiological protection to workers and the public.

- The high-dose material and solution is processed inside shielded areas. The hot cell shielding boundary (IROFS RS-04) provides shielding for workers and the public at workstations and occupied areas outside of the hot cell. The hot cell liquid confinement boundary (IROFS RS-01) prevents releases of liquid.
- Radioactive gases flow to the target dissolution offgas treatment, which is part of the hot cell secondary confinement boundary (IROFS RS-03).
- Before the uranyl nitrate solution is recycled to the target fabrication system, samples are analyzed to verify sufficient decay and extraction of fission products (IROFS RS-08).
- Certain high-activity tanks may require a backup purge if the normal purge is lost (IROFS FS-03). Additional detailed information about which tanks require backup purge will be developed for the Operating License Application.

4.4.1.6 Chemical Hazards

This section provides a summary of the maximum amounts of chemicals used in the process and the associated chemical hazards. This section also identifies any required chemical protection provisions that are designed into the process systems and components.

Chemical Inventory

The chemical reagents for the uranium recovery and recycle are listed in Table 4-54. In addition to the chemical reagents, offgases will include NO, NO_2, and nitric acid fumes.

Table 4-54. Uranium Recovery and Recycle Chemical Inventory

Chemical	OSU batch[a]	MURR batch[b]	Annual quantity[c]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Demineralized water[d]	24,320 L	6,450 L	480,000 L

[a] Represents sum of chemical additions to uranium systems calculated by NWMI-2013-CALC-002, *Overall Summary Material Balance – OSU Target Batch*, material balances for processing an irradiated target batch [Proprietary Information].

[b] Represents sum of chemical additions to uranium systems calculated by NWMI-2013-CALC-006, *Overall Summary Material Balance – MURR Target Batch*, material balances for processing an irradiated target [Proprietary Information].

[c] Annual quantity based on [Proprietary Information].

[d] Represents a combination of recycled water and fresh demineralized water.

[Proprietary Information]
[Proprietary Information]
[Proprietary Information]
MURR = University of Missouri Research Reactor.
OSU = Oregon State University.

Chemical Protection Provisions

The chemical hazards for the U recovery and recycle system are described in Chapter 9.0. Chemicals hazards of the system will be bounded by the radiological hazards. The features will prevent release of radioactive material and limit radiation exposure to protect workers and the public from hazardous chemicals.

4.4.2 Processing of Unirradiated Special Nuclear Material

This section describes the target fabrication system, which will produce LEU targets from fresh LEU metal and recycled uranyl nitrate. The system begins with the receipt of LEU from the DOE supplier, and ends with packaging new targets for shipment to the irradiation facilities.

The uranium received in the target fabrication will be both fresh LEU metal and purified recycled uranyl nitrate; therefore, the uranium within target fabrication may be handled directly without shielding.

Due to the variety of activities performed during target fabrication, the system description is divided into the nine subsystems listed in Table 4-55. The key interfaces between subsystems, including uranium flows, are shown in Figure 4-82.

Table 4-55. Target Fabrication Subsystems

No.	Subsystem name	Section
100	Fresh uranium receipt and dissolution	4.4.2.1.5
200	Nitrate extraction	4.4.2.3
300	ADUN concentration	4.4.2.4
400	[Proprietary Information]	4.4.2.5
500	[Proprietary Information]	4.4.2.6
600	[Proprietary Information]	4.4.2.7
700	Target fabrication waste	4.4.2.8
800	Target assembly	4.4.2.9
900	LEU storage	4.4.2.10

ADUN = acid-deficient uranyl nitrate.
LEU = low enriched uranium.

[Proprietary Information]

Figure 4-82. Key Subsystem Interfaces within Target Fabrication

4.4.2.1 Target Fabrication Design Basis

The target fabrication system will produce and ship targets for irradiation. The overall design basis includes:

- [Proprietary Information]
- [Proprietary Information]
- Ensuring LEU processing and storage meet security and criticality safety requirements
- Designating target fabrication as a material balance accountability area requiring measurements for SNM
- Controlling/preventing flammable gas from reaching lower flammability limit conditions of 5 percent H_2, designing for 25 percent of lower flammability limit

In addition to the overall design basis, more specific requirements of the design basis are divided into the sub-functions: receive fresh and recycled LEU, produce LEU target material, assemble LEU targets, and package and ship LEU targets. There is no significant radiological dose hazard associated with target fabrication activities.

Additional information on the design basis is provided in Chapter 3.0.

4.4.2.1.1 Receive Fresh and Recycled LEU

The receive fresh and recycled LEU sub-function will receive and store fresh LEU from DOE for producing targets, and recycled LEU from the U recovery and recycle system. The design basis for this sub-function is to:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
  - [Proprietary Information]
  - [Proprietary Information]
  - Fresh LEU impurities (based on draft DOE inputs) will be as specified in Table 4-56.

Table 4-56. Fresh Uranium Metal Specification (3 pages)

Specified item	Symbol	Units	Specification limits	EBC factor
Uranium purity	U	g U/g	[Proprietary Information]	[Proprietary Information]
^{232}U	U-232	µg/g U	[Proprietary Information]	[Proprietary Information]
^{234}U	U-234	µg/g U	[Proprietary Information]	[Proprietary Information]
^{235}U	U-235	wt%	[Proprietary Information]	[Proprietary Information]
(±0.2%)			[Proprietary Information]	[Proprietary Information]
^{236}U	U-236	µg/g U	[Proprietary Information]	[Proprietary Information]
$^{99}Tc + ^{90}Sr$	Tc-99	Bq/g U	[Proprietary Information]	[Proprietary Information]
TRU (alpha)	TRU	Bq/g U	[Proprietary Information]	[Proprietary Information]
Beta	Beta	Bq/g U	[Proprietary Information]	[Proprietary Information]
Activation products	ActProd	Bq/g U	[Proprietary Information]	[Proprietary Information]
Fission products	FissProd	Bq/g U	[Proprietary Information]	[Proprietary Information]

Table 4-56. Fresh Uranium Metal Specification (3 pages)

Specified item	Symbol	Units	Specification limits	EBC factor
Moisture	H_2O	ppm or µg/g oxide sample	[Proprietary Information]	[Proprietary Information]
Density	Density	g/cm^3	[Proprietary Information]	[Proprietary Information]
Surface area		m^2/g	[Proprietary Information]	[Proprietary Information]
Aluminum	Al	µg/g U	[Proprietary Information]	[Proprietary Information]
Antimony	Sb	µg/g U	[Proprietary Information]	[Proprietary Information]
Arsenic	As	µg/g U	[Proprietary Information]	[Proprietary Information]
Barium	Ba	µg/g U	[Proprietary Information]	[Proprietary Information]
Beryllium	Be	µg/g U	[Proprietary Information]	[Proprietary Information]
Boron	B	µg/g U	[Proprietary Information]	[Proprietary Information]
Cadmium	Cd	µg/g U	[Proprietary Information]	[Proprietary Information]
Calcium	Ca	µg/g U	[Proprietary Information]	[Proprietary Information]
Carbon	C	µg/g U	[Proprietary Information]	[Proprietary Information]
Cesium	Cs	µg/g U	[Proprietary Information]	[Proprietary Information]
Chromium	Cr	µg/g U	[Proprietary Information]	[Proprietary Information]
Cobalt	Co	µg/g U	[Proprietary Information]	[Proprietary Information]
Copper	Cu	µg/g U	[Proprietary Information]	[Proprietary Information]
Dysprosium	Dy	µg/g U	[Proprietary Information]	[Proprietary Information]
Europium	Eu	µg/g U	[Proprietary Information]	[Proprietary Information]
Gadolinium	Gd	µg/g U	[Proprietary Information]	[Proprietary Information]
Hafnium	Hf	µg/g U	[Proprietary Information]	[Proprietary Information]
Iron	Fe	µg/g U	[Proprietary Information]	[Proprietary Information]
Lead	Pb	µg/g U	[Proprietary Information]	[Proprietary Information]
Lithium	Li	µg/g U	[Proprietary Information]	[Proprietary Information]
Magnesium	Mg	µg/g U	[Proprietary Information]	[Proprietary Information]
Manganese	Mn	µg/g U	[Proprietary Information]	[Proprietary Information]
Mercury	Hg	µg/g U	[Proprietary Information]	[Proprietary Information]
Molybdenum	Mo	µg/g U	[Proprietary Information]	[Proprietary Information]
Nickel	Ni	µg/g U	[Proprietary Information]	[Proprietary Information]
Niobium	Nb	µg/g U	[Proprietary Information]	[Proprietary Information]
Nitrogen	N	µg/g U	[Proprietary Information]	[Proprietary Information]
Phosphorus	P	µg/g U	[Proprietary Information]	[Proprietary Information]
Potassium	K	µg/g U	[Proprietary Information]	[Proprietary Information]
Samarium	Sm	µg/g U	[Proprietary Information]	[Proprietary Information]
Silicon	Si	µg/g U	[Proprietary Information]	[Proprietary Information]
Silver	Ag	µg/g U	[Proprietary Information]	[Proprietary Information]
Sodium	Na	µg/g U	[Proprietary Information]	[Proprietary Information]

Table 4-56. Fresh Uranium Metal Specification (3 pages)

Specified item	Symbol	Units	Specification limits	EBC factor
Strontium	Sr	µg/g U	[Proprietary Information]	[Proprietary Information]
Tantalum	Ta	µg/g U	[Proprietary Information]	[Proprietary Information]
Thorium	Th	µg/g U	[Proprietary Information]	[Proprietary Information]
Tin	Sn	µg/g U	[Proprietary Information]	[Proprietary Information]
Titanium	Ti	µg/g U	[Proprietary Information]	[Proprietary Information]
Tungsten	W	µg/g U	[Proprietary Information]	[Proprietary Information]
Vanadium	V	µg/g U	[Proprietary Information]	[Proprietary Information]
Zinc	Zn	µg/g U	[Proprietary Information]	[Proprietary Information]
Zirconium	Zr	µg/g U	[Proprietary Information]	[Proprietary Information]
TMI (total impurities)		µg/g U	[Proprietary Information]	[Proprietary Information]
Equivalent boron content	EBC	µg EB/g U	[Proprietary Information]	[Proprietary Information]

[a] The values shown reflect the sum of the listed nuclides:
[Proprietary Information]
[Proprietary Information]
[Proprietary Information]
[Proprietary Information]

[b] EBC factors are taken from ASTM C1233-09, *Standard Practice for Determining EBC of Nuclear Materials*. EBC calculations will include boron, cadmium, dysprosium, europium, gadolinium, lithium, and samarium. Other EBC factors are provided for information only. The limit on EBC may restrict some elements to lower values than those shown in the table.

[c] The limit on EBC may restrict some elements to lower values than shown in the table.

EBC = equivalent boron content.
NM = not measured.
TBR = to be reported.
TMI = total metallic impurities
TRU = transuranic.
U = uranium.

