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NORTHWEST MEDICAL ISOTOPES

Chapter 3.0 – Design of Structures, Systems, and Components

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 3
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TERMS

Acronyms and Abbreviations

^{99}Mo	molybdenum-99
AASHTO	American Association of State Highway and Transportation Officials
ACGIH	American Conference on Governmental Industrial Hygienists
ACI	American Concrete Institute
AHRI	Air Conditioning, Heating and Refrigeration Institute
AISC	American Institute of Steel Construction
ALARA	as low as reasonably achievable
AMCA	Air Movement and Control Association
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BMS	building management system
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CRR	Collected Rules and Regulations
CSR	Missouri Code of State Regulations
Discovery Ridge	Discovery Ridge Research Park
DBE	design basis event
DBEQ	design basis earthquake
DOE	U.S. Department of Energy
EIA	Electronic Industries Alliance
ESF	engineered safety feature
FEMA	Federal Emergency Management Agency
FPC	facility process control
FSAR	final safety analysis report
H_2	hydrogen gas
HR	hydrometeorological report
HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and control
IAEA	International Atomic Energy Agency
IBC	International Building Code
ICC	International Code Council
ICC-ES	International Code Council Evaluation Service
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
IFC	International Fire Code
IROFS	items relied on for safety
ISA	International Society of Automation
ISG	Interim Staff Guidance
IX	ion exchange
LEU	low enriched uranium
MDNR	Missouri Department of Natural Resources
Mo	molybdenum

MODOT	Missouri Department of Transportation
MRI	mean recurrence interval
MU	University of Missouri
MURR	University of Missouri Research Reactor
NECA	National Electrical Contractors Association
NEMA	National Electrical Manufacturers Association
NEP	normal electrical power
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NETA	InterNational Electrical Testing Association
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
NS	non-seismic
NSR	non-safety-related
NWMI	Northwest Medical Isotopes, LLC
NWS	National Weather Service
PMF	probable maximum flood
PMP	probable maximum precipitation
PMWP	probable maximum winter precipitation
QA	quality assurance
QAPP	quality assurance program plan
RCA	radiologically controlled area
RPF	Radioisotope Production Facility
SEP	standby electrical power
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SNM	special nuclear material
SR	safety related
SSC	structures, systems and components
TIA	Telecommunications Industry Association
U.S.	United States
UL	Underwriters Laboratory
UPS	uninterruptible power supply
USGS	U.S. Geological Survey

Units

°C	degrees Celsius
°F	degrees Fahrenheit
μ	micron
cm	centimeter
cm^2	square centimeters
ft	feet
ft^2	square feet
ft^3	cubic feet
g	acceleration of gravity
gal	gallon
hp	horsepower
hr	hour
in.	inch
$in.^2$	square inch
kg	kilogram

kip	thousand pounds-force
km	kilometer
kW	kilowatt
L	liter
lb	pound
lbf	pound-force
m	meter
m^2	square meter
mi	mile
mi^2	square mile
min	minute
MT	metric ton
rad	absorbed radiation dose
sec	second

3.0 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

This chapter identifies and describes the principal architectural and engineering design criteria for the facility structures, systems and components (SSC) for the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility (RPF). The information presented emphasizes the safety and protective functions and related design features that help provide defense-in-depth against the uncontrolled release of radioactive material to the environment. The bases for the design criteria for some of the systems discussed in this chapter are developed in other chapters of the Construction Permit Application and are appropriately cross-referenced, when required.

NWMI's RPF design is based on applicable standards, guides, codes, and criteria and provides reasonable assurance that the RPF SSCs, including electromechanical systems, are:

- Built and will function as designed and required by the analyses in Chapter 13.0, "Accident Analysis"
- Built to have acceptable protection of the public health and safety and environment from radiological risks (e.g., radioactive materials, exposure) resulting from operations
- Protected against potential meteorological damage
- Protected against potential hydrological (water) damage
- Protected against seismic damage
- Provided surveillance activities and technical specifications required to respond to or mitigate consequences of seismic damage
- Based on technical specifications developed to ensure that safety-related functions of electromechanical systems and components will be operable and protect the health and safety of workers, the public, and environment

The design of the RPF and SSCs are based on defense-in-depth practices.

The NRC defines design-in-depth as the following:

> *An approach to designing and operating nuclear facilities that prevents and mitigates accidents that release radiation or hazardous materials. The key is creating multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon. Defense in depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures.*

Defense-in-depth is a design philosophy, applied from the outset and through completion of the design, that is based on providing successive levels of protection such that health and safety are not wholly dependent on any single element of the design, construction, maintenance, or operation of the facility. The net effect of incorporating defense-in-depth practices is a conservatively designed facility and systems that exhibit higher tolerances to failures and external challenges. The risk insights obtained through performance of accident analysis can then be used to supplement the final design by focusing attention on the prevention and mitigation of the higher risk potential accidents.

This application to the U.S. Nuclear Regulatory Commission (NRC) seeks to obtain a license for a production facility under Title 10, *Code of Federal Regulations* (CFR), Part 50 (10 CFR 50), "Domestic Licensing of Production and Utilization Facilities." Embedded in the 10 CFR 50-licensed facility will be several activities subject to 10 CFR 70, "Domestic Licensing of Special Nuclear Material," to receive, possess, use, and transfer special nuclear material (SNM) and 10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," to process and transport molybdenum-99 (^{99}Mo) for medical applications.

This 10 CFR 50 license application for the RPF follows the guidance in NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non Power Reactors – Format and Content*, that encompasses activities regulated under different NRC requirements (e.g., 10 CFR 70 and 10 CFR 30), in accordance with 10 CFR 50.31, "Combining Applications," and 10 CFR 50.32, "Elimination of Repetition."

The NRC has determined that a radioisotope separation and processing facility, which also conducts separation of SNM, will be considered a production facility and as such, will be subject to licensing under 10 CFR 50. The operation of the NWMI RPF will primarily be focused on the disassembly of irradiated low-enriched uranium (LEU) targets, separation and purification of fission product ^{99}Mo, and the recycle of LEU that is licensed under 10 CFR 50.

RPF operations will also include the fabrication of LEU targets, which will be licensed under 10 CFR 70. These targets will be shipped to NWMI's network of research or test reactors for irradiation (considered a connected action) and returned to the RPF for processing. The LEU used for the production of LEU target materials will be obtained from the U.S. Department of Energy (DOE) and from LEU reclaimed from processing the irradiated targets.

NWMI's licensing approach for the RPF defines the following unit processes and areas that fall under the following NRC regulations:

- 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities"
  - Target receipt and disassembly system
  - Target dissolution system
  - Molybdenum (Mo) recovery and purification system
  - Uranium recovery and recycle system
  - Waste management system
  - Associated laboratory and support areas
- 10 CFR 70, "Domestic Licensing of Special Nuclear Material"
  - Target fabrication system
  - Fresh LEU (from DOE) receipt area
  - Associated laboratory and support areas
- 10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material"
  - Any byproduct materials produced or extracted in the RPF

Design information for the complete range of normal operating conditions for various facility systems is provided throughout the Construction Permit Application, and includes the following.

- RPF-specific design criteria (e.g., codes and standards, NRC guidelines) for SSCs are provided in Sections 3.1.
- NRC general design criteria and associated applicability to the RPF SSCs are addressed in Section 3.5.

- RPF description is presented in Chapter 4.0, "Radioisotope Production Facility Description."
- Postulated initiating events and credible accidents that form the design basis for the SSCs are discussed in Chapter 13.0.
- Potential hazards and credible accidents that could be encountered in the RPF during operations involving SNM, irradiated and unirrradiated, Mo recovery and purification, uranium recovery and recycle, waste management, and/or the use of hazardous chemicals relative to these radiochemical processes that form the bases for the SSCs located in the RPF, are discussed in Chapter 13.0.
- Design redundancy of SSCs to protect against unsafe conditions with respect to single failures of engineered safety features (ESF) and control systems are described in Chapter 6.0, "Engineered Safety Features," and Chapter 7.0, "Instrumentation and Control System," respectively.
- ESFs are described in Chapter 6.0, and the administrative controls are discussed in Chapter 14.0, "Technical Specifications."
- Quality standards commensurate with the safety functions and potential risks that were used in the design of the SSCs are described in Table 3-7 (Section 3.1.7).
- Hydrological design bases describing the most severe predicted hydrological events during the life of the facility are provided in Chapter 2.0, "Site Characteristics," Section 2.4.
- Design criteria for facility SSCs to withstand the most severe predicted hydrological events during the lifetime of the facility are provided in Section 3.3.
- Seismic design bases for the facility are provided in Chapter 2.0, Section 2.5. Seismic design criteria for the facility SSCs are provided in Section 3.4.
- Analyses concerning function, reliability, and maintainability of SSCs are described throughout the Construction Permit Application.
- Meteorological design bases describing the most severe weather extremes predicted to occur during the life of the facility are provided in Chapter 2.0, Section 2.3. Design criteria for facility SSCs to withstand the most severe weather extremes predicted to occur during the life of the facility are provided in Section 3.2.
- Potential conditions or other items that will be probable subjects of technical specifications associated with the RPF structures and design features are discussed in Chapter 14.0.

3.1 DESIGN CRITERIA

Section 3.1 describes the design criteria applied to the RPF and SSCs within the facility. The principal design criteria for a production facility establish the necessary design, fabrication, construction, testing, and performance requirements for SSCs important to safety (i.e., those that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of workers and the public). The systems associated with the RPF are identified. Those items relied on for safety (IROFS) are identified in Chapters 6.0 and 13.0. Requirements are derived from:

- Code of Federal Regulations
- U.S. Nuclear Regulatory Commission
- Federal regulations, guidelines, and standards
- Local government regulations and requirements
- Discovery Ridge Research Park (Discovery Ridge) covenants
- University of Missouri System (MU) requirements
- Other codes and standards

3.1.1 Radioisotope Production Facility Structures, Systems, and Components

Table 3-1 lists the RPF systems and identifies the RPF material accountability area and the Construction Permit Application reference chapter that provides the associated detailed system descriptions.

Table 3-1. List of System and Associated Systems and Construction Permit Application Crosswalk (2 pages)

Primary structure and associated systems	Construction Permit Application reference (primary references)
Radioisotope Production Facility (RPF – primary structure)	
10 CFR 70[a]	
Target fabrication	Chapter 4.0, Sections 4.1.3.1 and 4.4
10 CFR 50[b]	
Target receipt and disassembly	Chapter 4.0, Section 4.1.3.2, 4.3.2, and 4.3.3
Target dissolution	Chapter 4.0, Sections 4.1.3.3 and 4.3.4
Molybdenum recovery and purification	Chapter 4.0, Sections 4.1.3.4 and 4.3.5
Uranium recovery and recycle	Chapter 4.0, Sections 4.1.3.5 and 4.3.6
Waste handling	Chapter 4.0, Section 4.1.3.6; Chapter 9.0, Section 9.7.2
Criticality accident alarm	Chapter 6.0, Section 6.3.3.1; Chapter 7.0, Section 7.3.7
Radiation monitoring	Chapter 7.0, Section 7.6; Chapter 11.0, Section 11.1.4
Normal electrical power	Chapter 8.0, Section 8.1
Standby electrical power	Chapter 8.0, Section 8.2
Process vessel ventilation	Chapter 9.0, Section 9.1
Facility ventilation	Chapter 9.0, Section 9.1
Fire protection	Chapter 9.0, Section 9.3
Plant and instrument air	Chapter 9.0, Section 9.7.1
Emergency purge gas	Chapter 6.0, Section 6.2.1.7.5
Gas supply	Chapter 9.0, Section 9.7.1

Table 3-1. List of System and Associated Systems and Construction Permit Application Crosswalk (2 pages)

Primary structure and associated systems	Construction Permit Application reference (primary references)
Process chilled water	Chapter 9.0, Section 9.7.1
Facility chilled water	Chapter 9.0, Section 9.7.1
Facility heated water	Chapter 9.0, Section 9.7.1
Process stream	Chapter 9.0, Section 9.7.1
Demineralized water	Chapter 9.0, Section 9.7.1
Chemical supply	Chapter 9.0, Section 9.7.4
Biological shield	Chapter 4.0, Section 4.2
Facility process control	Chapter 7.0, Section 7.2.3

[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.

In addition to Table 3-2, NWMI-2015-LIST-003, *NWMI Radioisotope Production Facility Master Equipment List*, provides a summary of the RPF systems, components, and equipment used in the RPF design.

Table 3-2 provides a summary of the IROFS identified by the accident analyses in Chapter 13.0, and a crosswalk to where the IROFS are described in the Construction Permit Application. Chapter 13.0 also provides the associated detailed descriptions. Table 3-2 also identifies whether the IROFS are considered ESFs or administrative controls. Additional IROFS may be identified (or the current IROFS modified) during the RPF final design and development of the Operating License Application.

Table 3-2. Summary of Items Relied on for Safety Identified by Accident Analyses (3 pages)

IROFS designator	Descriptor	ESF	AC	Construction Permit Application crosswalk (primary references)
RS-01	Hot cell liquid confinement boundary	✓		Chapter 6.0, Sections 6.2.1.1 – 6.2.1.6 Chapter 13.0, Section 13.2.2.8
RS-02	Reserved[a]			
RS-03	Hot cell secondary confinement boundary	✓		Chapter 6.0, Sections 6.2.1.1 – 6.2.1.6 Chapter 13.0, Sections 13.2.2.8, 13.2.3.8
RS-04	Hot cell shielding boundary	✓		Chapter 6.0, Sections 6.2.1.1 – 6.2.1.6 Chapter 13.0, Sections 13.2.2.8, 13.2.4.8
RS-05	Reserved[a]			
RS-06	Reserved[a]			
RS-07	Reserved[a]			
RS-08	Sample and analysis of low-dose waste tank dose rate prior to transfer outside the hot cell shielded boundary		✓	Chapter 13.0, Section 13.2.7.1

Table 3-2. Summary of Items Relied on for Safety Identified by Accident Analyses (3 pages)

IROFS designator	Descriptor	ESF	AC	Construction Permit Application crosswalk (primary references)
RS-09	Primary offgas relief system	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.3.8
RS-10	Active radiation monitoring and isolation of low-dose waste transfer	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.1
RS-11	Reserved[a]			
RS-12	Cask containment sampling prior to closure lid removal		✓	Chapter 13.0, Section 13.2.7.1
RS-13	Cask local ventilation during closure lid removal and docking preparations	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.1
RS-14	Reserved[a]			
RS-15	Cask docking port enabling sensor	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.1
CS-01	Reserved[a]			
CS-02	Mass and batch handling limits for uranium metal, uranium oxides, targets, and laboratory sample outside process systems		✓	Chapter 13.0, Section 13.2.7.2
CS-03	Interaction control spacing provided by administrative control		✓	Chapter 13.0, Section 13.2.7.2
CS-04	Interaction control spacing provided by passively designed fixtures and workstation placement	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-05	Container batch volume limit		✓	Chapter 13.0, Section 13.2.7.2
CS-06	Pencil tank, vessel, or piping safe geometry confinement using the diameter of tanks, vessels, or piping	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-07	Pencil tank and vessel spacing control using fixed interaction spacing of individual tanks or vessels	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.2.8
CS-08	Floor and sump geometry control of slab depth, sump diameter or depth for floor spill containment berms	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.2.8
CS-09	Double-wall piping	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.2.8
CS-10	Closed safe geometry heating or cooling loop with monitoring and alarm	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-11	Simple overflow to normally empty safe geometry tank with level alarm	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-12	Condensing pot or seal pot in ventilation vent line	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-13	Simple overflow to normally empty safe geometry floor with level alarm in the hot cell containment boundary	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2

Table 3-2. Summary of Items Relied on for Safety Identified by Accident Analyses (3 pages)

IROFS designator	Descriptor	ESF	AC	Construction Permit Application crosswalk (primary references)
CS-14	Active discharge monitoring and isolation	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-15	Independent active discharge monitoring and isolation	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-16	Sampling and analysis of uranium mass or concentration prior to discharge or disposal		✓	Chapter 13.0, Section 13.2.7.2
CS-17	Independent sampling and analysis of uranium concentration prior to discharge or disposal		✓	Chapter 13.0, Section 13.2.7.2
CS-18	Backflow prevention device	✓		Chapter 6.0, Sections 6.2.1.7 and 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-19	Safe-geometry day tanks	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-20	Evaporator or concentrator condensate monitoring	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-21	Visual inspection of accessible surfaces for foreign debris		✓	Chapter 13.0, Section 13.2.7.2
CS-22	Gram estimator survey of accessible surfaces for gamma activity		✓	Chapter 13.0, Section 13.2.7.2
CS-23	Nondestructive assay of items with inaccessible surfaces		✓	Chapter 13.0, Section 13.2.7.2
CS-24	Independent nondestructive assay of items with inaccessible surfaces		✓	Chapter 13.0, Section 13.2.7.2
CS-25	Target housing weighing prior to disposal		✓	Chapter 13.0, Section 13.2.7.2
CS-26	Processing component safe volume confinement	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-27	Closed heating or cooling loop with monitoring and alarm	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
FS-01	Enhanced lift procedure		✓	Chapter 13.0, Section 13.2.2.8 and 13.2.7.1
FS-02	Overhead cranes		✓	Chapter 13.0, Section 13.2.7.3
FS-03	Process vessel emergency purge system	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.3
FS-04	Irradiated target cask lifting fixture	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.6.5
FS-05	Exhaust stack height	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.3

[a] Reserved – IROFS designator currently unassigned.

AC = administrative control.
ESF = engineered safety feature.
IROFS = items relied on for safety.

3.1.2 Code of Federal Regulations

NWMI-DRD-2013-030, *NWMI Radioisotope Production Facility Design Requirements Document*, summarizes the CFR design inputs (in whole or in part) for the RPF, which include the following:

- 10 CFR 20, "Standards for Protection Against Radiation"
- 10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material"
- 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities"
- 10 CFR 70, "Domestic Licensing of Special Nuclear Material"
- 10 CFR 71, "Energy: Packaging and Transportation of Radioactive Material"
- 10 CFR 73, "Physical Protection of Plants and Materials"
- 10 CFR 74, "Material Control and Accounting of Special Nuclear Material"
- 10 CFR 851, "Worker Safety and Health Program"
- 21 CFR 210, "Current Good Manufacturing Practice in Manufacturing, Processing, Packaging, or Holding of Drugs'
- 21 CFR 211, "Current Good Manufacturing Practice for Finished Pharmaceuticals"
- 29 CFR 1910, "Occupational Safety and Health Standards"
- 40 CFR 61, "National Emissions Standards for Hazardous Air Pollutants (NESHAP)"
- 40 CFR 63, "NESHAP for Source Categories"
- 40 CFR 141, "National Primary Drinking Water Regulations"

3.1.3 U.S. Nuclear Regulatory Commission

Table 3-3 lists the NRC design inputs for the RPF identified in NWMI-DRD-2013-030. The RPF system design descriptions identify the specific requirements for that system produced by each applicable reference.

Table 3-3. Relevant U.S. Nuclear Regulatory Commission Guidance (3 pages)

CFR[a]	Title
Docket Number: NRC-2011-0135 (NRC, 2012)	*Final Interim Staff Guidance Augmenting NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Parts 1 and 2, for Licensing Radioisotope Production Facilities and Aqueous Homogeneous Reactors*
NRC Regulatory Guides – Power Reactors (Division 1)	
Regulatory Guide 1.29	*Seismic Design Classification*
Regulatory Guide 1.53	*Application of the Single-Failure Criterion to Safety Systems*, 2003 (R2011)
Regulatory Guide 1.60	*Design Response Spectra for Seismic Design of Nuclear Power Plants, 2014*
Regulatory Guide 1.61	*Damping Values of Seismic Design of Nuclear Power Plants*
Regulatory Guide 1.76	*Design Basis Tornado and Tornado Missiles for Nuclear Power Plants*, 2007
Regulatory Guide 1.92	*Combining Modal Responses and Spatial Components in Seismic Response Analysis*
Regulatory Guide 1.97	*Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants*, 2006 (R2013)
Regulatory Guide 1.100	*Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants*, 2009
Regulatory Guide 1.102	*Flood Protection for Nuclear Power Plants*
Regulatory Guide 1.122	*Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components*

Table 3-3. Relevant U.S. Nuclear Regulatory Commission Guidance (3 pages)

CFR[a]	Title
Regulatory Guide 1.152	*Criteria for Use of Computers in Safety Systems of Nuclear Power Plants*, 2011
Regulatory Guide 1.166	*Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post Earthquake Actions*, 1997
Regulatory Guide 1.167	*Restart of a Nuclear Power Plant Shut down by a Seismic Event*, 1997
Regulatory Guide 1.208	*Performance Based Approach to Define the Site-Specific Earthquake Ground Motion*, 2007
NRC Regulatory Guides – Fuels and Materials Facilities (Division 3)	
Regulatory Guide 3.3	*Quality Assurance Program Requirements for Fuel Reprocessing Plants and for Plutonium Processing and Fuel Fabrication Plants*, 1974 (R2013)
Regulatory Guide 3.6	*Content of Technical Specification for Fuel Reprocessing Plants*, 1973 (R2013)
Regulatory Guide 3.10	*Liquid Waste Treatment System Design Guide for Plutonium Processing and Fuel Fabrication Plants*, 1973 (R2013)
Regulatory Guide 3.18	*Confinement Barriers and Systems for Fuel Reprocessing Plants*, 1974 (R2013)
Regulatory Guide 3.20	*Process Offgas Systems for Fuel Reprocessing Plants*, 1974 (R2013)
Regulatory Guide 3.71	*Nuclear Criticality Safety Standards for Fuels and Materials Facilities*, 2010
NRC Regulatory Guides – Materials and Plant Protection (Division 5)	
Regulatory Guide 5.7	*Entry/Exit Control for Protected Areas, Vital Areas, and Material Access Areas*, May 1980 (R2010)
Regulatory Guide 5.12	*General Use of Locks in the Protection and Control of Facilities and Special Nuclear Materials*, 1973 (R2010)
Regulatory Guide 5.27	*Special Nuclear Material Doorway Monitors*, 1974
Regulatory Guide 5.44	*Perimeter Intrusion Alarm Systems*, 1997 (R2010)
Regulatory Guide 5.57	*Shipping and Receiving Control of Strategic Special Nuclear Material*, 1980
Regulatory Guide 5.65	*Vital Area Access Control, Protection of Physical Security Equipment, and Key and Lock Controls*, 1986 (R2010)
Regulatory Guide 5.71	*Cyber Security Programs for Nuclear Facilities*, 2010
NUREG-0700, *Human-System Interface Design Review Guidelines*	
NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*, LWR Edition	
Section 2.3.1	"Regional Climatology," Rev. 3, March 2007
Section 2.3.2	"Local Climatology," Rev. 3, March 2007
Section 3.3.1	"Wind Loading," Rev. 3, March 2007
Section 3.3.2	"Tornado Loading," Rev. 3, March 2007
Section 3.7.1	"Seismic Design Parameters," March 2007
Section 3.7.2	"Seismic System Analysis," Rev. 4, September 2013
Section 3.7.3	"Seismic Subsystem Analysis," Rev. 4, September 2013
NUREG-1513, *Integrated Safety Analysis Guidance Document*	
NUREG-1520, *Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility*	
Part 3, Appendix D	"Natural Hazard Phenomena"
NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, Part 1	

Table 3-3. Relevant U.S. Nuclear Regulatory Commission Guidance (3 pages)

CFR[a]	Title
NUREG/CR-4604, ***Statistical Methods for Nuclear Material Management***	
NUREG/CR-6410, ***Nuclear Fuel Cycle Facility Accident Analysis Handbook***	
Process hazard analysis	"Development of Quantitative Risk Analyses"
NUREG/CR-6463, ***Review Guidelines on Software Languages for Use in Nuclear Power Plant Safety Systems – Final Report***	
NUREG/CR-6698, ***Guide for Validation of Nuclear Criticality Safety Calculational Methodology***	

[a] Complete references are provided in Section 3.6.

3.1.4 Other Federal Regulations, Guidelines, and Standards

Table 3-4 lists other Federal design inputs for the RPF (NWMI-DRD-2013-030). The RPF system design descriptions identify the specific requirements for that system produced by each applicable reference.