4.4.2.1.2 Produce LEU target Material

The produce target sub-function will produce LEU target material. The design basis for this sub-function is to:

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

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

4.4.2.1.3 Assemble Low-Enriched Uranium Targets

The assemble LEU targets sub-function fills, seal welds, and examines targets. The design basis for this sub-function is to:

- Clean target hardware components prior to filling with LEU target material
- Provide capability to collect LEU target material spilled during target filling
- Provide capability to fill LEU targets to specifications in Table 4-57
- Perform qualification and verification examinations on assembled targets (e.g., helium leak check, weld inspection) to meet licensing requirements
- Process out-of-specification targets that fail quality assurance standard(s)

Table 4-57. Low-Enriched Uranium Target Physical Properties

Target parameter	Value
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]

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

^{235}U = uranium-235. U = uranium.
TBD = to be determined. [Proprietary Information]

4.4.2.1.4 Package and Ship Low-Enriched Uranium Targets

The package and ship LEU targets sub-function stores, packages for shipment, and ships unirradiated targets to the university reactors. The design basis for this sub-function is to:

- [Proprietary Information]
- Package targets per certificate of compliance for shipping cask
- Ship targets per 49 CFR 173

4.4.2.1.5 New Target Handling

New target handling is generally addressed in Chapter 9.0. The discussion is located in this chapter to maintain the continuity of discussion of all operations with SNM in the RPF. For that reason, the new target handling description is organized based on content required in NUREG-1537, Chapter 9. The system description also includes content required in NUREG-1537, Chapter 4.

The new target handling subsystem is designed to provide a means to handle and ship unirradiated targets via ES-3100 shipping casks from the RPF. The new target handling subsystem is between the target assembly or LEU storage subsystems and the transporter. The operational flow diagram for the new target handling subsystem is shown in Figure 4-83.

[Proprietary Information]

Figure 4-83. New Target Handling Flow Diagram

New targets will be stored in the [Proprietary Information] (described in Section 4.4.2.10.3) at the end of target assembly. The [Proprietary Information] will provide inherent physical protection of the new targets during storage. The [Proprietary Information]. Prior to shipment, targets will be loaded into ES-3100 shipping containers. Detailed information on the internal configuration within the ES-3100 shipping container will be developed for the Operating License Application.

The new target handling subsystem function begins with the arrival of the truck transporting the empty ES-3100 shipping casks to the fresh and unirradiated shipping and receiving area. The receiving area door will be opened, and the truck docked to the receiving bay for transfer of the shipping casks into the RPF. Single-loaded shipping casks will be unloaded from the truck onto the ES-3100 shipping cask transfer cart (TF-MC-900) using the ES-3100 shipping cask floor crane (TF-L-900) (Figure 4-85, Section 4.4.2.2.1). Pallet-loaded shipping casks will be unloaded from the truck using the ES-3100 shipping cask pallet jack (TF-PH-900). The unloaded ES-3100 shipping casks will then be documented for material tracking and accountability per the safeguards and security system requirements. The transfer cart carrying a single ES-3100 shipping cask and/or the pallet jack carrying multiple ES-3100 shipping casks will then be transferred to the shipping and receiving airlock door where the empty ES-3100 shipping casks will enter the target fabrication system.

After the ES-3100 shipping casks have been loaded with unirradiated targets in the target fabrication system, a shipping pallet loaded with multiple ES-3100 shipping casks will arrive from the shipping and receiving airlock door. The shipping pallet will be transported by the pallet jack from the shipping and receiving airlock to the fresh and unirradiated shipping and receiving area. The ES-3100 shipping casks containing unirradiated targets will then be documented for material tracking and accountability per the safeguards and security system requirements. The ES-3100 shipping cask pallet will be loaded to the truck via the ES-3100 shipping cask pallet jack (TF-PH-200). The shipping area door will be closed, and the truck and shipping cask will exit the RPF.

A more detailed description the new target physical control will be provided in the NWMI RPF Physical Security Plan (Chapter 12.0, Appendix B).

4.4.2.2 Fresh Uranium Receipt and Dissolution

The fresh uranium dissolution subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.2.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.4.2.2.2 and 4.4.2.2.3. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.2.4. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.4.2.2.5.

4.4.2.2.1 Process Description

Fresh Uranium Receipt

Fresh uranium will be received as uranium metal with an enrichment of 19.75 wt% ±0.20 wt% ^{235}U. The fresh uranium metal will be received in ES-3100 shipping containers. The ES-3100 shipping container design is shown in Figure 4-84.

[Proprietary Information]

Figure 4-84. ES-3100 Shipping Container

Fresh uranium receipt handling – The fresh LEU handling subsystem function will begin with the arrival of the truck transporting the ES-3100 shipping casks containing the fresh LEU material to the fresh and unirradiated shipping and receiving area. The receiving area door will be opened, and the truck docked to the receiving bay, allowing for transfer of the shipping casks into the RPF.

Single-loaded shipping casks will be unloaded from the truck onto the ES-3100 shipping cask transfer cart (TF-MC-900) using the ES-3100 shipping cask floor crane (TF-L-900) (Figure 4-85). Pallet-loaded shipping casks will be unloaded from the truck using the ES-3100 shipping cask pallet jack (TF-PH-900). The unloaded ES-3100 shipping casks will be documented for material tracking and accountability per the safeguards and security system requirements. The transfer cart carrying a single ES-3100 shipping cask and/or the pallet jack carrying multiple ES-3100 shipping casks will then be transferred through the shipping and receiving airlock (T103) to the target fabrication room (T104).

[Proprietary Information]

Fresh uranium verification – On receipt, a review of the supplier's certificate of conformance, included with the shipment, will verify that the impurities and enrichment meet the specification requirements listed in Table 4-56. The container of uranium will be opened, and the SNM weighed along with other MC&A requirements. The uranium will be repackaged in criticality-safe containers and placed into secured storage in the LEU can rack until needed for dissolution. The LEU can rack is within the LEU storage subsystem, which is described in Section 4.4.2.10.

Preparation of fresh uranium for use – Fresh LEU metal may be coated in oil by the supplier for shipment, which would require a uranium washing step. Additional information on fresh LEU metal washing will be developed for the Operating License Application.

[Proprietary Information]

Figure 4-85. Fresh Low-Enriched Uranium Handling and New Target Handling Equipment Arrangement

Fresh Uranium Dissolution

Figure 4-86 provides the stream numbers corresponding to the fresh uranium dissolution process description.

Fresh uranium metal (Stream F103) will be loaded into a basket within the dissolver (TF-D-100) for dissolution along with any rejected LEU target material (Stream F102) or recovered uranium (Stream F104). Note that the fresh uranium metal may need to be cleaned prior to loading into the basket. [Proprietary Information]. During initial startup for the facility, or as needed, the dissolver may be operated daily. During steady-state operations, the dissolver will be operated with a frequency of [Proprietary Information].

[Proprietary Information]

Figure 4-86. Fresh Uranium Dissolution Process Flow Diagram

The uranium will be dissolved with 6 M nitric acid. The uranium dissolution reactions are given as:

$$U + 4\,HNO_3 \longrightarrow UO_2(NO_3)_2 + 2\,NO + 2\,H_2O \qquad \text{Equation 4-6}$$

$$UO_2 + 4\,HNO_3 \longrightarrow UO_2(NO_3)_2 + 2\,NO_2 + 2\,H_2O \qquad \text{Equation 4-7}$$

The nitric acid will be added and the dissolver heated to [Proprietary Information]. Since the uranium dissolution reaction is exothermic, the dissolver will be cooled in a pipe-in-pipe heat exchanger (TF-E-120) as the reaction proceeds to maintain the temperature [Proprietary Information].

Although not shown in the reaction equations above, uranium metal dissolution with water can produce hydrogen. A sweep gas of air will continuously dilute any hydrogen gas generated to prevent the offgas (Stream F105B) from exceeding 25 percent of the lower flammability limit. The offgas will be vented to the vessel ventilation system.

A pump (TF-P-110) will be used to circulate the liquid for mixing. The uranium will be dissolved to produce a final solution around [Proprietary Information] and washed to ensure complete dissolution. Excess nitric acid will be acceptable in the product, as the product is fed to the nitrate extraction subsystem.

Following dissolution, the uranyl nitrate product will be cooled before transfer to the uranyl nitrate blending subsystem.

The use of a reflux condenser to limit NO_x emissions, along with an excessive loss of water, will be considered for the Operating License Application.

4.4.2.2.2 Process Equipment Arrangement

Fresh Uranium Receipt

The equipment arrangement associated with the fresh uranium receipt activities is described in Section 4.4.2.2.1.

Fresh Uranium Dissolution

The fresh uranium dissolution process equipment will be mounted on a single skid within room T104C, the wet side of the target fabrication room. Figure 4-87 shows the equipment arrangement, and Figure 4-88 shows the location of the process equipment.

[Proprietary Information]

Figure 4-87. Fresh Uranium Dissolution Equipment Arrangement

[Proprietary Information]

Figure 4-88. Dissolution Equipment Layout

4.4.2.2.3 Process Equipment Design

Fresh Uranium Receipt

Fresh uranium receipt activities will involve handling shipping casks and repackaging fresh LEU metal into criticality-safe containers. The design of the shipping containers is described in Section 4.4.2.2.1, and the design of the criticality-safe containers will be developed for the Operating License Application. The auxiliary equipment that will be used to move sealed containers includes:

- TF-L-900, ES-3100 shipping cask floor crane
- TF-MC-900, ES-3100 shipping cask transfer cart
- TF-PH-900, ES-3100 shipping cask pallet jack

Fresh Uranium Dissolution

This section identifies the processing apparatus and auxiliary equipment supporting the fresh uranium dissolution subsystem. This equipment is listed in Table 4-58 with design data developed during preliminary design. Because dimensions have not yet been defined, two fields are provided to identify the basis for equipment dimensions; capacity and whether the equipment is designed to be criticality-safe by geometry. Additional detailed information (e.g., dimensions) will be developed for the Operating License Application.

Table 4-58. Fresh Uranium Dissolution Process Equipment

Equipment name	Equipment no.	Capacity	Criticality-safe by geometry	MOC	Operating conditions	
					Temperature	Pressure
Uranium dissolver	TF-D-100	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium dissolution filter	TF-F-100	[Proprietary Information]	Yes	TBD[a]	[Proprietary Information]	[Proprietary Information]
Uranium dissolution pump	TF-P-110	[Proprietary Information]	Yes	TBD[a]	[Proprietary Information]	[Proprietary Information]
Uranium dissolution cooler	TF-E-120	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]

[a] Information will be provided in the Operating License Application submission.

MOC = materials of construction.
N/A = not applicable.
SS = stainless steel.
TBD = to be determined.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. Preliminary process sequences are provided in this section to identify the control strategy for normal operations, which sets requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information on the process monitoring and control equipment will be developed for the Operating License Application.

Fresh uranium dissolution will be a batch process. There are three normal modes of operation: loading, dissolution, product cooling and transfer.

- During **loading operations**, the operator will weigh [Proprietary Information] and load the LEU into the dissolver basket (in the dissolver, TF-D-100). The operator will close the dissolver, open the inlet air damper valve (TF-V-1002), and initiate the nitric acid addition. The nitric acid addition will be an automated process, adding a predetermined volume of [Proprietary Information].
- The operator will initiate the **dissolution** mode, which will start the dissolver heating and recirculation pump (TF-P-110). The dissolution will proceed at [Proprietary Information]. Density instrumentation will indicate that the uranium has dissolved.
- Once dissolution is complete, the operator will initiate the product **cooling** mode. The recirculation pump will continue to recirculate solution, and the heater will be deenergized. Chilled water will cool the product to ambient temperature by the uranium dissolution heat exchanger (TF-E-120). When the uranyl nitrate solution is cooled, the chilled water loop will be closed. The operator will open TF-V-1105 and close TF-V-1104 to transfer the uranyl nitrate solution to the uranyl nitrate storage tank (TF-TK-200).

4.4.2.2.4 Special Nuclear Material Description

Special Nuclear Material Inventory

Uranium within the fresh uranium receipt activities will be transient and bounded by the uranium inventory in the LEU storage SNM description (Section 4.4.2.10.4). Likewise, the criticality control features are discussed in the LEU storage SNM description.