Table 3-4. Other Federal Regulations, Guidelines, and Standards

Reference[a]	Title
Federal Emergency Management Agency (FEMA)	
N/A	"National Flood Insurance Program, Flood Insurance Rate Map, Boone County, Missouri and Incorporated Areas"
National Oceanic and Atmospheric Administration (NOAA)	
Hydrometeorological Report No. 51	*Probable Maximum Precipitation Estimates, United States East of the 105th Meridian*
Hydrometeorological Report No. 52	*Application of Probable Maximum Precipitation Estimates, United States East of the 105th Meridian*
Hydrometeorological Report No. 53	*Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105th Meridian*
U.S. Geological Survey (USGS)	
N/A	"2008 U.S. Geological Survey National Seismic Hazard Maps"
Open-File Report 2008-1128	*Documentation for the 2008 Update of the United States National Seismic Hazard Maps*
Centers for Disease Control and Prevention (CDC)	
NIOSH 2003-136	*Guidance for Filtration and Air-Cleaning Systems to Protect Building Environments from Airborne Chemical, Biological, and Radiological Attacks*

[a] Complete references are provided in Section 3.6

CDC = Centers for Disease Control and Prevention.
FEMA = Federal Emergency Management Agency.
NIOSH = National Institute for Occupational Safety and Health.
NOAA = National Oceanic and Atmospheric Administration.
USGS = U.S. Geological Survey.

3.1.5 Local Government Documents

Table 3-5 lists the design inputs for the RPF from the State of Missouri, City of Columbia, and Boone County government sources (NWMI-DRD-2013-030). The RPF system design descriptions identify the specific requirements for that system produced by each applicable reference.

Table 3-5. Local Government Documents (2 pages)

Reference[a]	Title
Missouri Code of State Regulations (CSR), Title 10	
10 CSR 10-6.01	Ambient Air Quality Standards
Missouri CSR, Title 20	
20 CSR 2030-2.040(1)	Evaluation Criteria for Building Design
Missouri Department of Transportation (MODOT) Standards and Specifications	
Missouri Department of Natural Resources (MDNR)	
Missouri State Adopted International Code Council (ICC) Building Code Set 2012	
Boone County Building Code	
City of Columbia, Missouri, Code of Ordinances Article II – Building and Fire Codes	
Section 6-16, Adopted	Building Code
Section 6-17, Amendments	Building Code
Section 9-21	Fire Code
Section 9-22	Fire Code

[a] Complete references are provided in Section 3.6

CSR = Code of State Regulations.
ICC = International Code Council.
MDNR = Missouri Department of Natural Resources.
MODOT = Missouri Department of Transportation.

3.1.6 Discovery Ridge/University of Missouri

Table 3-6 lists the MU system requirements and Discovery Ridge covenants design inputs for the RPF identified in NWMI-DRD-2013-030. The RPF system design descriptions identify the specific requirements for that system produced by each applicable reference.

Table 3-6. Discovery Ridge/University of Missouri Requirements

Requirements	Reference section/requirement[a]
Civil	Design and construction of the civil system is regulated by the NRC as required by Discovery Ridge/MU.
Collected Rules and Regulations (CRR)	
Structural	CRR Section 70.060.I, "Codes and Standards" – Adopts ICC codes
University of Missouri, Consultant Procedures and Design Guidelines	
Electrical	Section 2.4.2, "Building Codes and Standards for University Facilities"
HVAC	CPDG Division 23, "Heating, Ventilating, and Air-Conditioning (HVAC)"
Instrumentation and Controls	Section 2.4.2, "Building Codes and Standards for University Facilities"
Planning	CPDG Section 2.4, "Planning, Design and Contract Document Development Guidelines for Master Construction Delivery Method"
Plumbing	CPDG Division 22, "Plumbing"
Process	Section 2.4.2, "Building Codes and Standards for University Facilities"
University of Missouri, *Facilities Management Policy and Procedures Manual*	
Electrical	Chapter 2, "Design and Construction Policy"

Table 3-6. Discovery Ridge/University of Missouri Requirements

Requirements	Reference section/requirement[a]
Instrumentation and Controls	Chapter 2, "Design and Construction Policy"
Structural	Section 3.A, Refers to CRR 70.060 for the Basic Building Code Section 3.O, Refers to the University Building Adopted Codes for currently adopted codes
University Building Adopted Codes	
IMC-2012	*International Mechanical Code*
Structural	Adopts IBC 2012

[a] Complete references are provided in Section 3.6

CRR = Collected Rules and Regulations.
IBC = International Building Code.
ICC = International Code Council.
MU = University of Missouri.
NRC = U.S. Nuclear Regulatory Commission.

3.1.7 Codes and Standards

Table 3-7 lists design inputs for the RPF identified in NWMI-DRD-2013-030. The RPF system design descriptions identify the specific requirements for that system produced by each applicable reference.

The Construction Permit Application and associated preliminary design documents identify codes, standards, and other referenced documents that may be applicable to the RPF. The specific RPF design codes, standards, and other referenced documents, including exceptions or exemptions to the identified requirements, will be finalized in the RPF final design and provided to the NRC. In addition, the codes, standards, and referenced documents for the RPF safety SSCs that are needed to demonstrate compliance with regulatory requirements will be identified and committed to in the Operating License Application.

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
American Concrete Institute (ACI)	
ACI 349	*Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary*, 2013
American Institute of Steel Construction (AISC)	
ANSI/AISC N690	*Specification for Safety-Related Steel Structures for Nuclear Facilities*, 2012
Air Movement and Control Association (AMCA)	
AMCA Publication 201	*Fans and Systems*, 2002 (R2011)
AMCA Publication 203	*Field Performance Measurement of Fan Systems*, 1990 (R2011)
ANSI/AMCA 210	*Laboratory Methods for Testing Fans for Aerodynamic Performance Rating*, 2007
AMCA Publication 211	*Certified Ratings Program – Product Rating Manual for Fan Air Performance*, 2013
AMCA Publication 311	*Certified Ratings Program – Product Rating Manual for Fan Sound Performance*, 2006 (R2010)
American Conference on Governmental Industrial Hygienists (ACGIH)	
ACGIH 2097	*Industrial Ventilation: A Manual of Recommended Practice for Design*, 2013
American National Standards Institute (ANSI)	
ANSI/ITSDF B56.1	*Safety Standard for Low Lift and High Lift Trucks*

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
ANSI/IEEE C2	*2012 National Electrical Safety Code (NESC)*, 2012
ANSI C84.1	*American National Standard for Electric Power Systems and Equipment – Voltage Ratings (60 Hertz)*, 2011
ANSI N13 series	Addresses radiation monitoring equipment
ANSI N13.1	*Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities* 2011
ANSI N323D	*American National Standard for Installed Radiation Protection Instrumentation*, 2002
ANSI/AIHA/ASSE Z9.5	*Laboratory Ventilation*, 2012
ANSI/NEMA Z535.1	*Safety Colors*, 2006 (R2011)
ANSI/NEMA Z535.2	*Environmental and Facility Safety Signs*, 2011
ANSI/NEMA Z535.3	*Criteria for Safety Symbols*, 2011
ANSI/NEMA Z535.4	*Product Safety Signs and Labels*, 2011
ANSI/AMCA 204	*Balance Quality and Vibration Levels for Fans*, 2005 (R2012)
ANSI/AMCA 210	*Laboratory Methods of Testing Fans for Aerodynamic Performance Rating*, 2007
ANSI/AHRI Standard 390	*Performance Rating of Single Package Vertical Air-Conditioners and Heat Pumps*, 2003
ANSI/AHRI Standard 410	*Forced-Circulation Air-Cooling and Air-Heating Coils*, 2001
ANSI/AHRI Standard 430	*Performance Rating of Central Station Air-Handling Units*, 2009
ANSI/AHRI Standard 850	*Performance Rating of Commercial and Industrial Air Filter Equipment*, 2013
ANSI/HI 3.1-3.5	*Rotary Pumps*, 2008
ANSI N42.17B	*American National Standard Performance Specifications for Health Physics Instrumentation – Occupational Airborne Radioactivity Monitoring Instrumentation*, 1989
ANSI N42.18	*Specification and Performance of On-Site Instrumentation for Continuously Monitoring Radioactivity in Effluents*, 2004
ANSI/IEEE N320	*American National Standard* Performance *Specifications for Reactor Emergency Radiological Monitoring Instrumentation*, 1979
American Nuclear Society (ANS)	
ANSI/ANS-2.3	*Estimating Tornado, Hurricane, and Extreme Straight Line Wind Characteristics at Nuclear Facility Sites*, 2011
ANSI/ANS-2.26	*Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design*, 2004 (R2010)
ANSI/ANS-2.27	*Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard* Assessments, 2008
ANSI/ANS-2.29	*Probabilistic Seismic Hazard Analysis*, 2008
ANSI/ANS-6.4	*Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants*, 2006

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
ANSI/ANS-6.4.2	*Specification for Radiation Shielding Materials*, 2006
ANSI/ANS-8.1	*Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*, 1998 (R2007) (W2014)
ANSI/ANS-8.3	*Critically Accident Alarm System*, 1997 (R2012)
ANSI/ANS-8.7	*Nuclear Criticality Safety in the Storage of Fissile Materials*, 1998 (R2007)
ANSI/ANS-8.10	*Criteria for Nuclear Criticality Control in Operations with Shielding and Confinement*, 1983 (R2005)
ANSI/ANS-8.19	*Administrative Practices for Nuclear Criticality Safety*, 1996 (R2014)
ANSI/ANS-8.20	*Nuclear Criticality Safety Training*, 1991 (R2005)
ANSI/ANS-8.21	*Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors*, 1995 (R2011)
ANSI/ANS-8.24	*Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations*, 2007 (R2012)
ANSI/ANS-10.4	*Verification and Validation of Non-Safety-Related Scientific and Engineering Computer Programs for the Nuclear Industry*, 2008
ANSI/ANS-10.5	*Accommodating User Needs in Computer Program Development*, 2006 (R2011)
ANSI/ANS-15.17	*Fire Protection Program Criteria for Research Reactors*, 1981 (R2000) (W2010)
ANSI/ANS-40.37	*Mobile Low-Level Radioactive Waste Processing Systems*, 2009
ANSI/ANS-55.1	*Solid Radioactive Waste Processing System for Light Water Cooled Reactor Plants*, 1992 (R2009)
ANSI/ANS-55.4	*Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants*, 1993 (R2007)
ANSI/ANS-55.6	*Liquid Radioactive Waste Processing System for Light Water Reactor Plants*, 1993 (R2007)
ANSI/ANS-58.3	*Physical Protection for Nuclear Safety-Related Systems and Components*, 1992 (R2008)
ANSI/ANS-58.8	*Time Response Design Criteria for Safety-Related Operator Actions*, 1994 (R2008)
ANSI/ANS-59.3	*Nuclear Safety Criteria for Control Air Systems*, 1992 (R2002) (W2012)
Design Guides for Radioactive Material Handling Facilities and Equipment, Remote Systems Technology Division, 1988, Air Conditioning, Heating and Refrigeration Institute (AHRI)	
ANSI/AHRI Standard 365	*Performance Rating of Commercial and Industrial Unitary Air-Conditioning Condensing Units*, 2009
ANSI/AHRI Standard 410	*Forced-Circulation Air-Conditioning and Air-Heating Coils*, 2001
American Society of Civil Engineers (ASCE)	
ASCE 4	*Seismic Analysis of Safety-Related Nuclear Structures and Commentary*, 2000
ASCE 7	*Minimum Design Loads for Buildings and Other Structures*, 2005 (R2010)
ASCE 43	*Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*, 2005

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
ASCE Manual of Practice 37	*Design and Construction of Sanitary and Storm Sewers*, 1969
American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE)	
ANSI/ASHRAE Standard 15	*Safety Standard for Refrigeration Systems*, 2013
ANSI/ASHRAE 51-07	*Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating*, 2007
ANSI/ASHRAE Standard 52.2	*Method for Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size*, 2007
ANSI/ASHRAE Standard 55	*Thermal Environmental Conditions for Human Occupancy*, 2013
ANSI/ASHRAE Standard 62.1	*Ventilation for Acceptable Indoor Air Quality*, 2010
ASHRAE Standard 70	*Method of Testing the Performance of Air Outlets and Air Inlets*, 2011
ANSI/ASHRAE/IES Standard 90.1	*Energy Standard for Buildings Except Low-Rise Residential Buildings*, 2010
ANSI/ASHRAE 110	*Method of Testing Performance of Laboratory Fume Hoods*, 1995
ANSI/ASHRAE 111	*Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems*, 2008
American Society of Mechanical Engineers (ASME)	
ASME A17.1	*Safety Code for Elevators and Escalators, 2013*
ASME AG-1	*Code on Nuclear Air and Gas Treatment*, 2012
ASME B16.5	*Pipe Flanges and Flanged Fittings: NPW ½ through 24*, 2003
ASME B20.1	*Safety Standard for Conveyors and Related Equipment, 2012*
ASME B30.17	*Overheard and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist)*, 2006
ASME B30.20	*Below-the-Hook Lifting Devices*, 2013
ASME B31.3	*Process Piping*, 2014
ASME B31.9	*Building Services Piping*, 2011/2014
ASME B31.12	*Hydrogen Piping and Pipelines*, 2014
ASME B40.100	*Pressure Gauges and Gauge Attachments*, 2013
ASME B40.200	*Thermometers, Direct Reading and Remote Reading*, 2013
ASME Boiler and Pressure Vessel Code	Section VIII Division 1, 2010/2013 Section IX
ASME HST-1	*Performance Standard for Electric Chain Hoists, 2012*
ASME N509	*Nuclear Power Plant Air-Cleaning Units and Components*, 2002 (R2008)
ASME N510	*Testing of Nuclear Air-Treatment Systems*, 2007
ASME NQA-1	*Quality Assurance Requirements for Nuclear Facility Applications*, 2008 with NQA-1a-2009 addenda

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
ASME QME-1	*Qualification of Active Mechanical Equipment Used in Nuclear Power Plants*, 2012
American Society for Nondestructive Testing (ASNT)	
SNT-TC-1A	*Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing*, 2011
American Society for Testing and Materials (ASTM)	
ASTM C1055	*Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries*, 2003 (2014)
ASTM C1217	*Standard Guide for Design of Equipment for Processing Nuclear and Radioactive Materials*, 2000
ASTM C1533	*Standard Guide for General Design Considerations for Hot Cell Equipment*, 2015
ASTM C1554	*Standard Guide for Materials Handling Equipment for Hot Cells*, 2011
ASTM C1572	*Standard Guide for Dry Lead Glass and Oil-Filled Lead Glass Radiation Shielding Window Components for Remotely Operated Facilities*, 2010
ASTM C1615	*Standard Guide for Mechanical Drive Systems for Remote Operation in Hot Cell Facilities*, 2010
ASTM C1661	*Standard Guide for Viewing Systems for Remotely Operated Facilities*, 2013
ASTM E493	*Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode*, 2011
ASTM F1471	*Standard Test Method for Air Cleaning Performance of High-Efficiency Particulate Air-Filter System*, 2009
American Welding Society (AWS)	
AWS B2.1/B2.1M	*Specification for Welding Procedure and Performance Qualification*, 2009
AWS D1.1/ D1.1M	*Structural Welding Code – Steel*, 2010
AWS D1.3/D1.3M	*Structural Welding Code – Sheet Steel*, 2008
AWS D1.6/D1.6M	*Structural Welding Code – Stainless Steel*, 2007
AWS D9.1/ D9.1M	*Sheet Metal Welding Code*, 2006
AWS QC1	*Standard for AWS Certification of Welding Inspectors*, 2007
Centers for Disease Control and Prevention (CDC) – National Institute for Occupational Safety and Health (NIOSH)	
DHHS (NIOSH) Publication No. 2003-136	*Guidance for Filtration and Air Cleaning Systems to Protect Building Environments from Airborne Chemical, Biological, and Radiological Attacks*, 2003
Electronic Industries Alliance (EIA)/Telecommunications Industry Association (TIA)	
ANSI/TIA-568-C.1	*Commercial Building Telecommunications Cabling Standard*, 2012
ANSI/TIA-568-C.2	*Balanced Twisted-Pair Telecommunications Cabling and Components Standards*, 2014
ANSI/TIA-568-C.3	*Optical Fiber Cabling and Components Standard*, 2011
ANSI/TIA-569	*Telecommunications Pathways and Spaces*, 2013
ANSI/TIA-606	*Administration Standard for Commercial Telecommunications Infrastructure*, 2012

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
ANSI/TIA-607	*Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications*, 2013
ANSI/TIA-758-A	*Customer-Owned Outside Plant Telecommunications Infrastructure Standard*, 2004
International Code Council	
ICC A117.1	*Accessible and Usable Buildings and Facilities Standard*, 2009
IECC	*2012 International Energy Conservation Code*, May 2011
IMC	*2012 International Mechanical Code*, June 2011
IPC	*International Plumbing Code*, April 2011
Institute of Electrical and Electronics Engineers (IEEE)	
IEEE 7-4.3.2	*Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations*, 2003
IEEE 141	*Recommended Practice for Electric Power Distribution for Industrial Plants (Red Book)*, 1993 (R1999)
IEEE 142	*Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book)*, 2007
IEEE 241	*Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)*, 1990 (R1997)
IEEE 242	*Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)*, 2001
IEEE 308	*Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations*, 2012
IEEE 315	*Graphic Symbols for Electrical and Electronics Diagrams*, 1975 (R1993)
IEEE 323	*Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*, 2003
IEEE 336	*Recommended Practice for Installation, Inspection, and Testing for Class IE Power, Instrumentation, and Control Equipment at Nuclear Facilities*, 2010
IEEE 338	*Standard for Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems*, 2012
IEEE 344	*Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*, 2013
IEEE 379	*Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems*, 2014
IEEE 384	*Standard Criteria for Independence of Class 1E Equipment and Circuits*, 2008
IEEE 399	*Recommended Practice for Power Systems Analysis (Brown Book)*, 1997
IEEE 446	*Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)*, 1995 (R2000)
IEEE 493	*Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)*, 2007

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
IEEE 497	*Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations*, 2010
IEEE 519	*Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems*, 2014
IEEE 535	*Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations*, 2013
IEEE 577	*Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Facilities*, 2012
IEEE 603	*Standard Criteria for Safety Systems for Nuclear Power Generating Stations*, 2009
IEEE 650	*Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations*, 2006
IEEE 739	*Recommended Practice for Energy Management in Industrial and Commercial Facilities (Bronze Book)*, 1995 (R2000)
IEEE 828	*Standard for Configuration Management in Systems and Software Engineering*, 2012
IEEE 829	*Standard for Software and System Test Documentation*, 2008
IEEE 902	*Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems (Yellow Book)*, 1998
IEEE 946	*Generating Stations*, 2004
IEEE 1012	*Standard Criteria for Software Verification and Validation*, 2012
IEEE 1015	*Recommended Practice Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)*, 2006 (C2007)
IEEE 1023	*Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations*, 2004 (R2010)
IEEE 1028	*Standard for Software Reviews and Audits*, 2008
IEEE 1046	*Application Guide for Distributed Digital Control and Monitoring for Power Plants*, 1991 (R1996)
IEEE 1050	*Guide for Instrumentation and Control Equipment Grounding in Generating Stations*, 2004
IEEE 1100	*Recommended Practice for Powering and Grounding Electronic Equipment (Emerald Book)*, 2005
IEEE 1289	*Guide for the Application of Human Factors Engineering in the Design of Computer-Based Monitoring and Control Displays for Nuclear Power Generating Stations*, 1998 (R2004)
IEEE 1584	*IEEE Guide for Performing Arc-Flash Hazard Calculations*, 2002
ANSI/IEEE C2	*2012 National Electrical Safety Code (NESC)*, 2012
Illuminating Engineering Society of North America (IES)	
IES-2011	*The Lighting Handbook*, 2011
ANSI/IES RP-1-12	*American National Standard Practice for Office Lighting*, 2012

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
IES RP-7	*American National Standard Practice for Lighting Industrial Facilities*, 1991 (W2001)
International Society of Automation (ISA)	
ANSI/ISA-5.1-2009	*Instrumentation Symbols and Identification*, 2009
ISA-5.3-1983	*Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic, and Computer Systems*, 1983
ISA-5.4-1991	*Instrument Loop Diagrams*, 1991
ISA-5.5-1985	*Graphic Symbols for Process Displays*, 1985
ANSI/ISA-5.06.01-2007	*Functional Requirements Documentation for Control Software Applications*, 2007
ANSI/ISA 7.0.01-1996	*Quality Standard for Instrument Air*
ANSI/ISA-12.01.01-2013	*Definitions and Information Pertaining to Electrical Equipment in Hazardous (Classified) Locations*, 2013
ISA-18.1-1979	*Annunciator Sequences and Specifications*, 1979 (R2004)
ISA-TR20.00.01-2007	*Specification Forms for Process Measurement and Control Instruments Part 1: General Considerations Updated with 27 new specification forms in 2004-2006 and updated with 11 new specification forms in 2007*
ISA-RP60.1-1990	*Control Center Facilities*, 1990
ISA-67.01.01-2002	*Transducer and Transmitter Installation for Nuclear Safety Applications*, 2002 (R2007)
ANSI/ISA-67.04.01-2006	*Setpoints for Nuclear Safety-Related Instrumentation*, 2006 (R2011)
ISA-RP67.04.02-2010	*Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation*, 2010
ANSI/ISA-75.05.01-2000	*Control Valve Terminology*, 2000 (R2005)
ANSI/ISA-82.03-1988	*Safety Standard for Electrical and Electronic Test, Measuring, Controlling, and Related Equipment*, 1988
ISA-TR84.00.04-2011	*Part 1 Guideline for the Implementation of ANSI/ISA-84.00.01-2004 (IEC 61511)*, 2011
ISA-TR84.00.09-2013	*Security Countermeasures Related to Safety Instrumented Systems (SIS)*, 2013
ISA-TR91.00.02-2003	*Criticality Classification Guideline for Instrumentation*, 2003
ANSI/ISA-TR99.00.01-2007	*Security Technologies for Industrial Automation and Control Systems*, 2007
International Atomic Energy Agency (IAEA)	
IAEA-TECDOC-1250	*Seismic Design Considerations of Nuclear Fuel Cycle Facilities*, 2001
IAEA-TECDOC-1347	*Consideration of External Events in the Design of Nuclear Facilities Other Than Nuclear Power Plants, With Emphasis on Earthquakes*, 2003
IAEA-TECDOC-1430	*Radioisotope Handling Facilities and Automation of Radioisotope Production*, 2004
International Code Council (ICC)	
IBC 2012	International Building Code, 2012
IFC 2012	*International Fire Code*, 2012

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
IMC 2012	*International Mechanical Code*, 2012
International Code Council Evaluation Service (ICC-ES)	
ICC-ES AC156	"Acceptance Criteria for Seismic Certification by Shake-Table Testing of Nonstructural Components," 2010
National Electrical Contractors Association (NECA)	
NECA 1	*Standard Practice of Good Workmanship in Electrical Construction*, 2010
NECA 90	*Recommended Practice for Commissioning Building Electrical Systems (ANSI)*, 2009
NECA 100	*Symbols for Electrical Construction Drawings (ANSI)*, 2013
NECA 101	*Standard for Installing Steel Conduits (Rigid, IMC, EMT) (ANSI)*, 2013
NECA/AA 104	*Standard for Installing Aluminum Building Wire and Cable (ANSI)*, 2012
NECA/NEMA 105	*Standard for Installing Metal Cable Tray Systems (ANSI)*, 2007
NECA 111	*Standard for Installing Nonmetallic Raceways (RNC, ENT, LFNC) (ANSI)*, 2003
NECA 120	*Standard for Installing Armored Cable (Type AC) and Metal-Clad Cable (Type MC) (ANSI)*, 2013
NECA 202	*Standard for Installing and Maintaining Industrial Heat Tracing Systems (ANSI)*, 2013
NECA 230	*Standard for Selecting, Installing, and Maintaining Electric Motors and Motor Controllers (ANSI)*, 2010
NECA/FOA 301	*Standard for Installing and Testing Fiber Optics*, 2009
NECA 331	*Standard for Building and Service Entrance Grounding and Bonding*, 2009
NECA 400	*Standard for Installing and Maintaining Switchboards (ANSI)*, 2007
NECA 402	*Standard for Installing and Maintaining Motor Control Centers (ANSI)*, 2007
NECA/EGSA 404	*Standard for Installing Generator Sets (ANSI)*, 2014
NECA 407	*Recommended Practice for Installing and Maintaining Panelboards (ANSI)*, 2009
NECA 408	*Standard for Installing and Maintaining Busways (ANSI)*, 2009
NECA 409	*Standard for Installing and Maintaining Dry-Type Transformers (ANSI)*, 2009
NECA 410	*Standard for Installing and Maintaining Liquid-Filled Transformers (ANSI)*, 2013
NECA 411	*Standard for Installing and Maintaining Uninterruptible Power Supplies (UPS) (ANSI)*, 2006
NECA 420	*Standard for Fuse Applications (ANSI)*, 2014
NECA 430	*Standard for Installing Medium-Voltage Metal-Clad Switchgear (ANSI)*, 2006
NECA/IESNA 500	*Recommended Practice for Installing Indoor Lighting Systems (ANSI)*, 2006
NECA/IESNA 501	*Recommended Practice for Installing Exterior Lighting Systems (ANSI)*, 2006
NECA/IESNA 502	*Recommended Practice for Installing Industrial Lighting Systems (ANSI)*, 2006
NECA/BICSI 568	*Standard for Installing Building Telecommunications Cabling (ANSI)*, 2006