The SNM inventory in the fresh uranium dissolution subsystem will consist of dissolving fresh LEU metal to uranyl nitrate. Table 4-59 lists the SNM inventory, accounting for both forms even though the maximum mass of both forms will not be present at the same time.

Table 4-59. Fresh Uranium Dissolution Design Basis Special Nuclear Material Inventory

Location	Form	Concentration[a]	Volume	SNM mass[a]
Uranium dissolver (TF-D-100)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Uranium dissolver (TF-D-100)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤19.95 wt% ^{235}U).

[b] Total uranium in the dissolver will not exceed this value. The form will change from uranium metal to uranyl nitrate during dissolution, so the SNM mass in the dissolver will remain constant.

^{235}U	= uranium-235.	N/A	= not applicable.
^{238}U	= uranium-238.	SNM	= special nuclear material.
LEU	= low-enriched uranium.	U	= uranium.

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-005, *NWMI Preliminary Criticality Safety Evaluation: Target Fabrication Uranium Solution Processes*. These features, including passive design features, active engineered features, and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are identified in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem include the passive design features, active engineered features, and administrative controls with designators of PDF, AEF, and AC, respectively, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features affect the design of process equipment, ventilation piping, and the room floor, and will include the following.

- The geometry of the process equipment is inherently criticality-safe (CSE-05-PDF3) and maintains a subcritical geometry during and after a facility DBE (CSE-05-PDF4). To prevent inadvertent interaction with mobile containers or carts, sidewalls surround the process skids (CSE-05-PDF5).
- Liquid systems vessels and piping are designed for chemical operating conditions such that corrosion and leaking of tank walls and seals are prevented or minimized (CSE-05-PDF6).
- Workstations where fresh LEU metal is handled do not have spill-prevention lips higher than 2.5 cm (1 in.) (CSE-05-PDF7).
- The ventilation system connected to process equipment containing fissile material is inherently criticality-safe by geometry, and overflow drains prevent liquid accumulation beyond the criticality-safe geometry (CSE-05-PDF8).
- For the case of a liquid leak, the floor is criticality-safe (CSE-05-PDF1), and a barrier or seal prevents penetration of fissile material into the floor (CSE-05-PDF2).

The active design features will include:

- The geometry of the closed-loop chilled water system is inherently criticality-safe (CSE-05-AEF1), which prevents criticality in case of an internal failure of the heat exchanger.
- Monitoring of the chilled water loop provides indication of the failure.

The administrative controls will include:

- Minimum spacing between movable containers and process equipment (CSE-05-AC1)
- Carrying limit of one fissile-bearing container per operator (CSE-05-AC2)
- [Proprietary Information] (CSE-05-AC3)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the fresh uranium dissolution activities.

- Fresh LEU metal for dissolution is handled in approved containers and within the mass and batch handling limits (IROFS CS-02). While moving the LEU metal, minimum spacing between the fresh LEU container and other fissile material is managed administratively (IROFS CS-03). These measures: (1) limit the operator to handle one container at a time, (2) require use of approved workstations with interaction control spacing from other fissile material, and (3) provide interaction guards at normally accessible fissile solution process equipment.
- The dissolver, heat exchanger, and associated piping and equipment are designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including the outside diameter of the process equipment and piping (IROFS CS-06), and fixed spacing between the process equipment with fissile solution (IROFS CS-07).
- The supply of nitric acid is a potential source for backflow of fissile solution to the large geometry of the chemical supply system. To prevent backflow, nitric acid is provided through an anti-siphon air break that separates the supply from the process equipment (IROFS CS-18). The anti-siphon air break is a pipe discharging to a funnel with a vertical offset so that siphoning is impossible.
- The dissolver receives nitric acid from the chemical supply system. Anti-siphon breaks (IROFS CS-18) on the nitric acid supply prevent backflow of fissile material to the chemical supply system.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features include:

- Administrative batch limits are set based on worst-case moderation, even though uranium is dry during normal conditions.
- Administrative interaction controls are based on many evenly spaced units contributing to the return of neutrons. Administrative failures during handling between workstations generally involve only two containers.
- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.2.5 Chemical Hazards

Chemical Inventory

The chemical reagents for the fresh uranium dissolution are listed in Table 4-60. In addition to the chemical reagents, offgases will include NO, NO_2, and nitric acid fumes.

Table 4-60. Fresh Uranium Dissolution Chemical Inventory

Chemical	Quantity	Physical form	Concentration (if applicable)
Nitric acid (HNO_3)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Note: This table does not include the SNM identified in Table 4-59.

SNM = special nuclear material.

Chemical Protection Provisions

The primary chemical hazards in the fresh uranium dissolution subsystem will be a chemical spray of nitric acid or uranyl nitrate, and personnel exposure to offgases. A spray shield installed on the skid will protect the operator from chemical burns in the event of a spray leak from the dissolver or associated piping. The headspace above the dissolver will be purged by a sweep gas and maintained at a negative pressure to prevent personnel exposure to offgases.

4.4.2.3 Nitrate Extraction Subsystem

The nitrate extraction subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.3.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.4.2.3.2 and 4.4.2.3.3.

A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.3.4. A description of hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are presented in Section 4.4.2.3.5.

4.4.2.3.1 Process Description

Figure 4-89 provides the stream numbers corresponding to the nitrate extraction process description.

[Proprietary Information]

Figure 4-89. Nitrate Extraction Process Flow Diagram

Fresh uranyl nitrate will be received from the [Proprietary Information]. The specifications of the recycled uranium are summarized in Table 4-61.

Table 4-61. Recycled Uranium Specification (2 pages)

Chemical or physical property[a]	Specification	Comment
Form	[Proprietary Information]	[Proprietary Information]
Total uranium, nitric acid	[Proprietary Information]	[Proprietary Information]
Uranium Isotopes		
^{232}U	[Proprietary Information]	[Proprietary Information]
^{233}U	[Proprietary Information]	[Proprietary Information]
^{234}U	[Proprietary Information]	[Proprietary Information]
^{235}U	[Proprietary Information]	[Proprietary Information]
^{236}U	[Proprietary Information]	[Proprietary Information]
Other Actinides		
^{238}Pu	[Proprietary Information]	[Proprietary Information]
^{239}Pu	[Proprietary Information]	[Proprietary Information]
^{240}Pu	[Proprietary Information]	[Proprietary Information]
^{242}Pu	[Proprietary Information]	[Proprietary Information]
^{241}Am	[Proprietary Information]	[Proprietary Information]
^{237}Np	[Proprietary Information]	[Proprietary Information]
^{231}Pa	[Proprietary Information]	[Proprietary Information]
^{233}Pa	[Proprietary Information]	[Proprietary Information]
^{230}Th	[Proprietary Information]	[Proprietary Information]
Fission Products		
^{95}Zr	[Proprietary Information]	[Proprietary Information]
^{95}Nb	[Proprietary Information]	[Proprietary Information]
^{103}Ru	[Proprietary Information]	[Proprietary Information]
All others total	[Proprietary Information]	[Proprietary Information]
Other Impurities		
Iron	[Proprietary Information]	[Proprietary Information]
Chromium	[Proprietary Information]	[Proprietary Information]

Table 4-61. Recycled Uranium Specification (2 pages)

Chemical or physical property[a]	Specification	Comment
Nickel	[Proprietary Information]	[Proprietary Information]
Sodium	[Proprietary Information]	[Proprietary Information]

Source: NWMI-2013-049, *Process System Functional Specification*, Rev. C, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

[a] No constraint is imposed on the recycled uranium for chemical or physical properties that are not listed in this table.

[b] **(α, n) source limit** = These isotopes represent potential sources of worker exposure due to interaction of alpha particles with light elements (e.g., oxygen) that generate neutrons and could influence shielding requirements for target fabrication and handling systems. The specification is based on limiting the neutron generation rate increase of an individual isotope to [Proprietary Information]. Estimate simplifications are described in NWMI-2013-049.

[c] The facility will process LEU; processing higher uranium enrichments is not included in the process scope. A maximum product specification for ^{235}U is assumed to still be documented as part of the criticality safety controls. A minimum ^{235}U content is expected to be identified in the future based on target economics and is not included in the preconceptual design scope.

[d] **γ source limit** = These isotopes represent potential gamma emitter sources of worker exposure and could influence shielding requirements for target fabrication and handling systems. The specification is based on limiting the unshielded dose [Proprietary Information]. Estimate simplifications are described in NWMI-2013-049.

LEU = low-enriched uranium.
ppmp U = parts per million parts uranium by mass.
TBD = to be determined.
U = uranium.
[Proprietary Information]

The uranyl nitrate solution will be stored in a tank (TF-TK-200) and blended and diluted with demineralized water to create [Proprietary Information] uranyl nitrate solution with consistent ^{235}U enrichment and impurities.

The nitrate extraction subsystem will use a solvent extraction process to remove nitrate from the solution to convert uranyl nitrate with excess nitric acid to ADUN with a ratio of [Proprietary Information]. The nitrate extraction process will last less than 4 hr/batch of uranyl nitrate received. The nitrate extraction reactions are given as:

$$RNH_2 + HNO_3 \longrightarrow RNH_3NO_3 \quad \text{Equation 4-8}$$

$$RNH_3NO_3 + NaOH \longrightarrow RNH_2 + NaNO_3 + H_2O \quad \text{Equation 4-9}$$

The solvent extraction process will be accomplished with a [Proprietary Information]. Red oil formation is not a concern in this process because tributyl phosphate (TBP) is not present. The temperature for the solvent extraction process will be maintained at [Proprietary Information] by inline heaters for all feeds (TF-E-220, TF-E-223, TF-E-226, and TF-E-255). To avoid uranium losses due to undesirable reactions, the uranium concentration will be controlled [Proprietary Information].

1. The nitrate extraction contactor (TF-Z-230) will mix the uranyl nitrate solution with [Proprietary Information] in solvent to extract nitrates (ORNL-5300, *Resin-Based Preparation of HGTR Fuels: Operation of an Engineering-Scale Uranium Loading System*). The inlet flow of uranyl nitrate will be [Proprietary Information]. An inline pH meter and transmitter on the uranyl nitrate stream will control the speed of the nitrate extraction solvent pump (TF-P-250). The aqueous product from the nitrate extraction contactor (TF-Z-230) will flow to the phase separator (TF-SP-270). The solvent will flow to the uranium recovery contactors (TF-Z-231A/B).

2. The two uranium recovery contactors, configured in series (TF-Z-231A/B), will wash the solvent stream with demineralized water to minimize uranium losses. The demineralized water will be fed at a combined ratio of [Proprietary Information]. The aqueous products from the uranium recovery contactors (TF-Z-231A/B) will flow to the phase separator (TF-SP-270), and the solvent will flow to the organic regeneration contactor (TF-Z-232).
3. The organic regeneration contactor (TF-Z-232) will regenerate the amine using [Proprietary Information]. An inline pH meter and transmitter on the solvent stream will control the flow of the sodium hydroxide solution. The aqueous effluent (sodium nitrate solution) will drain to a surge tank that pumps the solution to the aqueous waste holding subsystem, and the solvent will flow to the wash contactor (TF-Z-233).
4. The wash contactor (TF-Z-233) will wash the solvent with demineralized water to scrub entrained aqueous waste from the solvent. The demineralized water will be fed at a ratio of [Proprietary Information]. The aqueous effluent (sodium nitrate solution) will drain to a surge tank that pumps the solution to the aqueous waste holding subsystem, and the solvent will drain to the nitrate extraction solvent feed tank (TF-TK-240).
5. The aqueous product from the nitrate extraction contactor (TF-Z-230) and the uranium recovery contactors (TF-Z-231A/B) may have entrained solvents or excess solvent due to process upsets. The phase separator (TF-SP-270) will separate solvent from the aqueous product. Solvent recovered from the phase separator will flow to the nitrate extraction solvent feed tank (TF-TK-240). The aqueous product will drain to an ADUN surge tank (TF-TK-280) and will be pumped to the recycled uranyl nitrate concentration subsystem.