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
NECA/NCSCB 600	*Recommended Practice for Installing and Maintaining Medium-Voltage Cable (ANSI)*, 2014
NECA/NEMA 605	*Installing Underground Nonmetallic Utility Duct (ANSI)*, 2005
National Electrical Manufacturers Association (NEMA)	
NEMA MG-1	*Motors and Generators*, 2009
InterNational Electrical Testing Association (NETA)	
ANSI/NETA ATS-2013	*Standard for Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*, 2013
ANSI/NETA ETT-2010	*Standard for Certification of Electrical Testing Technicians*, 2010
ANSI/NETA MTS-2011	*Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*, 2011
National Fire Protection Association (NFPA)	
NFPA 1	*Fire Code*, 2015
NFPA 2	*Hydrogen Technologies Code*, 2011
NFPA 4	*Standard for Integrated Fire Protection and Life Safety System Testing*, 2015
NFPA 10	*Standard for Portable Fire Extinguishers*, 2013
NFPA 13	*Standard for the Installation of Sprinkler Systems*, 2013
NFPA 14	*Standard for the Installation of Standpipe and Hose Systems*, 2013
NFPA 20	*Standard for the Installation of Stationary Pumps for Fire Protection*, 2013
NFPA 22	*Standard for Water Tanks for Private Fire Protection*, 2013
NFPA 24	*Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2013
NFPA 25	*Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2014
NFPA 30	*Flammable and Combustible Liquids Code*, 2015
NFPA 37	*Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 2015
NFPA 45	*Standard on Fire Protection for Laboratories Using Chemicals*, 2015
NFPA 55	*Compressed Gases and Cryogenic Fluids Code*, 2013
NFPA 68	*Standard on Explosion Protection by Deflagration Venting*, 2013
NFPA 69	*Standard on Explosion Prevention Systems*, 2014
NFPA 70	*National Electrical Code (NEC)*, 2014
NFPA 70B	*Recommended Practice for Electrical Equipment Maintenance*, 2013
NFPA 70E	*Standard for Electrical Safety in the Workplace*, 2015
NFPA 72	*National Fire Alarm and Signaling Code*, 2013
NFPA 75	*Standard for the Fire Protection of Information Technology Equipment*, 2013
NFPA 79	*Electrical Standard for Industrial Machinery*, 2015
NFPA 80	*Standard for Fire Doors and Other Opening Protectives*, 2013

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
NFPA 80A	*Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 2012
NFPA 86	*Standard for Ovens and Furnaces*, 2015
NFPA 86C	*Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1999
NFPA 90A	*Standard for the Installation of Air-Conditioning and Ventilating System*, 2015
NFPA 90B	*Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*, 2015
NFPA 91	*Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 2015
NFPA 92	*Standard for Smoke Control Systems*, 2012
NFPA 92A	*Standard for Smoke-Control Systems Utilizing Barriers and Pressure Differences*, 2009
NFPA 92B	*Standard for Smoke Management Systems in Malls, Atria, and Large Spaces*, 2009
NFPA 101B	*Code for Means of Egress for Buildings and Structures*, 2002 (W-Next Edition)
NFPA 105	*Standard for the Installation of Smoke Door Assemblies and Other Opening Protectives*, 2013
NFPA 110	*Standard for Emergency and Standby Power Systems*, 2013
NFPA 111	*Standard on Stored Electrical Energy Emergency and Standby Power Systems*, 2013
NFPA 170	*Standard for Fire Safety and Emergency Symbols*, 2012
NFPA 204	*Standard for Smoke and Heat Venting*, 2012
NFPA 220	*Standard on Types of Building Construction*, 2015
NFPA 221	*Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2015
NFPA 262	*Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces*, 2015
NFPA 297	*Guide on Principles and Practices for Communications Systems*, 1995
NFPA 329	*Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases*, 2015
NFPA 400	*Hazardous Materials Code*, 2013
NFPA 496	*Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 2013
NFPA 497	*Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2012
NFPA 704	*Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2012
NFPA 730	*Guide for Premises Security*, 2014
NFPA 731	*Standard for the Installation of Electronic Premises Security Systems*, 2015
NFPA 780	*Standard for the Installation of Lightning Protection Systems*, 2014
NFPA 791	*Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation*, 201

Table 3-7. Design Codes and Standards (12 pages)

Document number[a]	Document title
NFPA 801	*Standard for Fire Protection for Facilities Handling Radioactive Materials*, 2014
Sheet Metal and Air Conditioning Contractors National Association (SMACNA)	
National Oceanic and Atmospheric Administration (NOAA)	
NOAA Atlas 14	*Precipitation-Frequency Atlas of the United States,* Vol. 8 Version 2.0, 2013
SMACNA 1143	*HVAC Air Duct Leakage Test*, 1985
SMACNA 1520	*Round Industrial Duct Construction Standard*, 1999
SMACNA 1922	*Rectangular Industrial Duct Construction Standard*, 2004
SMACNA 1966	*HVAC Duct Construction Standard – Metal and Flexible*, 2006
SMACNA-2006	*HVAC Systems Duct Design*, 2006
ANSI/SMACNA 001-2008	*Seismic Restraint Manual: Guidelines for Mechanical Systems*, 2008
U.S. Weather Bureau	
Technical Paper No. 40	*Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*, 1963
Underwriters Laboratory, Inc. (UL) Federal Specifications	
UL 181	*Standard for Factory-Made Air Ducts and Connectors*, 2013
UL 499	*Standard for Electric Heating Appliances*, 2014
UL 555	*Standard for Fire Dampers*, 2006
UL 586	*Standard for High Efficiency, Particulate, Air Filter Units*, 2009
UL 900	*Standard for Air Filter Units*, 2004
UL 1995	*Heating and Cooling Equipment*, 2011

[a] Complete references are provided in Section 3.6

ACGIH = American Conference on Governmental Industrial Hygienists.
ACI = American Concrete Institute.
AHRI = Air Conditioning, Heating and Refrigeration Institute.
AISC = American Institute of Steel Construction.
AMCA = Air Movement and Control Association.
ANS = American Nuclear Society.
ANSI = American National Standards Institute.
ASCE = American Society of Civil Engineers.
ASHRAE = American Society of Heating, Refrigeration and Air-Conditioning Engineers.
ASME = American Society of Mechanical Engineers.
ASNT = American Society for Nondestructive Testing.
ASTM = American Society for Testing and Materials.
AWS = American Welding Society.
CDC = Centers for Disease Control and Prevention.
EIA = Electronic Industries Alliance.
IAEA = International Atomic Energy Agency.
ICC = International Code Council.
ICC-ES = International Code Council Evaluation Service.
IEEE = Institute of Electrical and Electronics Engineers.
IES = Illuminating Engineering Society.
ISA = International Society of Automation.
NECA = National Electrical Contractors Association.
NEMA = National Electrical Manufacturers Association.
NETA = InterNational Electrical Testing Association.
NFPA = National Fire Protection Association.
NIOSH = National Institute for Occupational Safety and Health.
NOAA = National Oceanic and Atmospheric Administration
SMACNA = Sheet Metal and Air Conditioning Contractors National Association.
TIA = Telecommunications Industry Association.
UL = Underwriters Laboratory.

3.2 METEOROLOGICAL DAMAGE

RPF meteorological accidents with radiological consequences are evaluated in NWMI-2015-SAFETY-011, *Evaluation of Natural Phenomenon and Man-Made Events on Safety Features and Items Relied on for Safety*. The basis for the structural design of the RPF is described in NWMI-2013-043, *NWMI Radioisotope Production Facility Structural Design Basis*.

Updates and development of technical specifications associated with the meteorological design of the RPF SSCs will be provided in Chapter 14.0 as part of the Operating License Application.

The demands on structural elements due to applied loads are evaluated using the criteria and methodology discussed below. The effect of each load case is determined separately, and total demand is determined by combining the load effects using the load combinations for evaluating strength and evaluating the serviceability criteria given below.

Four categories of load cases are used: normal, severe environmental, extreme environmental, and abnormal loads. The definition of each load is the following:

- **Normal loads** are loads that are expected to be encountered during normal plant operations and shutdown, and load due to natural hazard phenomena likely to be encountered during the service life of the facility.
- **Severe environmental loads** are loads that may be encountered infrequently during the service life of the facility.
- **Extreme environmental loads** are loads that are credible but are highly improbable to occur during the service life of the facility.
- **Abnormal loads** are loads generated by a postulated high-energy pipe break accident used as a design basis.

Definitions of load case symbols are provided in Table 3-8.

Table 3-8. Load Symbol Definitions (2 pages)

Symbol	Definition
Normal Load Cases	
D	Dead loads due to the weight of the structural elements, fixed-position equipment, and other permanent appurtenant items; weight of crane trolley and bridge
F	Load due to fluids with well-defined pressures and maximum heights
H	Load due to lateral earth pressure, groundwater pressure, or pressure of bulk materials
L	Live load due to occupancy and moveable equipment, including impact
L_r	Roof live load
C_{cr}	Rated capacity of crane (will include the maximum wheel loads of the crane and the vertical, lateral, and longitudinal forces induced by the moving crane)
S	Snow load as stipulated in ASCE 7[a] for risk category IV facilities
R	Rain load
T_o	Self-staining load, thermal effects, and loads during normal operating, startup, or shutdown conditions, based on the most critical transient or steady-state condition

Table 3-8. Load Symbol Definitions (2 pages)

Symbol	Definition
R_o	Pipe reactions during normal operating, startup, or shutdown conditions, based on the most critical transient or steady-state condition
Severe Environmental Load Cases	
D_i	Weight of ice
F_a	Flood load
W	Load due to wind pressure
W_a	Load based on serviceability wind speed
W_i	Wind-on-ice
E_o	Where required as part of the design basis, loads generated by the operating basis earthquake, as defined in 10 CFR 50,[b] Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," or as specified by the authority having jurisdiction
Extreme Environmental Load Cases	
S_r	Weight of the 48-hour probable maximum winter precipitation superimposed on S
W_t	Loads generated by the specified design basis tornado, including wind pressures, pressure differentials, and tornado-borne missiles, as defined in NUREG-0800,[c] or as specified by the authority having jurisdiction
E_{ss}	Loads generated by the safe shutdown, or design basis earthquake, as defined in 10 CFR 50,[b] Appendix S, or as specified by the authority having jurisdiction
Abnormal Load Cases	
P_a	Maximum differential pressure load generated by the postulated accident
R_a	Pipe and equipment reactions generated by the postulated accident, including R_o
T_a	Thermal loads generated by the postulated accident, including T_o
Y_j	Jet impingement load generated by the postulated accident
Y_m	Missile impact load, such as pipe whip generated by or during the postulated accident
Y_r	Loads on the structure generated by the reaction of the broken high-energy pipe during the postulated accident

[a] ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2005 (R2010).

[b] 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.

[c] NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*, LWR Edition, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, Washington, D.C., 1987.

3.2.1 Combinations of Loads

Load combinations used for evaluating strength and serviceability are given in the following subsections. Combinations for strength-based acceptance criteria are given for both nuclear safety-related SSCs and for commercial SSCs.

3.2.1.1 Nuclear Safety-Related Structures, Systems, and Components

For nuclear safety-related SSCs, the loading combinations from ACI 349, *Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary*, are used. The load combinations from ACI 349 are essentially identical to the combination from ANSI/AISC N690, *Specification for Safety-Related Steel Structures for Nuclear Facilities*. Table 3-9 presents nuclear safety-related SSC loads. In addition, the load combination for extreme winter precipitation load (S_r) takes DC/COL-ISG-007, *Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures*, guidance into account.

Table 3-9. Load Combinations for Strength Based Acceptance Criteria, Nuclear Safety-Related

Combination	ACI 349[a]	ANSI/AISC N690[b]
Normal Load Combinations		
$1.4(D + F + R_o) + T_o$	(9-1)	(NB2-1)
$1.2(D + F + T_o + R_o) + 1.6(L + H) + 1.4C_{cr} + 0.5(L_r \text{ or } S \text{ or } R)$	(9-2)	(NB2-2)
$1.2(D + F + R_o) + 0.8(L + H) + 1.4C_{cr} + 1.6(Lr \text{ or } S \text{ or } R)$	(9-3)	(NB2-3)
Severe Environmental Load Combinations		
$1.2(D + F + R_o) + 1.6(L + H + E_o)$	(9-4)	(NB2-4)
$1.2(D + F + R_o) + 1.6(L + H + W)$	(9-5)	(NB2-5)
Extreme Environmental and Abnormal Load Combinations		
$D + F + 0.8L + C_{cr} + H + T_o + R_o + E_{ss}$	(9-6)	(NB2-6)
$D + F + 0.8L + H + T_o + R_o + W_t$	(9-7)	(NB2-7)
$D + F + 0.8L + C_{cr} + H + T_a + R_a + 1.2P_a$	(9-8)	(NB2-8)
$D + F + 0.8L + H + T_a + R_a + P_a + Y_r + Y_j + Y_m + E_{ss}$	(9-9)	(NB2-9)
$D + F + 0.8L + C_{cr} + H + T_o + R_o + S_r$	-	-

[a] ACI 349, *Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary*, American Concrete Institute, Farmington Hills, Michigan, 2013.

[b] ANSI/AISC N690, *Specification for Safety-Related Steel Structures for Nuclear Facilities*, American Institute of Steel Construction, Chicago, Illinois, January 31, 2012.

3.2.1.2 Commercial and Nuclear Non-Safety-Related Structures, Systems, and Components

For commercial and nuclear non-safety-related SSCs, the loading combinations from American Society of Civil Engineers (ASCE) 7, Chapter 2 are used. When the loading includes earthquake effects, the special seismic load combinations are taken from ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, Chapter 12. The basic load combinations for the strength design of commercial type and non-safety-related nuclear SSCs are given in Table 3-10. The combinations listed are obtained from the 2012 International Building Code (IBC) and ASCE 7. The crane live load case (C_{cr}) is separated from other live loads in the combinations for design purposes.

Table 3-10. Load Combinations for Strength Base Acceptance Criteria, Commercial

Combination	IBC[a]	ASCE 7[b]
Basic Load Combinations		
1.4(D +F)	(16-1)	1
1.2(D + F) + 1.6(L + Ccr + H) + 0.5(L_r or S or R)	(16-2)	2
1.2(D + F) + 1.6(L_r or S or R) + 1.6H + [f_1(L + C_{cr}) or 0.5W]	(16-3)	3
1.2(D + F) + 1.0W + f_1(L + C_{cr}) + 1.6H + 0.5(L_r or S or R)	(16-4)	4
1.2(D + F) + 1.0E + f_1(L + C_{cr}) + 1.6H + f_2S	(16-5)	5
0.9D+ 1.0W+ 1.6H	(16-6)	6
0.9(D + F) + 1.0E+ 1.6H	(16-7)	7
Load Combinations, including Flood Load		
1.2D + (0.5W + 1.0F_a) + L + 0.5(L_r or S or R)	§1605.2.1	§2.3.3.2
0.9D + (0.5W + 1.0F_a)	§1605.2.1	§2.3.3.2
Load Combinations, including Atmospheric Ice		
1.2D + 1.6L +(0.2D_i + 0.5S)	§1605.2.1	§2.3.4.1
1.2D + L + (D_i + W_i + 0.5S)	§1605.2.1	§2.3.4.2
0.9D + (D_i + W_i)	§1605.2.1	§2.3.4.3

Where:
f1 = 0.5 for other live loads.
f2 = 0.7 for flat roof configurations, which do not shed snow, and 0.2 for other roof configurations

[a] IBC 2012, *International Building Code*, International Code Council, Inc., Washington D.C.
[b] ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2010.

3.2.2 Combinations for Serviceability Based Acceptance Criteria

Based on ASCE 7, Appendix C Commentary, the load combinations given in Table 3-11 are used when evaluating serviceability based acceptance criteria.

Table 3-11. Load Combinations for Serviceability Based Acceptance Criteria

Combination	ASCE 7
Short-Term Effects	
D + L	(CC-1a)
D + 0.5S	(CC-1b)
Creep, Settlement and Similar Long-Term of Permanent Effects	
D + 0.5L	(CC-2)
Drift of Walls and Frames	
D + 0.5L + W_a	(CC-3)
Seismic Drift	
Per ASCE 7, Section 12.8.6	

[a] Appendix C, Commentary, of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2013.

3.2.3 Normal Loads

The RPF is required to resist loads due to:

- Operating conditions of the systems and components within the RPF
- Normal and severe natural phenomena hazards, remaining operational to maintain life-safety and safety-related SSCs
- Extreme natural phenomena hazards, maintaining life-safety and safety-related SSCs

Structural loads are due to the following:

- Self-weight of building materials and SSCs
- Occupancy and normal use of the RPF
- Off-normal conditions and accidents
- Natural phenomena hazards

Section 3.1 describes the structural discipline source requirements for these criteria. Structural load criteria are summarized below. Site-specific natural phenomena hazard criteria are based on the physical location of the RPF given in Chapter 2.0, Sections 2.3 and 2.5.

3.2.3.1.1 Dead Loads

Dead loads consist of the weight of all materials of construction comprising the building, including walls, floors, roofs, ceilings, confinement doors, stairways, built-in partitions, wall and floor finishes, and cladding. Dead loads also consist of the weight of fixed equipment, including the weight of cranes. The density of all interconnections (e.g., heating, ventilation, and air conditioning [HVAC] ductwork, conduits, cable trays, and piping) between equipment will be conservatively estimated and included in the final design for dead load for fixtures attached to ceilings or anchored to floors in the RPF.

3.2.3.1.2 Lateral Earth and Ground Water Pressure Loads

Lateral earth and groundwater pressure loads are lateral pressures due to the weight of adjacent soil and groundwater, respectively. The design lateral earth load is a function of the composition of the soil. The Discovery Ridge Phase 1 Environmental Assessment (Terracon, 2011a) indicates that the soils present are clayey gravels consistent with the Unified Soil Classification "GC." In addition, the assessment indicates that expansive soils are present. Chapter 2.0, Section 2.5.3 presents additional on-site soil information.

The design lateral earth pressure load for the RPF is based on ASCE 7, Table 3.2.1, and has been augmented to account for the expansive soils (e.g., surcharge load is applied to account for the weight of the facility above the soils adjacent to the tank hot cell).

The design groundwater depth is estimated to be approximately 5.5 meters (m) (18 feet [ft]) below-ground surface and will be verified pending final geotechnical investigation. Additional information is presented in Chapter 2.0, Section 2.4.2.

The lateral earth pressure loads for the RPF are presented in Table 3-12.

Table 3-12. Lateral Earth Pressure Loads

Element	Value
Base design lateral soil load	45 lb/ft^2 per ft
Design lateral load (expansive increase)	60 lb/ft^2 per ft

Reference: Table 3.2-1 of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2013.

3.2.3.1.3 Live Loads

Floor Live Load

Live loads are produced by the use and occupancy of the RPF, and as such, different live load magnitudes are appropriate for different areas of the facility. Design floor loads provided in Table 3-13 are based on ASCE 7, Sections 4.3 and 4.4, and Section C4.3 Commentary.

During the structural analysis, unknown loads (e.g., hot cell roof in Table 3-13) will have a conservative value assumed and marked with "(HOLD)." As the design matures, the actual values will be inserted in the analysis and the HOLDs removed. Final design media cannot be issued if there are HOLDs identified. The facility live loads will be established during the completion of the final facility design and provided as part of the Operating License Application.

Table 3-13. Floor Live Loads

Description	Uniform	Concentrated
Production area	250 lb/ft^2	3,000 lb
Hot cell roof	TBD	TBD
Cover block laydown	TBD	TBD
Mechanical rooms	200 lb/ft^2	2,000 lb
Laboratory	100 lb/ft^2	2,000 lb
Office	50 lb/ft^2	2,000 lb
Office partitions	20 lb/ft^2	-
Corridors	100 lb/ft^2	-
Truck bay	Per AASHTO	-

Based on Sections 4.3, 4.4, and C4.3 Commentary of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2013.

AASHTO = American Association of State Highway and Transportation Officials.
TBD = to be determined.

Roof Live Load

The minimum roof live load (L_r) prescribed by the City of Columbia is 20 pounds (lb)/square foot (ft^2), non-reducible (Ordnance No. 21804, Section 6-17). Snow loads (e.g., normal and extreme rain-on-snow) are discussed separately in Section 3.2.5.2.

Crane Loads

The design basis crane load criteria are given in Table 3-14 and are based on a preliminary quote provided in NWMI-2015-SDD-001, *RPF Facility SDD*. The crane design is to run a top-running bridge crane with a remotely operated, powered bridge and hoist.

Table 3-14. Crane Load Criteria

Element	Value
Crane capacity	75 ton (150 kip)
Crane weight (with hoists)	69,990 lbf
Bridge weight	62,330 lbf
Hoist and trolley weight	7,660 lbf
Wheel load (static)	54.3 kip

The crane design basis will be refined in the final design and Operating License Application to account for the following:

- ASCE 7, Chapter 3 – Include weights of crane and runway beams in dead loads
- ASCE 7, Chapter 4 – Increase wheel load by 25 percent to account for vertical impact
- ASCE 7, Chapter 4 – Determine lateral force by multiplying sum of hoist and trolley weight and rated capacity of crane by 20 percent
- ASCE 7, Chapter 4 – Determine longitudinal force by multiplying the wheel load by 10 percent

3.2.4 Wind Loading

3.2.4.1 Wind Load

Per NUREG-1537, Section 2.3.1, "General and Local Climate," wind loads will be based on the 100-year return period wind speed. In addition, based on NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*, Section 3.3.1, the wind speed will be transformed to equivalent pressure per ASCE 7-05. For RPF SSCs per current applicable 2012 IBC guidance, ASCE 7-10 is used for this transformation of wind speed to equivalent pressure. From Table 1.5-1 of ASCE 7-10 and based on use and occupancy of the RPF, a Risk Category IV is assigned to RPF SSCs. Figure 26.5-1B for a Risk Category IV building of ASCE 7-10 is used to obtain the basic wind speed for the RPF site.

The mean recurrence interval (MRI) of the basic wind speed for Risk Category IV buildings is 1,700 years. Since the MRI stipulated in ASCE 7-10 is more stringent than NUREG-1537 100-year wind speeds, wind loads will be determined in accordance with ASCE 7-10, Chapters 26 through 30, as applicable, for a Risk Category IV building.

The surface roughness surrounding RFP SSCs is currently Surface Category C, which in turn indicates Exposure Category C for the RFP per ASCE 7-10. The RPF main building is an enclosed building. The wind loading criteria are provided in Table 3-15. The basic wind speed given in Table 3-15 is a 3-second (sec) gust wind speed at 10 m (33 ft) aboveground for Exposure Category C and Risk Category IV.

Table 3-15. Wind Loading Criteria

Element	Value
Basic wind speed, V	193.1 km/hr (120 mi/hr)
Exposure category	C
Enclosure classification	Enclosed
Risk category	IV

Source: ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2010.

The wind loading criteria will be updated in the Operating License Application.

3.2.4.2 Tornado Loading

Tornado loads are a combination of tornado wind effects, atmospheric pressure change, and tornado-generated missile impact effects and are discussed separately in the following sections. NUREG-1520, *Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility*, Part 3, Appendix D, states that an annual exceedance probability of 10^{-5} may need to be considered. The maximum tornado wind speed from NRC Regulatory Guide 1.76, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*, for Region I, has an annual exceedance probability of 10^{-7} that is significantly lower than the target probability stated in NUREG-1520.

For the RPF preliminary safety analysis report, the maximum tornado wind speed from NRC Regulatory Guide 1.76 for Region I will be used. The tornado load criteria will be updated by using tornado loading in accordance with 10^{-5} annual probability of exceedance in the Operating License Application.

3.2.4.2.1 Maximum Tornado Wind Speed

Table 3-16. Design-Basis Tornado Field Characteristics

Description	Value
Tornado region	Region I
Maximum wind speed	370.1 km/hr (230 mi/hr)
Translational speed	74.0 km/hr (46 mi/hr)
Radius of maximum rotational speed	45.7 m (150 ft)
Pressure drop, ΔP	(1.2 lb/in.^{2})

Source: NRC Regulatory Guide 1.76, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*, Rev. 1, U.S. Nuclear Regulatory Commission, Washington, D.C., March 2007.