The nitrate extraction solvent will be purged at a rate of [Proprietary Information], and fresh solvent will be added at the same frequency. The purged solvent will be discharged to [Proprietary Information] containers and analyzed for uranium concentration in the analytical laboratory before disposal.

4.4.2.3.2 Process Equipment Arrangement

The nitrate extraction process equipment will be mounted on one skid and one workstation within room T104C, the wet side of the target fabrication room. Figure 4-90 shows the location of the process equipment.

[Proprietary Information]

Figure 4-90. Nitrate Extraction Equipment Layout

Figure 4-91 shows the arrangement of the uranyl nitrate storage tank, which will receive the recycled uranyl nitrate from the U recovery and recycle system and feed the nitrate extraction process.

[Proprietary Information]

Figure 4-91. Uranyl Nitrate Storage Tank Arrangement

Figure 4-92 shows the arrangement of the nitrate extraction process. The solvent extraction will occur in bench-mounted contactors. Uranyl nitrate will enter at the nitrate extraction contactor (TF-Z-230), and the ADUN product will flow to the phase separator (TF-SP-270). The product from the phase separator will drain to the ADUN surge tank (TF-TK-240) and will be pumped to the ADUN concentration subsystem. Aqueous waste from the contactors will drain to the aqueous waste surge tank (TF-TK-260) and will be pumped to the target fabrication waste subsystem. The solvent will be fed to the nitrate extraction contactor and to the subsequent contactors (TF-Z-231A through TF-Z-233) before draining back to the nitrate extraction solvent feed tank (TF-TK-240) for recycle.

[[Proprietary Information]

Figure 4-92. Nitrate Extraction Equipment Arrangement

4.4.2.3.3 Process Equipment Design

This section identifies the processing apparatus and auxiliary equipment supporting the nitrate extraction subsystem. This equipment is listed in Table 4-62 with design data developed during preliminary design. Because dimensions have not yet been defined, two fields are provided to identify the basis for equipment dimensions: capacity and whether the equipment is designed to be criticality-safe by geometry. Additional detailed information (e.g., dimensions) will be developed for the Operating License Application.

Table 4-62. Nitrate Extraction Process Equipment

Equipment name	Equipment no.	Individual tank capacity	Criticality-safe by geometry	Tank material	Operating range	
					Temperature	Pressure
Uranyl nitrate storage tank	TF-TK-200	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Uranyl nitrate storage pump	TF-P-210	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
Uranyl nitrate feed pump	TF-P-215	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
Uranyl nitrate heater	TF-E-220	[Proprietary Information]	N/A	TBD	[Proprietary Information]	[Proprietary Information]
Water heater	TF-E-223	[Proprietary Information]	N/A	TBD	[Proprietary Information]	[Proprietary Information]
Caustic heater	TF-E-226	[Proprietary Information]	N/A	TBD	[Proprietary Information]	[Proprietary Information]
Nitrate extraction contactor	TF-Z-230	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium recovery contactor	TF-Z-231A	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Uranium recovery contactor	TF-Z-231B	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Organic regeneration contactor	TF-Z-232	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Wash contactor	TF-Z-233	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Nitrate extraction solvent feed tank	TF-TK-240	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Nitrate extraction solvent pump	TF-P-250	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
Solvent heater	TF-E-255	[Proprietary Information]	N/A	TBD	[Proprietary Information]	[Proprietary Information]
Aqueous waste surge tank	TF-TK-260	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Aqueous waste surge pump	TF-P-265	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
Phase separator	TF-SP-270	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
ADUN surge tank	TF-TK-280	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
ADUN surge tank pump	TF-P-285	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]

ADUN = acid-deficient uranyl nitrate.
N/A = not applicable.
SS = stainless steel.
TBD = to be determined.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. Preliminary process sequences are provided in this section to identify the control strategy for normal operations, which sets requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information on the process monitoring and control equipment will be developed for the Operating License Application.

Nitrate extraction will be a semi-batch process. There are four normal modes of operation: standby, extraction preparation, nitrate extraction, and end of extraction.

- During **standby** mode, the uranyl nitrate storage tank (TF-TK-200) may receive recycled uranyl nitrate, fresh uranyl nitrate, and/or water for dilution. Pumps, heaters, and contactors will all be deenergized. The surge tank pumps will remain energized.
- During **extraction preparation** mode, the uranyl nitrate storage pump (TF-P-210) will mix uranyl nitrate within TF-TK-200 by recirculation. The contactors (TF-Z-230 – TF-Z-233), solvent pump (TF-P-250), and solvent heater (TF-E-255) will be energized to preheat the contactors.
- To initiate **nitrate extraction,** all feed streams (uranyl nitrate, demineralized water, and 1.5 M caustic) will be opened, and their respective heaters energized. The first three contactors (TF-Z-230, TF-Z-231A/B) will recover ADUN as their aqueous product. The product will flow through the phase separator (TF-SP-270) to the ADUN surge tank (TF-TK-280), where product will be pumped to the ADUN evaporator feed tank (TF-TK-300).
- The **end of extraction** operations has not been defined.

4.4.2.3.4 Special Nuclear Material Description

Special Nuclear Material Inventory

The SNM inventory in the nitrate extraction subsystem will consist of the recycled uranyl nitrate. Table 4-63 lists the SNM inventory, which includes the recycled uranyl nitrate storage tank.

Table 4-63. Nitrate Extraction Special Nuclear Material Inventory

Location	Form	Concentration[a]	Volume	SNM mass[a]
Uranyl nitrate storage tank (TF-TK-200)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent the total amount of LEU (combined ^{235}U and ^{238}U at ≤19.95 wt% ^{235}U).

^{235}U = uranium-235
^{238}U = uranium-238
LEU = low-enriched uranium.
SNM = special nuclear material.
U = uranium.

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-005. These features, including passive design features, active engineered features, and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem include the passive design features, active engineered features, and administrative controls with designators of PDF, AEF, and AC, respectively, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features affect the design of process equipment, ventilation piping, and the room floor, and will include the following.

- The geometry of the process equipment is inherently criticality-safe (CSE-05-PDF3) and maintains subcritical geometry during and after a facility DBE (CSE-05-PDF4). To prevent inadvertent interaction with mobile containers or carts, sidewalls surround the process skids (CSE-05-PDF5).
- Liquid systems vessels and piping are designed for chemical operating conditions such that corrosion and leaking of tank walls and seals are prevented or minimized (CSE-05-PDF6).
- The ventilation system connected to storage tanks, or other equipment with fissile material, is inherently criticality-safe by geometry, and overflow drains prevent liquid accumulation beyond the criticality-safe geometry (CSE-05-PDF8).
- For the case of a liquid leak, the floor is criticality-safe (CSE-05-PDF1), and a barrier or seal prevents penetration of fissile material into the floor (CSE-05-PDF2).

The administrative controls will include:

- Minimum spacing between movable containers and process equipment (CSE-05-AC1)

Chapter 13.0, Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the nitrate extraction activities.

- The tanks, contactors, heat exchangers and associated piping and equipment are designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including: (1) outside diameter of process equipment and piping (IROFS CS-06) and (2) fixed spacing between process equipment with fissile solution (IROFS CS-07).
- The supplies of sodium hydroxide solution and demineralized water are potential sources for backflow of fissile solution to the large geometry of the chemical supply system or the demineralized water system. To prevent backflow, reagents are provided through an anti-siphon air break that separates the supply from the process equipment (IROFS CS-18). The anti-siphon air break is a pipe discharging to a funnel with a vertical offset so that siphoning is impossible.
- Instrument air supplied for level measurement is a potential source for backflow of fissile solution to the large geometry of the instrument air system. To prevent backflow, the instrument air supply piping has a high point above the maximum liquid level before connecting to the vented tank (IROFS CS-20). If instrument air supply pressure is lost, the highest liquid level is below the supply piping high point, so backflow is impossible.

In addition to the features that apply the double-contingency principle, several features provide defense-in-depth in criticality control. These features will include the following.

- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.3.5 Chemical Hazards

Chemical Inventory

The nitrate extraction chemical inventory is summarized in Table 4-64.

Table 4-64. Nitrate Extraction Chemical Inventory

Chemical	Quantity	Physical form	Concentration (if applicable)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Note: This table does not include the SNM identified in Table 4-63.

SNM = special nuclear material.

Chemical Protection Provisions

The primary chemical hazards in the nitrate extraction subsystem will be a chemical spray of uranyl nitrate or solvent, and personnel exposure to offgases. A spray shield installed on the skids will protect the operator from chemical burns in the event of a spray leak from the process equipment or associated piping. The headspace above the process equipment will be maintained at a negative pressure and vented to the vessel ventilation system to prevent personnel exposure to offgases.

4.4.2.4 Acid-Deficient Uranyl Nitrate Concentration Subsystem

The ADUN concentration subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.4.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 0 and 4.4.2.4.3. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.4.4. A description of hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are presented in Section 4.4.2.4.5.

4.4.2.4.1 Process Description

Figure 4-93[Proprietary Information]

Figure 4-93 provides the stream numbers corresponding to the ADUN concentration process description.

ADUN solution from the nitrate extraction subsystem will be fed to the ADUN concentration subsystem at less than [Proprietary Information]. The dilute ADUN solution will be stored in the ADUN evaporator feed tank (TF-TK-300) and then fed into the steam-heated evaporator (TF-V-340 and TF-E-330), where it will be [Proprietary Information].

The evaporator level will be monitored by a bubbler that compensates for density. When the level is too low, additional ADUN will be fed from the ADUN evaporator feed tank (TF-TK-300). The concentrated ADUN will be cooled to [Proprietary Information] and stored in the ADUN storage tanks (TF-TK-400, TF-TK-405, TF-TK-410, and TF-TK-415).

The overheads from the evaporator will be condensed in the ADUN evaporator condenser (TF-E-350) and drained to the aqueous waste pencil tanks (TF-TK-700, 705). Non-condensable vapors from the condenser will vent to the vessel ventilation system.

[Proprietary Information]

Figure 4-93. Acid-Deficient Uranyl Nitrate Concentration Process Flow Diagram

4.4.2.4.2 Process Equipment Arrangement

The ADUN concentration process equipment will be mounted on two skids within room T104C, the wet side of the target fabrication room. Figure 4-94 shows the location of the process equipment.

[Proprietary Information]

Figure 4-94. Acid-Deficient Uranyl Nitrate Concentration Equipment Layout

Figure 4-95 shows the arrangement of the ADUN concentration feed tank where ADUN will be received from the nitrate extraction subsystem. Figure 4-96 shows the arrangement of the concentration equipment, including the evaporator column (TF-V-340), the reboiler (TF-E-330), and the condenser (TF-E-350). Concentrated ADUN from the evaporator will be cooled to near-ambient temperature by the ADUN product heat exchanger (TF-E-360).