Tornado wind field characteristics used to calculate tornado wind pressures on the RPF are provided in Table 3-16 per NRC Regulatory Guide 1.76. The maximum tornado wind speed has two components: translational and rotational. The maximum total tornado wind speed is the sum of these two components and is applied to the RPF building from each direction separately. Based on NUREG-0800, Section 3.3.2, ASCE 7-05 may be used to transform maximum tornado wind speed to equivalent pressure. For RPF SSCs per current applicable 2012 IBC guidance, Chapters 26 and 27 of ASCE 7-10 is used for this transformation of tornado wind speed to equivalent pressure. From Table 1.5-1 of ASCE 7-10 and based on use and occupancy of the RPF, a Risk Category IV is assigned to RPF SSCs. Per NUREG-800, Section 3.3.2, tornado wind speed is assumed not to vary with the height aboveground. Additional information is provided in Chapter 2.0, Section 2.3.1.5, and Chapter 13.0, Section 13.2.6.1.

3.2.4.2.2 Atmospheric Pressure Change

NRC Regulatory Guide 1.76 provides guidance for determining the pressure drop and the rate of pressure drop caused by the passing of a tornado. Depending on the final design of the RPF building and whether it is enclosed (unvented) or partially enclosed (vented structure), the procedures outlined in NUREG-800 Section 3.3.2 will be used to account for atmospheric pressure change effects. At the preliminary stage of the design, the RPF building is known not to be open. The value for atmospheric pressure drop, corresponding to the design-basis tornado is given in Table 3-16.

3.2.4.2.3 High Straight-Line Winds

Similar to the tornado, high straight-line winds can also damage the facility structure, which in turn can lead to damage to SSCs relied on for safety. This evaluation demonstrates how the facility design addressed straight-line winds with a return interval of 100 years or more, as required by building codes.

The RPF is designed as a Risk Category IV structure, a standard industrial facility with equivalent chemical hazards, in accordance with ASCE 7. The return frequency of the basic (design) wind speed for Risk Category IV structures is 5.88×10^{-4}/year (MRI = 1,700 year). The provisions of ASCE 7, when used with companion standards such as American Concrete Institute (ACI) 318, *Building Code Requirements for Structural Concrete*, and American Institute of Steel Construction (AISC) 360, *Specification for Structural Steel Buildings*, are written to achieve the target maximum annual probabilities of established in ASCE 7. The highest maximum probability of failure targeted for Risk Category IV structures is 5.0×10^{-6}.

3.2.4.2.4 Tornado-Generated Missile Impact Effects

The missile is assumed rigid in this analysis for maximum penetration. Note that in Columbia, Missouri, the location of the University of Missouri Research Reactor (MURR) facility, the expected speed of tornado missiles is larger than the expected speed of any hurricane-generated missiles at the same annual frequency of exceedance (NUREG/CR–7005, *Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants*).

Tornado-generated missile impact effects are based on the standard design missile spectrum from NRC Regulatory Guide 1.76 and are presented in Table 3-17. In addition, wind velocities in excess of 34 m/sec (75 mi/hr) are capable of generating missiles from objects lying within the path of the tornado wind and from the debris of nearby damaged structures per Regulatory Guide 1.76.

These requirements are considered more severe than the characteristics from DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, that are cited in NUREG-1520, Section 3. The recommended RPF roof and wall system design criteria are also taken from DOE-STD-1020, Table 3-4.

Table 3-17. Design-Basis Tornado Missile Spectrum

Description	Weight	Dimensions	Horizontal velocity	Vertical velocity
Automobile	4,000 lb	16.4 ft × 6.6 ft × 4.3 ft	92 mi/hr	62 mi/hr
Pipe	287 lb	6.625 in. diameter × 15 ft long	92 mi/hr	62 mi/hr
Steel Sphere	0.147 lb	1.0 in. diameter	18 mi/hr	12 mi/hr

Source: NRC Regulatory Guide 1.76, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington, D.C., March 2007.

The impact-type missile, an automobile is limited to a height of no more than 9.1 m (30 ft) above-grade. Structural wall openings are subjected to the impact of a 0.25 centimeters (cm) (1-inch [in.]) diameter steel sphere. The vertical velocities are taken as 0.67 of the horizontal velocity. For an automobile and pipe missile, a normal impact is assumed. The tornado load criteria will be updated by using tornado loading in accordance with 10^{-5} annual probability of exceedance in the Operating License Application and accordingly, the design-basis tornado missile spectrum will also be updated. Note that in Columbia, Missouri, the location of the MURR facility, the expected speed of tornado missiles is larger than the expected speed of any hurricane-generated missiles at the same annual frequency of exceedance (NUREG/CR–7005).

3.2.4.2.5 Combined Tornado Load Effects

After tornado-generated wind pressure effects, atmospheric pressure change effects and missile impact effects are determined; the combination thereof will be established in accordance with procedures outlined n NUREG-800, Section 3.3.2. The effect of atmospheric pressure drop by itself will be considered, and the total effects of wind pressure and missile impact effects with one-half of the atmospheric pressure drop effects will be considered jointly.

3.2.4.3 Effect of Failure of Structures, Systems, or Components Not Designed for Tornado Loads

SSCs, in which failure during a tornado event could affect the safety-related portions of the RPF, are either designed to:

- Resist the tornado loading or the effect on the safety-related structures from the failure of these SSCs
- Be bounded by the tornado missile or aircraft impact evaluations

The effects and mitigations of failure of SSCs not designed for tornado loads will be developed during final design and the Operating License Application.

3.2.5 Rain, Snow, and Ice Loading

3.2.5.1 Rain Loads

From the National Weather Service (NWS)/National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Report No. 51, *Probable Maximum Precipitation Estimates, United States East of the 105th Meridian*, the probable maximum precipitation (PMP) is defined as "theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage area at a certain time of year."

Per NUREG-1537, Section 2.3.1, "General and Local Climate," rain loads will be based on the estimate of the weight of the 48-hour (hr) probable maximum precipitation, as specified by the U.S. Geological Survey. This rain load estimate is compared with the local building code rain load (i.e., ASCE 7-10), and the greater value is used in design of the RPF roof.

The roof of the RPF is designed to prevent rainwater from accumulating on the roof. In accordance with 2012 IBC and ASCE 7-10, the roof structure is designed to safely support the weight of rainwater accumulation with the primary drainage system blocked and the secondary drainage system at its design flow rate when subjected to a rainfall intensity based on the 48-hr probable maximum precipitation.

Rain loads are determined by the amount of water that can accumulate on the undeflected building roof if the primary drainage system becomes blocked (static head), plus a uniform depth of water above the inlet of the secondary drainage system at its design flow (hydraulic head). The rain load criteria are determined per ASCE 7-10, Chapter 8, and are provided in Table 3-18.

Table 3-18. Rain Load Criteria

Element	Value
Static head	5 cm (2-in)
Hydraulic head	TBD
Rainfall intensity	3.14 in./hr[a]

[a] NOAA Atlas 14, *Precipitation-Frequency Atlas of the United States*, Volume 8, Version 2.0: Midwestern States, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, 2013.

TBD = to be determined.

The hydraulic head is dependent on the roof drain size, roof area drained, and the rainfall intensity. The rainfall intensity used to determine the hydraulic head is taken from NOAA Atlas 14, *Precipitation-Frequency Atlas of the United States*, web tool for the 100-year storm, 1-hr duration.

The rain load criteria will be updated in the Operating License Application.

3.2.5.2 Snow Load

Per the guidance in DC/COL-ISG-007, two types of snow load are considered: normal snow load and the extreme winter precipitation load. The normal snow load will be included in normal load combinations given below. Per the guidance in the DC/COL-ISG-007, the extreme winter precipitation load is included in the extreme environmental load combinations.

The snow load criteria will be updated in the Operating License Application.

3.2.5.2.1 Normal Snow Load

Per NUREG-1537, Section 2.3.1 and DC/COL-ISG-007, the normal snow load is the 100-year ground snow, modified using the procedures of ASCE 7 to determine the roof snow load, including snow drifting. The 100-year ground snow load is calculated by factoring the ground snow load stipulated in the City of Columbia Code of Ordinances amendments (City of Columbia, 2014) and IBC 2012 and is equivalent to the mapped ground snow load from Figure 7-1 of ASCE 7. This information is determined using the conversion factor provided in ASCE 7, Table C7-3.

The exposure factor provided in ASCE 7, Table 7-2, for partially exposed roof in terrain category C is similar with the exposure used for determining wind loads. Since the RPF does not fall into any of the special cases indicated in ASCE 7, Table 7-3, the thermal factor is assumed to be 1.0.

The importance factor is taken to be unity from ASCE 7-10, Table 1.5-2, for the RPF, which is designated Risk Category IV. Snow load criteria are summarized in Table 3-19.

Table 3-19. Snow Load Criteria

Element	Value
Mapped ground snow load (50-year)	[a]20 lb/ft^2
Conversion factor, 100-year to 50-year	[b]0.82
Design ground snow load, p_g (100-year)	24.4 lb/ft^2
Exposure factor (C_e)	1.0[b]
Thermal factor (C_t)	1.0[b]
Importance factor	1.0[b]

[a] City of Columbia, "City of Columbia Code of Ordinances," www.gocolumbiamo.com/Council/Code_of_Ordinances_PDF/, accessed September 8, 2014.

[b] ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2013.

3.2.5.2.2 Extreme Winter Precipitation Load

Per NUREG-1537, Section 2.3.1 and DC/COL-ISG-007, the extreme winter precipitation load is the normal snow load as presented in Section 3.2.5.2.1, plus the liquid weight of the 48-hr probable maximum winter precipitation (PMWP).

The 48-hr PMWP is determined from the NOAA/NWS Hydrometeorological Report (HR) 53, *Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105th Meridian*, for a 10-mi^2 area. HR 53 gives mid-month PMP estimates for six 24- and 72-hr durations. Based on the example of variation of PMP depths given in HR 53, Figure 46, the 48-hr PMP is linearly interpolated from the 24- and 72-hr PMP depths and gives a PMWP of 51.8 cm (20.4 in.). However, using the NOAA web tool for Columbia (NOAA, 2017), a two-day (48-hr) average 100-year rain is 22.2 cm (8.73 in.) precipitation. The months of December, January, February, and March were used to determine the PMWP. In addition, using HR 53, Figures 26 through 45, the PMWP was determined to occur in the month of March. The PMWP criteria are given in Table 3-20.

Table 3-20. Extreme Winter Precipitation Load Criteria

Element	Value
24-hr, 10-mi^2 PMWP	46.7 cm (18.2 in.)[a]
72-hr, 10-mi^2 PMWP	56.9 cm (22.5 in.)[a]
48-hr, 10-mi^2 PMWP (interpolated)	22.2 cm (8.73 in.)[b]
Weight of 48-hr PMWP	106 lb/ft^2

[a] NWS/NOAA HR 53, *Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105th Meridian*, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, 1980.

[b] NOAA, 2017, "NOAA Atlas 14 Point Precipitation Frequency Estimates: Mo," https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=mo, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, accessed 2017.

PMWP = probable maximum winter precipitation.

Winter weather events since 1996 in Boone County, Missouri, are provided in Chapter 2.0, Table 2-36.

3.2.5.3 Atmospheric Ice Load

For SSCs to be considered sensitive to ice, the ice thickness and concurrent wind loads are determined using the procedures in ASCE 7, Chapter 10. Consistent with the requirements for snow and wind loads, the mapped values are converted to 100-year values using the MRI multipliers given in ASCE 7, Table C10-1. Criteria for ice loading are given in Table 3-21.

Table 3-21. Atmospheric Ice Load Criteria

Element	Value[a]
Ice thickness (50-year)	2.54 cm (1 in.)
Concurrent wind speed	64.4 km/hr (40 mi/hr)
Ice thickness MRI multiplier	1.25
Wind speed MRI multiplier	1.00
Importance factor	1.00

[a] ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2013.

MRI = mean recurrence interval.

3.2.6 Operating Thermal/Self-Straining Loads

The operating thermal/self-straining loads will be evaluated in the Operating License Application. These loads will be consistent with the requirements of ACI 349 or ANSI/AISC N690, as applicable to the material of construction.

3.2.7 Operating Pipe Reaction Loads

The operating pipe reaction loads will be evaluated in the Operating License Application. These loads will be consistent with the requirements of applicable American Society of Mechanical Engineers (ASME) B31, *Standards of Pressure Piping*, codes.