[Proprietary Information]

Figure 4-95. Acid-Deficient Uranyl Nitrate Concentration Feed Equipment Arrangement

Figure 4-96. Acid-Deficient Uranyl Nitrate Concentration Equipment Arrangement

4.4.2.4.3 Process Equipment Design

This section identifies the processing apparatus and auxiliary equipment supporting the ADUN concentration subsystem. This equipment is listed in Table 4-65 with design data developed during preliminary design. Because dimensions have not yet been defined, two fields are provided to identify the basis for equipment dimensions: capacity and whether the equipment is designed to be criticality-safe by geometry. Additional detailed information (e.g., dimensions) will be developed for the Operating License Application.

Table 4-65. Acid Deficient Uranyl Nitrate Concentration Process Equipment

Equipment name	Equipment no.	Individual tank capacity	Criticality-safe by geometry	Tank material	Operating range	
					Temperature	Pressure
ADUN evaporator feed tank	TF-TK-300	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
ADUN evaporator feed pump	TF-P-310	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
ADUN evaporator pump	TF-P-320	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
ADUN evaporator reboiler	TF-E-330	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
ADUN evaporator	TF-V-340	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
ADUN evaporator condenser	TF-E-350	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
ADUN product heat exchanger	TF-E-360	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]

ADUN = acid-deficient uranyl nitrate.
N/A = not applicable.
SS = stainless steel.
TBD = to be determined.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. Preliminary process sequences are provided in this section to identify the control strategy for normal operations, which sets requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information of the process monitoring and control equipment will be developed for the Operating License Application.

ADUN concentration is a semi-batch process. There will be three normal modes of operation: standby, concentration, and end of concentration.

- During **standby** mode, the ADUN evaporator feed tank (TF-TK-300) may receive dilute ADUN from the nitrate extraction subsystem. Steam and chilled water supply valves will be closed, and pumps de-energized. TF-P-310 may be energized to mix contents.
- The evaporator will **concentrate** the ADUN [Proprietary Information]. Level measurement will control the dilute ADUN inlet valve, and density measurement will control the product discharge valve. The product will be cooled to ambient temperatures in TF-E-360. The operator will initiate concentration mode by:
  - Feeding dilute ADUN to the ADUN evaporator (TF-V-340)
  - Beginning forced recirculation by energizing TF-P-320
  - Opening steam and chilled water supply valves to TF-E-330, TF-E-350, and TF-E-360
- The **end of concentration** mode will begin when feed from TF-TK-300 is exhausted and the ADUN within the evaporator has reached a [Proprietary Information]. The steam supply valve will be closed, and the concentrated ADUN will be pumped by TF-P-320 to TF-TK-400. TF-P-320 will be deenergized, and the chilled water supply valves will be closed. After the end of concentration mode, the ADUN concentration subsystem will return to standby mode.

4.4.2.4.4 Special Nuclear Material Description

Special Nuclear Material Inventory

The SNM inventory in the ADUN concentration subsystem will consist of dilute and concentrated ADUN. Table 4-66 lists the SNM inventory, including the feed tank and evaporator.

Table 4-66. Acid-Deficient Uranyl Nitrate Concentration Maximum Special Nuclear Material Inventory

Location	Form	Concentration[a]	Volume	SNM mass[a]
ADUN evaporator feed tank (TF-TK-300)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
ADUN evaporator	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤19.95 wt% ^{235}U).

[b] ADUN evaporator cannot receive more SNM mass than is in the ADUN evaporator feed tank due to the nature of the batch processing, so the evaporator feed tank provides a bounding estimate for the subsystem.

^{235}U	= uranium-235.	LEU	= low-enriched uranium.
^{238}U	= uranium-238.	SNM	= special nuclear material.
ADUN	= acid-deficient uranyl nitrate.	U	= uranium.

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-005. These features, including passive design features, active engineered features and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem include the passive design features, active engineered features, and administrative controls with designators of PDF, AEF, and AC, respectively, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features affect the design of process equipment, ventilation piping, and the room floor, which will include the following.

- The geometry of the process equipment is inherently criticality-safe (CSE-05-PDF3) and maintains subcritical geometry during and after a facility DBE (CSE-05-PDF4). To prevent inadvertent interaction with mobile containers or carts, sidewalls surround the process skids (CSE-05-PDF5).
- Liquid systems vessels and piping are designed for chemical operating conditions such that corrosion and leaking of tank walls and seals are prevented or minimized (CSE-05-PDF6).
- The ventilation system connected to the evaporator feed tanks and the evaporator is inherently criticality-safe by geometry, and overflow drains prevent liquid accumulation beyond the criticality-safe geometry (CSE-05-PDF8).
- For the case of a liquid leak, the floor is criticality-safe (CSE-05-PDF1), and a barrier or seal prevents penetration of fissile material into the floor (CSE-05-PDF2).

The active design features will include:

- The geometry of the closed-loop chilled water system is inherently criticality safe (CSE-05-AEF1), which prevents criticality in case of an internal failure of the heat exchanger. Monitoring of the chilled water loop provides indication of the failure.
- The condensate return from the ADUN reboiler is monitored for uranium. If uranium is detected, an isolation valve prevents the condensate from returning to the process steam system (CSE-05-AEF2).

The administrative controls will include:

- Minimum spacing between movable containers and process equipment (CSE-05-AC1)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the ADUN concentration activities.

- The tanks, evaporator, heat exchangers, and associated piping and equipment are designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including the outside diameter of the process equipment and piping (IROFS CS-06), and fixed spacing between the process equipment with fissile solution (IROFS CS-07).
- The ADUN evaporator reboiler (TF-E-330) is an interface between the large-geometry steam system and fissile material. In the case of a heat exchanger failure simultaneous with a change in pressure differential, the condensate return piping could contain fissile material. A conductivity switch and interlock would close an isolation valve on the condensate return to prevent fissile material from proceeding to the process steam system (IROFS CS-10).
- Instrument air piping for level measurement is a potential source for backflow of fissile solution to the large geometry of the instrument air system. To prevent backflow, the instrument air supply piping has a high point above the maximum liquid level before connecting to the vented tank (IROFS CS-20). If instrument air supply pressure is lost, the highest liquid level is below the supply piping high point, so backflow is impossible.

In addition to the features that apply the double-contingency principle, several features provide defense-in depth in criticality control. These features will include the following

- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.4.5 Chemical Hazards

Chemical Inventory

The chemical inventory in the ADUN concentration subsystem is represented in the SNM inventory in Table 4-66.

Chemical Protection Provisions

The primary chemical hazard in the ADUN concentration subsystem will be a chemical spray of ADUN. A spray shield installed on the skids will protect the operator from chemical burns in the event of a spray leak from the process equipment or associated piping.

4.4.2.5 [Proprietary Information]

The [Proprietary Information] subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.5.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 0 and 4.4.2.5.3. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.5.4. A description of hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are presented in Section 4.4.2.5.5.

4.4.2.5.1 Process Description

Figure 4-97 provides the stream numbers corresponding to the [Proprietary Information].

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

Figure 4-97. Sol-Gel Column Feed Process Flow Diagram

4.4.2.5.2 Process Equipment Arrangement

[Proprietary Information]. Figure 4-98 shows the location of the process equipment.

[Proprietary Information]

Figure 4-98. Sol-Gel Column Feed Equipment Layout

[Proprietary Information]

[Proprietary Information]

Figure 4-99. Concentrated Acid-Deficient Uranyl Nitrate Storage Equipment Arrangement

Figure 4-100. Sol-Gel Column Feed Equipment Arrangement

4.4.2.5.3 Process Equipment Design

This section identifies the processing apparatus and auxiliary equipment supporting the [Proprietary Information] subsystem. This equipment is listed in Table 4-67 with design data developed during preliminary design. Because dimensions have not yet been defined, two fields are provided to identify the basis for equipment dimensions: capacity and whether the equipment is designed to be criticality-safe by geometry. Additional detailed information (e.g., dimensions) will be developed for the Operating License Application.

Table 4-67. [Proprietary Information] Process Equipment

Equipment name	Equipment no.	Individual tank capacity	Criticality-safe by geometry	Tank material	Operating range	
					Temperature	Pressure
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

ADUN = acid-deficient uranyl nitrate.
N/A = not applicable.
SS = stainless steel.
TBD = to be determined.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. Preliminary process sequences are provided in this section to identify the control strategy for normal operations, which sets requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information of the process monitoring and control equipment will be developed for the Operating License Application.

[Proprietary Information]

- [Proprietary Information]

- [Proprietary Information]

4.4.2.5.4 Special Nuclear Material Description

Subsystem Special Nuclear Material Inventory

[Proprietary Information]

Table 4-68. [Proprietary Information] Special Nuclear Material Inventory

Location	Form	Concentration[a]	Volume	SNM mass[a]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤19.95 wt% ^{235}U).

^{235}U	= uranium-235.	LEU	= low-enriched uranium.
^{238}U	= uranium-238.	SNM	= special nuclear material.
ADUN	= acid-deficient uranyl nitrate.	U	= uranium.

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-004, *NWMI Preliminary Criticality Safety Evaluation: Low-Enriched Uranium Target Material Production*. These features, including passive design features, active engineered features, and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2.

The criticality control features for this subsystem include the passive design features, active engineered features, and administrative controls with designators of PDF, AEF, and AC, respectively, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features will include:

- The geometry of the process equipment is inherently criticality safe (CSE-04-PDF3, CSE-04-PDF7) and maintains subcritical geometry during and after a facility DBE (CSE-04-PDF4). To prevent inadvertent interaction with mobile containers or carts, sidewalls surround the process skids (CSE-04-PDF5). Process equipment and piping are designed for the normal process fluids and operating temperatures to minimize leakage (CSE-04-PDF6). At interfaces between large-geometry equipment and criticality-geometry equipment, anti-siphon air breaks prevent backflow (CSE-04-PDF12).
- The ventilation system connected to process equipment containing fissile material is inherently criticality-safe by geometry, and overflow drains prevent liquid accumulation beyond the criticality-safe geometry (CSE-04-PDF16).
- For the case of a liquid leak, the floor is criticality-safe (CSE-04-PDF1), and a barrier or seal prevents penetration of fissile material into the floor (CSE-04-PDF2).

The active engineered features will include:

- Continuous ventilation of tanks containing fissile material (CSE-04-AEF1)

The administrative features will include:

- Minimum spacing between movable containers and process equipment (CSE-04-AC3)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. [Proprietary Information].

- The tanks, heat exchangers and associated piping and equipment are designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including: (1) outside diameter of process equipment and piping (IROFS CS-06), and (2) fixed spacing between process equipment with fissile solution (IROFS CS-07).
- The supply of HMTA-urea solution is a potential source for backflow of fissile solution to the large geometry tanks. To prevent backflow, reagents are provided through an anti-siphon air break that separates the supply from the process equipment (IROFS CS-18). The anti-siphon air break is a pipe discharging to a funnel with a vertical offset so that siphoning is impossible.
- Instrument air piping for level measurement is a potential source for backflow of fissile solution to the large geometry of the instrument air system. To prevent backflow, the instrument air supply piping has a high point above the maximum liquid level before connecting to the vented tank (IROFS CS-20). If instrument air supply pressure is lost, the highest liquid level is below the supply piping high point, so backflow is impossible.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include the following.

- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.5.5 Chemical Hazards

Chemical Inventory

The chemical inventory for the [Proprietary Information] subsystem is summarized in Table 4-69.

Table 4-69. Chemical Inventory for the Sol-Gel Column Feed Subsystem

Chemical	Quantity	Physical form	Concentration (if applicable)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Note: This table does not include the SNM identified in Table 4-68.

SNM = special nuclear material.

Chemical Protection Provisions

[Proprietary Information]. A spray shield installed on the skids will protect the operator from chemical burns in the event of a spray leak from the process equipment or associated piping. The headspace above the process equipment will be maintained at a negative pressure and vented to the vessel vent system to prevent personnel exposure to offgases.

4.4.2.6 [Proprietary Information] Subsystem

[Proprietary Information]. The process description (Section 4.4.2.6.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.4.2.6.2 and 4.4.2.6.3. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.6.4. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.4.2.6.5.

4.4.2.6.1 Process Description

Figure 4-101 provides the stream numbers corresponding to [Proprietary Information].

[Proprietary Information

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

Figure 4-101. [Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

4.4.2.6.2 Process Equipment Arrangement

[Proprietary Information]

[Proprietary Information]

Figure 4-102. [Proprietary Information] Layout

[Proprietary Information]

4.4.2.6.3 Process Equipment Design

This section identifies the processing apparatus and [Proprietary Information] column subsystem. This equipment is listed in Table 4-70 with design data developed during preliminary design. Because dimensions have not yet been defined, two fields are provided to identify the basis for equipment dimensions: capacity and whether the equipment is designed to be criticality-safe by geometry. Additional detailed information (e.g., dimensions) will be developed for the Operating License Application.

[Proprietary Information]

Figure 4-103. [Proprietary Information] Arrangement

Table 4-70. [Proprietary Information]

Equipment name	Equipment no.	Individual tank capacity	Criticality-safe by geometry	Tank material	Operating range	
					Temperature	Pressure
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

N/A = not applicable.
SS = stainless steel.
TBD = to be determined.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. Preliminary process sequences are provided in this section to identify the control strategy for normal operations, which set requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information of the process monitoring and control equipment will be developed for the Operating License Application.

[Proprietary Information].

- [Proprietary Information]
- [Proprietary Information]

4.4.2.6.4 Special Nuclear Material Description

Special Nuclear Material Inventory

[Proprietary Information]

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-006, *NWMI Preliminary Criticality Safety Evaluation: Target Finishing*. These features, including passive design features, active engineered features, and administrative controls, allow for adherence to the double-contingency principle.

This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem include the passive design features, active engineered features, and administrative controls with designators of PDF, AEF, and AC, respectively, listed below. The passive design features include requirements for the floor, process equipment, workstations, and ventilation system. Active engineered features include the requirement of continuous ventilation. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features will include the following.

- The geometry of the process equipment is inherently criticality-safe (CSE-04-PDF3, CSE-04-PDF7, CSE-04-PDF8, CSE-04-PDF9, CSE-04-PDF10, CSE-04-PDF15) and maintains subcritical geometry during and after a facility DBE (CSE-04-PDF4). To prevent inadvertent interaction with mobile containers or carts, sidewalls surround the process skids (CSE-04-PDF5, CSE-04-PDF13). Process equipment and piping are designed for the normal process fluids and operating temperatures to minimize leakage (CSE-04-PDF6). At interfaces between large-geometry equipment and criticality-geometry equipment, anti-siphon air breaks prevent backflow (CSE-04-PDF12).
- Workstations where LEU target material is handled do not have spill-prevention lips higher than 2.54 cm (1 in.) (CSE-04-PDF11, CSE-04-PDF14).
- The ventilation system connected to process equipment containing fissile material is inherently criticality-safe by geometry, and overflow drains prevent liquid accumulation beyond the criticality-safe geometry (CSE-04-PDF16).
- For the case of a liquid leak, the floor is criticality-safe (CSE-04-PDF1), and a barrier or seal prevents penetration of fissile material into the floor (CSE-04-PDF2).

The active engineered features will include:

- Continuous ventilation of tanks containing fissile material (CSE-04-AEF1)

The administrative features will include:

- Minimum spacing between movable containers and process equipment (CSE-04-AC3)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the [Proprietary Information].

- The tanks, heat exchangers, and associated piping and equipment are designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including: (1) outside diameter of process equipment and piping (IROFS CS-06), and (2) fixed spacing between process equipment with fissile solution (IROFS CS-07).
- Instrument air piping for level measurement is a potential source for backflow of fissile solution to the large geometry of the instrument air system. To prevent backflow, the instrument air supply piping has a high point above the maximum liquid level before connecting to the vented tank (IROFS CS-20). If instrument air supply pressure is lost, the highest liquid level is below the supply piping high point, so backflow is impossible.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include the following.

- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided in the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.6.5 Chemical Hazards

Chemical Inventory

[Proprietary Information]

Table 4-71. [Proprietary Information] Subsystem

Chemical	Quantity	Physical form	Concentration (if applicable)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Note: This table does not include the SNM identified in Table 4-68.

SNM = special nuclear material.

Chemical Protection Provisions

[Proprietary Information].

4.4.2.7 [Proprietary Information] Subsystem

The [Proprietary Information] subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.7.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.4.2.7.2 and 4.4.2.7.3. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.7.4. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.4.2.7.5.

4.4.2.7.1 Process Description

Figure 4-104 provides the stream numbers corresponding to the [Proprietary Information] descriptions.

[Proprietary Information]

Figure 4-104. [Proprietary Information] Flow Diagram

[Proprietary Information]

[Proprietary Information]

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

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

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

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

Table 4-72. [Proprietary Information]

Process operation	Probable recycle material
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]

LEU = low-enriched uranium.
[Proprietary Information]
[Proprietary Information]

4.4.2.7.2 Process Equipment Arrangement

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

Figure 4-105. [Proprietary Information] Layout

[Proprietary Information]

[Proprietary Information]

Figure 4-106. [Proprietary Information] Arrangement

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

Figure 4-107. [Proprietary Information] Arrangement

[Proprietary Information]

Figure 4-108. [Proprietary Information] Layout

Figure 4-109 shows the arrangement of the [Proprietary Information].

[Proprietary Information]

Figure 4-109. [Proprietary Information] Arrangement

4.4.2.7.3 Process Equipment Design

[Proprietary Information]. Equipment is listed in Table 4-73 with the design data developed during preliminary design. Because dimensions have not yet been defined, two fields are provided to identify the basis for equipment dimensions: capacity and whether the equipment is designed to be criticality-safe by geometry. Additional detailed information (e.g., dimensions) will be developed for the Operating License Application.

Table 4-73. [Proprietary Information]

Equipment name	Equipment no.	Individual tank capacity	Criticality-safe by geometry	Tank material	Operating range	
					Temperature	Pressure
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[Proprietary Information]
LEU = low-enriched uranium.
N/A = not applicable.
[Proprietary Information].
SS = stainless steel.
TBD = to be determined.
TCE = trichloroethylene.

Process Monitoring and Control Equipment

Process monitoring and control equipment was not defined during preliminary design. Preliminary process sequences are provided in this section to identify the control strategy for normal operations, which sets requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information of the process monitoring and control equipment will be developed for the Operating License Application.

[Proprietary Information]

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

4.4.2.7.4 Special Nuclear Material Description

Spent Nuclear Material Inventory

[Proprietary Information]

Table 4-74. [Proprietary Information]

Location	Form	Concentration[a]	Volume	SNM mass[a]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U).

^{235}U = uranium-235.
^{238}U = uranium-238.
LEU = low-enriched uranium.
N/A = not applicable.
SNM = special nuclear material.
U = uranium.
[Proprietary Information]
[Proprietary Information]

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-004. These features, including passive design features, active engineered features, and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem include the passive design features, active engineered features, and administrative controls with designators of PDF, AEF, and AC, respectively, listed below. The passive design features include requirements of the floor, process equipment, workstations, and ventilation system. Active engineered features include the requirement of continuous ventilation. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features will include the following.

- The geometry of the process equipment is inherently criticality-safe (CSE-04-PDF3, CSE-04-PDF8, CSE-04-PDF9, CSE-04-PDF10) and maintains subcritical geometry during and after a facility DBE (CSE-04-PDF4). To prevent inadvertent interaction with mobile containers or carts, sidewalls surround the process skids (CSE-04-PDF5, CSE-04-PDF13). Process equipment and piping are designed for the normal process fluids and operating temperatures to minimize leakage (CSE-04-PDF6).
- Workstations where LEU target material is handled do not have spill-prevention lips higher than 2.54 cm (1 in.) (CSE-04-PDF11, CSE-04-PDF14).
- The ventilation system connected to process equipment containing fissile material is inherently criticality-safe by geometry, and overflow drains prevent liquid accumulation beyond the criticality-safe geometry (CSE-04-PDF16).
- For the case of a liquid leak, the floor is criticality-safe (CSE-04-PDF1), and a barrier or seal prevents penetration of fissile material into the floor (CSE-04-PDF2).

The active engineered features will include:

- Continuous ventilation of tanks containing fissile material (CSE-04-AEF1)

The administrative controls will include:

- Size limit of process apparatus holding target material (CSE-04-AC1 and CSE-04-AC2)
- Minimum spacing between movable containers and process equipment (CSE-04-AC3)
- Carrying limit of one fissile-bearing container per operator (CSE-04-AC4)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the [Proprietary Information] activities.

- [Proprietary Information]
- [Proprietary Information]

- The surge tanks and associated piping and equipment are designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including (1) outside diameter of process equipment and piping (IROFS CS-06), and (2) fixed spacing between process equipment with fissile solution (IROFS CS-07).
- The offgas heat exchanger (TF-E-670) on the [Proprietary Information] presents a source of water that could cause criticality or other hazard if the heat exchanger fails. A drain pot on the exhaust line discharges water to the floor in the case of a heat exchanger leak (IROFS CS-12). The drain pot is a liquid-filled pot beneath the vent header. Under normal conditions, there is no flow through the drain pot. In the case of a heat exchanger failure, the vent piping is sloped to drain water into the drain pot.
- [Proprietary Information]

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include:

- Administrative batch limits are set based on worst-case moderation, even though most uranium is dry during normal conditions.
- Administrative interaction controls are based on many evenly spaced units contributing to the return of neutrons. Administrative failures during handling between workstations generally involve only two containers.
- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.7.5 Chemical Hazards

Chemical Inventory

The chemical reagents for the [Proprietary Information] subsystem are listed in Table 4-75. In addition to the chemical reagents, offgases are released during the drying and reduction steps.

Table 4-75. Chemical Inventory for the [Proprietary Information] Subsystem

Chemical	Quantity	Physical form	Concentration (if applicable)
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information][a]	[Proprietary Information]	[Proprietary Information]

Note: This table does not include the SNM identified in Table 4-74.

[a] [Proprietary Information].

SNM = special nuclear material.

Chemical Protection Provisions

The primary chemical hazard in the [Proprietary Information]. The method of ventilation will be determined for the Operating License Application. Tanks with the bulk chemicals will be maintained at a negative pressure and vented to the vessel ventilation system. The offgases formed during [Proprietary Information] will be contained within the process equipment and vented to the vessel ventilation system.

4.4.2.8 Target Fabrication Waste Subsystem

The target fabrication waste subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.8.1) provides a detailed account of the SNM in process during normal operation and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.4.2.8.2 and 4.4.2.8.3. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.8.4. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.4.2.8.5.

4.4.2.8.1 Process Description

Figure 4-110 provides the stream numbers corresponding to the target fabrication waste process description.

Trichloroethylene Recovery

[Proprietary Information]. The TCE will be pumped to TCE recycle tanks (TF-TK-720, TF-TK-725), where the solvent will accumulate for one week and then sampled to verify the absence of fissile material. Once the absence of fissile material is verified, the solvent will be fed to a commercial distillation-type TCE recovery package (TF-Z-740). The recovered solvent will be pumped to the solvent feed tank. The waste from the solvent recovery package will be collected locally to be discarded.

Aqueous Waste Holding

Aqueous waste will be generated in the nitrate extraction, ADUN concentration, and [Proprietary Information] subsystems. Under normal operating conditions, no fissile material will be present in the aqueous waste; however, process upsets may cause fissile solution to be transferred to the aqueous waste pencil tanks (TF-TK-700, TF-TK-705). Each tank will be sized to receive the highest normal operations demand in 2 days of operation to allow time for recirculation, sampling, and transfer. When one tank is full, the inlet will be manually changed from one tank to the other. The aqueous waste pump will recirculate the contents to ensure adequate mixing for representative samples. Independent aliquots will be drawn from the tanks and analyzed. After the laboratory analysis verifies the content of fissile material is below [[Proprietary Information], the valve lineup will be changed manually to transfer the aqueous waste to the waste handling system. The value will be determined during development of the final RPF design.

[Proprietary Information]

Figure 4-110. Target Fabrication Waste Process Flow Diagram

Target Fabrication Vessel Ventilation Overflow Protection

Based on the configuration of tanks and pumps, a tank with fissile material could potentially overflow to the vessel ventilation header due to equipment failure or operator error. In this accident scenario, the first line of defense will be the vessel ventilation overflow tank. The overflow tank will receive the solution and alarm to notify operators of the accident. Overflows that exceed the volume of the overflow tank, or otherwise enter the vessel ventilation header, would be discharged to the floor through a drain pot.

4.4.2.8.2 Process Equipment Arrangement

The fresh target fabrication waste equipment will be mounted on three skids within room T104C, the wet side of the target fabrication room. Figure 4-111 shows the location of the process equipment.

[Proprietary Information]

Figure 4-111. Target Fabrication Waste Equipment Layout

Figure 4-112 shows the typical arrangement of the aqueous waste holding tank skids. Figure 4-113 shows the equipment arrangement of the TCE recovery skid. Spent TCE from the [Proprietary Information] will accumulate in one of the TCE recycle tanks (TF-TK-720 or TF-TK-725). The recycle tanks will be sampled before feeding the TCE recovery package (TF-Z-740). As the solvent is recovered, TCE will drain to the regenerated TCE tank (TF-TK-750) and then be pumped to the TCE tank (TCE-TK-760, not pictured).

[Proprietary Information]

Figure 4-112. Aqueous Waste Holding Tank

[Proprietary Information]

Figure 4-113. Trichloroethylene Recovery Skid Arrangement

4.4.2.8.3 Process Equipment Design

This section identifies the processing apparatus and auxiliary equipment supporting the target fabrication waste subsystem. This equipment is listed in Table 4-76 with design data developed during preliminary design. Because dimensions have not yet been defined, two fields are provided to identify the basis for equipment dimensions: capacity and whether the equipment is designed to be criticality-safe by geometry. Additional detailed information (e.g., dimensions) will be developed for the Operating License Application.

Table 4-76. Target Fabrication Waste Process Equipment

Equipment name	Equipment no.	Individual tank capacity	Criticality-safe by geometry	Tank material	Operating range	
					Temperature	Pressure
Aqueous waste pencil tank	TF-TK-700	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Aqueous waste holding tank	TF-TK-705	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Aqueous waste pump	TF-P-710	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
Aqueous waste pump	TF-P-715	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
TCE recycle tank	TF-TK-720	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
TCE recycle tank	TF-TK-725	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
TCE recycle pump	TF-P-730	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]
TCE recovery package	TF-Z-740	[Proprietary Information]	No	TBD	[Proprietary Information]	[Proprietary Information]
Regenerated TCE tank	TF-TK-750	[Proprietary Information]	No	304L SS	[Proprietary Information]	[Proprietary Information]
Regenerated TCE pump	TF-P-755	[Proprietary Information]	No	TBD	[Proprietary Information]	[Proprietary Information]
TCE tank	TF-TK-760	[Proprietary Information]	No	304L SS	[Proprietary Information]	[Proprietary Information]
Target fabrication overflow tank	TF-TK-770	[Proprietary Information]	Yes	304L SS	[Proprietary Information]	[Proprietary Information]
Target fabrication overflow pump	TF-P-775	[Proprietary Information]	Yes	TBD	[Proprietary Information]	[Proprietary Information]

N/A = not applicable.
SS = stainless steel.
TBD = to be determined.
TCE = trichloroethylene.

Process Monitoring and Control Equipment

Process monitoring and control equipment were not defined during preliminary design. Preliminary process sequences are provided in this section to identify the control strategy for normal operations, which sets requirements for the process monitoring and control equipment and the associated instrumentation. Other information on instrumentation and controls is provided in Chapter 7.0. Additional detailed information of the process monitoring and control equipment will be developed for the Operating License Application.

The aqueous waste holding function will be a batch process. The aqueous waste holding function will have one tank available for filling at all times. When one tank is full, the operator will change the valve alignment to direct incoming aqueous waste to the parallel tank (TF-TK-700 or TF-TK-705). The recirculation pump (TF-P-710 or TF-P-715) will mix the full tank by recirculation for [TBD] hr (the value will be determined during development of the final RPF design). Samples will be analyzed in the laboratory system for uranium concentration before transfer. The product discharge valve will be opened, and the aqueous waste will be transferred to the waste handling system.

TCE recovery will be a batch process:

- The TCE recovery function will have one tank available for filling at all times. When one tank is full, the operator will change the valve alignment to direct incoming spent TCE to the parallel tank (TF-TK-720 or TF-TK-725). The recirculation pump (TF-P-730) will mix the full tank by recirculation for [TBD] hr (the value will be determined during development of the final RPF design). Samples will be analyzed in the laboratory system for uranium concentration before transfer. The product discharge valve will be opened, and the spent TCE will be transferred to the solvent recovery package (TF-Z-740).
- The operator will then begin the automated solvent recovery cycle. The product will drain to a collection tank during operation. At the end of the solvent recovery cycle, the waste will be collected for organic waste disposal.

4.4.2.8.4 Special Nuclear Material Description

Special Nuclear Material Inventory

The target fabrication waste subsystem will be capable of holding aqueous SNM for off-normal or accident scenarios, but there will be no regular SNM inventory.

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-009, *NWMI Preliminary Criticality Safety Evaluation: Liquid Waste Processing*. These features, consisting of administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem are the administrative controls, with a designator of AC, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The administrative controls will include:

- Mass limit of accumulation within the low-dose waste tanks (CSE-09-AC1)
- Sampling requirements before transferring aqueous waste to large geometry low-dose tanks (CSE-09-AC2)
- Management or supervisor verification of sampling results before transferring aqueous waste to large geometry low-dose tanks (CSE-09-AC3).

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the target fabrication waste activities.

- The TCE recycle tanks (TF-TK-720, TF-TK-725) and the aqueous waste pencil tanks (TF-TK-700, TF-TK-705) do not contain uranium during normal operations. For the case of an upset, the tanks and associated piping and equipment are designed to be inherently safe by geometry to prevent criticality. This approach applies limitations on the configuration, including (1) outside diameter of process equipment and piping (IROFS CS-06), and (2) fixed spacing between process equipment with fissile solution (IROFS CS-07). These tanks discharge to large geometry equipment, so measurements are needed to prevent fissile solutions from entering large geometry equipment. This measurement is accomplished by two independent samples and analyses of uranium concentration by the analytical laboratory (IROFS CS-16/CS-17).

- Instrument air piping for level measurement is a potential source for backflow of fissile solution to the large geometry of the instrument air system. To prevent backflow, the instrument air supply piping has a high point above the maximum liquid level before connecting to the vented tank (IROFS CS-20). If instrument air supply pressure is lost, the highest liquid level is below the supply piping high point, so backflow is impossible.

In addition to the features that apply double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include:

- During normal operations, no uranium is present within the target fabrication waste subsystem.
- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.8.5 Chemical Hazards

Chemical Inventory

The target fabrication waste chemical inventory is summarized in Table 4-77.

Table 4-77. Target Fabrication Waste Chemical Inventory

Chemical	Quantity	Physical form	Concentration (if applicable)
Trichloroethylene	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Aqueous waste (may contain ammonium hydroxide, ammonium nitrate, HMTA, nitric acid, sodium hydroxide, sodium nitrate, and urea)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

HMTA = hexamethylenetetramine. N/A = not applicable.

Chemical Protection Provisions

The primary chemical hazards in the target fabrication waste subsystem will be a chemical spray of aqueous waste or TCE, and personnel exposure to offgases. A spray shield installed on the skids will protect the operator from chemical burns in the event of a spray leak from the process equipment or associated piping. The headspace above the process equipment will be maintained at a negative pressure and vented to the vessel ventilation system to prevent personnel exposure to offgases.

4.4.2.9 Target Assembly Subsystem

The target assembly subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.9.1) provides a detailed account of the SNM in process during normal operations and provides the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.4.2.9.2 and 0. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.9.4. The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.4.2.9.5.

4.4.2.9.1 Process Description

Target Loading

Target loading will be performed using the target loading preparation workstation (TF-WT-800) and target loading workstation (TF-WT-810) located within the target assembly area (TF-800), as shown in Figure 4-114. An interim transfer container of LEU target material will be received from the LEU can rack. All handling of open LEU target material containers will occur in an anti-static work area. Target hardware from the target hardware storage rack will be weighed, and the partially assembled target will be vertically secured in a target-loading fixture in preparation for loading. An [Proprietary Information] will be weighed following the material accountability procedure and loaded into a feed hopper of the target loading fixture. [Proprietary Information].

[Proprietary Information]

Figure 4-114. Target Loading Preparation and Target Loading Workstation

After target loading is complete, the upper aluminum washer and temporary upper end fitting will be installed. The loaded target will be removed from the target holding fixture, and the material accountability procedure will be followed. The filled target will be placed in the target transfer cart for further processing at the target welding enclosure (TF-EN-820).

Target Welding and Weld Finishing

[Proprietary Information]

Figure 4-115. Target Welding Enclosure

[Proprietary Information]

Figure 4-116. Target Weld Finishing Workstation

The target and its necessary components will be transferred to the target welding enclosure (TF-EN-820) via the target entry airlock. The airlock will be sized to minimize helium consumption during target entry activities. The airlock will be configured at an angle with target capture features to provide safe and controlled target entry into the glovebox. A helium environment in the enclosure will provide a cover gas within the target and allow for the subsequent helium leak check. Targets will be secured in a target welding fixture. The temporary upper end fitting will be manually removed, and the upper cap washer positioned for the first weld.

The glovebox environment will be maintained at a minimum concentration of 90 percent helium and monitored and maintained by a circulation loop with a gas analyzer and a helium feed stream. The upper cap washer and the upper end fitting will be manually loaded into the target welding fixture through glove ports. The fiber optic laser will have three fixed positions; the first position for welding the inner seam of the upper cap washer, the second position for welding the outer seam of the upper cap washer, and the third position for welding the outer seam of the upper end fitting. The target welding fixture will rotate during welding. A layout of the target welding enclosure is shown in Figure 4-115. Welded targets will be routed to the target weld finishing workstation (TF-WT-820) for grinding and polishing of the welded areas of the target. A layout of the target weld finishing workstation is shown in Figure 4-116.

Target Qualification

Immediately following the removal of welded targets from the welding enclosure, the welds will be finished at the target weld finishing workstation (TF-WT-820) and inspected at the target weld inspection workstation (TF-WT-830) (Figure 4-117). Following the weld inspection, the target assembly will be weighed and checked for dimensional conformance using go/no-go gauges.

Targets will be placed in the helium leak test chamber where background gases are pumped out, and the chamber pressure will be lowered to draw out helium if leaks exist in the target. A helium mass spectrometer will indicate the helium leak rate for the tested target. Targets that pass the helium leak test will be scanned and cleaned of any surface contamination. These analyses will verify that the: (1) targets are sealed, (2) weld integrities are adequate, and (3) target physical dimensions and weight meet specifications.

[Proprietary Information]

Figure 4-117. Target Weld Inspection Station and Target Weight Inspection Equipment

Target Qualification Failure

Completed targets that fail any of the quality checking and verification analyses will be recycled and the LEU target material will be recovered as off-specification uranium. The primary steps involved in handling failed targets are provided in Section 4.1.4.4. The failed target will be transferred to a target disassembly workstation (TF-WT-870), which will house a target cutting tool and a target unloading system for collecting the LEU target material. The retrieved LEU target material will be handled as off-specification uranium for uranium recovery, since unwanted foreign material may be present. A layout of the target disassembly workstation is shown in Figure 4-118.

[Proprietary Information]

Figure 4-118. Target Disassembly Workstation

4.4.2.9.2 Process Equipment Arrangement

The target assembly process equipment will be located throughout room T104B, the dry side of the target fabrication room. Figure 4-119 shows the location of the process equipment. The arrangement of the target assembly process equipment is discussed throughout the process description.

[Proprietary Information]

Figure 4-119. Target Assembly Equipment Layout

4.4.2.9.3 Process Equipment Design

The process equipment in the target assembly subsystem will consist of containers and target assemblies that house the LEU target material, target filling equipment, target welding equipment, target QC equipment, and storage carts, as identified in the process description. The target assemblies are described in this section, and the target storage carts are described in Section 4.4.2.10.3. The auxiliary equipment that is identified in Section 4.4.2.9.1 is listed in Table 4-78. Additional detailed information on the target assembly equipment will be developed for the Operating License Application.

Table 4-78. Target Assembly Auxiliary Equipment

Equipment name	Equipment no.
LEU can transfer cart	TF-MC-800
Target loading prep workstation	TF-WT-800
Target loading workstation	TF-WT-810
Target welding enclosure	TF-EN-820
Target weld finishing workstation	TF-WT-820
Target weld inspection workstation	TF-WT-830
Target specification check workstation	TF-WT-840
Target leak check workstation	TF-WT-850
Target surface contamination check workstation	TF-WT-860
Target disassembly workstation	TF-WT-870

LEU = low-enriched uranium.

Target Design

The target hardware physical description is as described in Docket Number 50-243, "Oregon State TRIGA Reactor License Amendment for Irradiation of Fuel Bearing Targets for Production of Molybdenum-99."

[Proprietary Information] as shown in Figure 4-120.

[Proprietary Information]

Source: Docket Number 50-243, "Oregon State TRIGA Reactor License Amendment for Irradiation of Fuel Bearing Targets for Production of Molybdenum-99," April 2012.

Figure 4-120. Target Assembly Diagram (Doc-No 50-243)

[Proprietary Information]. Design parameters are summarized in Table 4-79.

The inner and outer aluminum cladding sections will be welded to a cap washer at the top and bottom to provide the primary seal. The [Proprietary Information].

Upper and lower end fittings will be welded to the top and bottom of the annular target-bearing section. The upper fitting will be designed to interface with the upper gridplate holes and will incorporate a pin that allows handling of the target using the standard [Proprietary Information]. The lower fitting will be designed to position the LEU material portion of the target at a fixed height and incorporate a pin that interfaces with the indexing holes in the lower gridplate. Fittings will be mounted to the LEU material-bearing portion of the target by a welded triangular spider that allows coolant flow through the inner portion of the target.

Table 4-79. Target Design Parameters

Parameter	Nominal design value
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]

Source: Docket Number 50-243, "Oregon State TRIGA Reactor License Amendment for Irradiation of Fuel Bearing Targets for Production of Molybdenum-99," April 2012.

LEU = low-enriched uranium.
[Proprietary Information].

4.4.2.9.4 Special Nuclear Material Description

Special Nuclear Material Inventory

The SNM inventory in the target assembly subsystem will consist [Proprietary Information]. Table 4-80 lists the SNM inventory, which will be limited per workstation to the amount of LEU in one target.

Table 4-80. Target Assembly Special Nuclear Material Inventory

Location	Form	Concentration [a]	Volume	SNM mass[a]
Target loading preparation workstation (TF-WT-800)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target loading workstation (TF-WT-810)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target welding enclosure (TF-EN-820)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target weld finishing workstation (TF-WT-820)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target weld inspection workstation (TF-WT-830)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target specification check workstation (TF-WT-840)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target leak check workstation (TF-WT-850)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target surface contamination check workstation (TF-WT-860)	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U).

^{235}U = uranium-235.
^{238}U = uranium-238.
N/A = not applicable.
SNM = special nuclear material.
[Proprietary Information]

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-006. These features, consisting of passive design features, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem are the passive design features, with a designator of PDF, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

The passive design features will define the following requirements of the workstations:

- Workstations where LEU target material is handled, including the equipment on the workstations, remain in place during and following a facility DBE (CSE-06-PDF1).
- Spill-prevention lips on the workstations do not exceed 2.54 cm (1 in.) (CSE-06-PDF2)

The administrative controls will define the following requirements for which containers should be used for specific activities, quantity limits of handling fissile material, and spacing requirements:

- Size limit of process apparatus holding target material (CSE-06-AC1 and CSE-06-AC2)
- Minimum spacing between movable containers and process equipment (CSE-06-AC3)
- Carrying limit of one fissile-bearing container per operator (CSE-06-AC4), limit of one container or target per workstation (CSE-06-AC6), and containers are closed or covered when unattended (CSE-06-AC5)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the target assembly activities.

- LEU target material is handled in approved containers and within the mass and batch handling limits (IROFS CS-02).
- While moving the [Proprietary Information], minimum spacing between the container and other fissile material is managed administratively (IROFS CS-03). These measures: (1) limit the operator to handle [Proprietary Information], (2) require use of approved workstations with interaction control spacing from other fissile material, and (3) provide interaction guards at normally accessible fissile solution process equipment.

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include the following.

- Administrative batch limits are set based on worst-case moderation, even though uranium is dry during normal conditions.
- Administrative interaction controls are based on many evenly spaced units contributing to the return of neutrons. Administrative failures during handling between workstations generally involve only two containers.
- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.9.5 Chemical Hazards

Chemical hazards have not been identified during preliminary design for the target assembly subsystem. Assembled targets may require a solvent wash, which would be managed similar to the solvent in the [Proprietary Information] step.

4.4.2.10 Low-Enriched Uranium Storage Subsystem

The LEU storage subsystem description provides information regarding the process, process equipment, SNM inventory, and the hazardous chemicals used in the subsystem. The process description (Section 4.4.2.10.1) identifies the normal operations and the basis for equipment design. The arrangement and design of the processing equipment, including normal operating conditions, are described in Sections 4.4.2.10.2 and 4.4.2.10.3. A description of the SNM in terms of physical and chemical form, volume in process, and criticality control features is provided in Section 4.4.2.10.4.

The hazardous chemicals that are used or may evolve during the process, along with the provisions to protect workers and the public from exposure, are described in Section 4.4.2.10.5.

4.4.2.10.1 Process Description

The LEU storage will provide storage of fresh LEU, unirradiated target material, and welded targets. There will be no processes unique to the LEU storage subsystem. Operations are described in Sections 4.4.2.1.5 and 4.4.2.9.

4.4.2.10.2 Process Equipment Arrangement

The LEU storage equipment will be located within the [Proprietary Information]. Figure 4-121 shows the location of the process equipment.

[Proprietary Information]

Figure 4-121. Low-Enriched Uranium Storage Equipment Layout

4.4.2.10.3 Process Equipment Design

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

[Proprietary Information]

Figure 4-122. Low-Enriched Uranium Can Rack

[Proprietary Information]

Figure 4-123. 12-Position Target Cart

4.4.2.10.4 Special Nuclear Material Description

Special Nuclear Material Inventory

[Proprietary Information]

[Proprietary Information]

Table 4-81. Low-Enriched Uranium Storage Maximum Special Nuclear Material Inventory

Location	Form	Concentration[a]	Volume	SNM mass[a]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U).
[Proprietary Information]

^{235}U	= uranium-235.	SNM	= special nuclear material.
^{238}U	= uranium-238.	U	= uranium.
LEU	= low-enriched uranium.	[Proprietary Information]	
N/A	= not applicable.		

Criticality Control Features

Criticality control features are required in this subsystem, as defined in NWMI-2015-CSE-007, *NWMI Preliminary Criticality Safety Evaluation: Target and Can Storage and Carts*. These features, including passive design features and administrative controls, allow for adherence to the double-contingency principle. This section applies the criticality control features that are described in Chapter 6.0, Section 6.3. The technical specifications required for criticality control will be developed for the Operating License Application and described in Chapter 14.0. The criticality accident sequences are described and analyzed in Chapter 13.0, Section 13.2, where accident prevention measures and features are identified.

The criticality control features for this subsystem are the passive design features and administrative controls, with designators of PDF and AC, respectively, listed below. Chapter 6.0 provides detailed descriptions of the criticality control features.

[Proprietary Information]

- [Proprietary Information]
- [Proprietary Information]

The following administrative controls define the requirements for which containers should be used for specific activities, quantity limits of handling fissile material, and spacing requirements:

- Volume and mass limits of target material containers (CSE-07-AC1, CSE-07-AC6) and fresh LEU metal containers (CSE-07-AC2, CSE-07-AC6)
- Interaction limits between movable containers and process equipment (CSE-07-AC3)
- Carrying limit of one fissile-bearing container per operator (CSE-07-AC4), and containers will be closed or covered when unattended (CSE-07-AC5, CSE-07-AC7)

Some or all of the engineered safety features and administrative controls are classified as IROFS according to the accident analyses in Chapter 13.0, Section 13.2. Section 13.2 provides a description of the IROFS. The following IROFS will be applicable to the LEU storage activities.

- [Proprietary Information] (2) require use of approved workstations with interaction control spacing from other fissile material, and (3) provide interaction guards at normally accessible fissile solution process equipment.
- [Proprietary Information]

In addition to the features that apply the double-contingency principle, several features will provide defense-in-depth in criticality control. These features will include:

- Administrative batch limits are set based on worst-case moderation, even though uranium is dry during normal conditions.
- Administrative interaction controls are based on many evenly spaced units contributing to the return of neutrons. Administrative failures during handling between workstations generally involve only two containers.
- Criticality calculations analyzed concentrations, mass limits, and volumes that are not anticipated under normal conditions, so the controls can sustain multiple upsets.
- The criticality alarm system provides criticality monitoring and alarm in all areas where SNM is handled, processed, or stored, as described in Chapter 6.0.

The criticality control features provided throughout the irradiated target receipt process will be in accordance with the double-contingency principle, and the RPF will provide suitable defense-in-depth for the contained processes.

4.4.2.10.5 Chemical Hazards

Chemical hazards have not been identified, and are not anticipated, for the LEU storage subsystem.

4.5 REFERENCES

10 CFR 20, "Standards for Protection Against Radiation," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 70, "Domestic Licensing of Special Nuclear Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.

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