3.2.8 External Hazards

External hazards include aircraft impact, external explosions, and external fire. The RPF is a production facility, as opposed to a nuclear power reactor, as such 10 CFR 50.150(a)(3) is interpreted to mean that the requirement for the aircraft impact assessment is not applicable to this facility. Sources of accidental external explosions have been considered and were found to not be an accident of concern. The RPF is constructed of robust, noncombustible materials, and adequate setbacks from transportation routes and landscaping consisting of fire fuels are provided such that externals fires are not an accident of concern.

3.3 WATER DAMAGE

This section identifies the requirements and guidance for the water damage design of the RPF SSCs. NUREG-1520 and ASCE 7, Chapter 5, provide guidance on flood protection of nuclear safety-related SSCs. Updates and development of technical specifications associated with the water damage design of the RPF SSCs will be provided in Chapter 14.0 as part of the Operating License Application.

3.3.1 Flood Protection

This subsection discusses the flood protection measures that are applicable to safety-related SSCs for both external flooding and postulated flooding from failures of facility components containing liquid. A compliance review will be conducted of the as-built design against the assumptions and requirements that are the basis of the flood evaluation presented below.

Additional information is presented in Chapter 2.0, Section 2.4.3 and Chapter 13.0, Section 13.2.6.4. This as-built evaluation will be documented in a flood analysis report and be part of the Operating License Application.

3.3.1.1 Flood Protection Measures for Structures, Systems, and Components

3.3.1.1.1 Flooding from Precipitation Events

Regional flooding from large precipitation events raising the water levels of local streams and rivers to above the 500-year flood level can have an adverse impact on the structure and SSCs within. These impacts include the structural damage from water and the damage to power supplies and instrument control systems for SSCs relied on for safety. The infiltration of flood water into the facility could cause the failure of moderation control requirements and lead to an accidental nuclear criticality. Direct damage or impairment of SSCs could also be caused by flooding in the facility.

The site will be graded to direct the stormwater from localized downpours with a rainfall intensity for the 100-year storm for a 1-hr duration around and away from the RPF. Thus, no flooding from local downpours is expected based on standard industrial design. Rainwater that falls on the waste management truck ramp and accumulates in the trench drain has low to no consequence for radiological, chemical, and criticality hazards.

Situated on a ridge, the RPF will be located above the 500-year flood plain according to the flood insurance rate map for Boone County, Missouri, Panel 295 (FEMA, 2011). The site is above the elevation of the nearest bodies of water (two small ponds and a lake), and no dams are located upstream on the local streams. This data conservatively provides a 2×10^{-3} year return frequency flood, which can be considered an unlikely event according to performance criteria. However, the site is located at an elevation of 248.4 m (815 ft), and the 500-year flood plain starts at an elevation of 231.6 m (760 ft), or 16.8 m (55 ft) below the site. Since the site, located only 6.1 m (20 ft) below the nearest high point on a ridge (relative to the local topography), is well above the beginning of the 500-year flood plain, and is considered a dry site, the probable maximum flood from regional flooding is considered highly unlikely, without further evaluation.[1]

[1] The recommended standard for determining the probably maximum flood, ANS 2.8, *Determining Design Basis Flooding at Power Reactor Sites*, has been withdrawn.

Per NUREG-1520, Section 3.2.3.4(1)(c), and ASCE 7, Chapter 5, flood loads will be based on the water level of the 100-year flood (one percent probability of exceedance per year). The facility has been determined to be above both the 100-year and the 500-year flood plain. Chapter 2, Section 2.4.3, provides additional detail for flood protection measures.

Postulated flooding from component failures in the building compartments will be prevented from adversely affecting plant safety or posing any hazard to the public. Exterior or access openings and penetrations into the RPF will be above the maximum postulated flooding level. Therefore, flood loads are considered highly unlikely and are not considered design loads.

3.3.1.1.2 Flooding from Inadvertent Discharge of Fire Protection System Water

Design of fire suppression systems using water (e.g., automatic sprinklers, hose stations) includes elements such as the grading and channeling of floors, raising of equipment mounts above floors, shelving and floor drains, and other passive means. These features will ensure sufficient capacity for gravity-driven collection and drainage of the maximum water discharge rate and duration to avoid localized flooding and resulting water damage to equipment within the area. In addition, particularly sensitive systems and components, whether electrical, optical, mechanical and/or chemical, are typically protected within enclosures designed for the anticipated adverse environmental conditions resulting from these types of water discharges. If critical for safety, these water-sensitive systems and components will be installed within the appropriate severe environment-rated enclosures in accordance with the relevant industry standard(s) (e.g., National Electrical Manufacturers Association [NEMA] enclosure standards).

Selection of specific fire suppression systems for facility locations will be guided by recommendations in relevant industry standards (e.g., NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*) and will depend on the level of fire hazards at those locations, as determined from the final facility and process systems designs. These final detailed designs will include any facility design elements and sensitive equipment protection measures deemed necessary for addressing the maximum inadvertent rate and duration of water discharges from the fire protection systems. The final comprehensive facility design, along with commitments to design codes, standards, and other referenced documents (including any exceptions or exemptions to the identified requirements), will be identified and provided as part of the Operating License Application.

3.3.1.2 Flood Protection from External Sources

Safety-related components located below-grade will be protected using the hardened protection approach. The safety-related systems and components will be protected from external water damage by being enclosed in a reinforced concrete safety-related structure. The RPF will have the following characteristics:

- Exterior safety-related walls below-grade will be 0.61 m (2-ft) thick minimum
- Water stops will be provided in all construction joints below-grade
- Waterproof coating will be applied to external surfaces below-grade and as required above-grade
- Roofs will be designed to prevent pooling of large amounts of water in accordance with Regulatory Guide 1.102, *Flood Protection for Nuclear Power Plants*

Waterproofing of foundations and walls of safety-related structures below-grade will be accomplished primarily by the use of water stops at expansion and construction joints. In addition to water stops, waterproofing of the RPF will be provided to protect the external surfaces from exposure to water. The level above the RPF first level where waterproofing is to be used will be determined in the Operating License Application.

The flood protection measures that are described above will also guard against flooding from the rupture of the on-site fire protection water storage tank (if future design development determines that a fire protection storage tank is necessary). Any flash flooding that may result from tank rupture will drain away from the RPF and thereby cause no damage to facility equipment.

3.3.1.3 Compartment Flooding from Fire Protection Discharge

The total discharge from the failure of fire protection piping consists of the combined volume from any sprinkler and hose systems. The sprinkler system, if used, is capable of delivering a water density of 20 gallons per minute (gal/min) (76 liters per minute [L/min]) over a 139 m^2 (1,500 ft^2) design area; therefore, the sprinkler system is calculated to have a flow rate of 1,136 L/min (300 gal/min). The hose stream will be a manually operated fire hose capable of delivering up to 946 L/min (250 gal/min). In accordance with NFPA 801, Section 5.10, the credible volume of discharge is sized for the suppression system operating for a duration of 30 min. The design of water-sensitive, safety-related equipment will ensure that potential flooding from sprinkler discharge will not adversely affect the safety features. For example, equipment may be raised from the floor sufficiently such that the potential flooding due to sprinkler discharge will not impact the criticality analyses.

Outside of the radiologically controlled area (RCA), as defined in Chapter 11.0, "Radiation Protection and Waste Management," there is limited water discharge from fire protection systems. Any water-sensitive, safety-related equipment will be installed above the floor slab at-grade to ensure that the equipment remains above the flooded floor during sprinkler discharge.

3.3.1.4 Compartment Flooding from Postulated Component Failures

Piping, vessels, and tanks with flooding potential in the safety-related portions of the RPF will be seismically qualified. Water-sensitive, safety-related equipment will be raised above the floor. The depth of water on the floor will be minimized by using available floor space to spread the flood water and limiting the water volumes. Analyses of the worst flooding due to pipe and tank failures and their consequences will be developed in the Operating License Application.

3.3.1.4.1 Potential Failure of Fire Protection Piping

The total discharge from the operation of the fire protection system bounds the potential water collection due to the potential failure of the fire protection piping.

3.3.1.5 Permanent Dewatering System

There is no permanent dewatering system provided for the flood design.

3.3.1.6 Structural Design for Flooding

Since the design PMP elevation is at the finished plant-grade and the probable maximum flood (PMF) elevation is approximately 6.1 m (20 ft) below-grade, there is no dynamic force due to precipitation or flooding. The lateral surcharge pressure on the structures due to the design PMP water level is calculated and does not govern the design of the below-grade walls. The load from buildup of water due to discharge of the fire protection system in the RCA is supported by slabs-on-grade, with the exception of the mezzanine floor. Drainage is provided for the second level in the RCA to ensure that the second level slab is not significantly loaded. The second level slab is designed to a live load of 610 kilograms (kg)/m^2 (125 lb/ft^2); therefore, the slab is capable of withstanding any temporary water collection that may occur while water is draining from that floor.

3.4 SEISMIC DAMAGE

Seismic analysis criteria used for the RPF will conform to IAEA-TECDOC-1347, *Consideration of External Events in the Design of Nuclear Facilities Other Than Nuclear Power Plants, with Emphasis on Earthquakes*. This report provides requirements and guidance for the seismic design of nuclear facilities other than nuclear power plants. NUREG-0800 and other NRC Regulatory Guides provide additional detailed guidance for the seismic analysis and design of the RPF. Additional information is provided in Chapter 2.0, Section 2.5.4, and Chapter 13.0, Section 13.2.6.5. Updates and development of technical specifications associated with the seismic damage design of the RPF SSCs will be provided in Chapter 14.0 as part of the Operating License Application.

3.4.1 Seismic Input

3.4.1.1 Design Response Spectra

Safe-Shutdown Earthquake

The NRC has recommended using Regulatory Guide 1.60, *Design Response Spectra for Seismic Design of Nuclear Power Plants*, for radioisotopes production facilities (e.g., 10 CFR 50). NWMI will use a spectrum anchored to 0.20 g peak ground acceleration for the RPF design basis. Regulatory Guide 1.60 is not indexed to any specific soil type, with its frequency content sufficiently broad to cover all soil types. Therefore, soil type for the RPF will not be a parameter used to determine the RPF's design response spectra. The composition of soil in which the RPF is embedded will be included in the soil-structure-interaction analysis as part of the building response analysis. This information will be provided in the final safety analysis report (FSAR) as part of Operating License Application.

This peak ground acceleration matches that of the University of Missouri Research Reactor (Adams, 2016) and the Calloway Nuclear Generating Station, which both are within 80.5 km (50 mi) of the RPF, as suggested by the NRC staff during the November 10, 2016 Public Meeting. The analysis procedure develops ground motion acceleration time histories that match or exceed the Regulatory Guide 1.60 spectrum as input to the building finite element model. Structural damping will follow the recommendations of Regulatory Guide 1.61, *Damping Values for Seismic Design of Nuclear Power Plants*, which range from about 3 to 7 percent.

Response spectra corresponding to the recommended damping values of Regulatory Guide 1.61 will be used to derive seismic loads. Damping varies depending on the type of SSC. Structural damping will follow Regulatory Guide 1.61 guidance (ranging from about 3 to 7 percent). Plotting response spectra at 5 percent damping for purposes of illustration is a convention within the nuclear industry, but for analysis loads, damping will vary depending on the earthquake level (operating basis earthquake or safe-shutdown earthquake) and the type of SSC.

Soil-Structure Interaction and Dynamic Soil Pressures

The structure is supported on a shallow foundation system on stiff competent soils. The Phase 1 Assessment (Terracon, 2011a/b) stated the site is classified as Site Class C. Prescribed in ASCE 7, Table 20.3-1, the typical shear wave velocities for the soils present at the site are 1,200 to 2,500 ft/sec. Typical practice is to define competent soil as having a shear wave velocity greater than 1,000 ft/sec. The analysis of the RPF building structure to the safe shutdown earthquake will include the effects of a soil-structure interaction. Dynamic soil pressures were determined using ASCE 4, *Seismic Analysis of Safety-Related Nuclear Structures and Commentary*, Section 3.5.3.2, and applied to the earth retaining walls in the hot cell area.

Operating Basis Earthquake

For preliminary design, the operating basis earthquake was selected to be one-third the safe-shutdown earthquake defined previously (based on Regulatory Guide 1.61). Since this option was selected, explicit design and analysis of the facility structure for the operating basis earthquake ground-motion is not required.

3.4.1.2 Method of Analysis

The effect of loads other than earthquake-induced (seismic) loads is determined by static analysis methods in accordance with ASCE 7 and the fundamental principles of engineering. Seismic analysis of SSCs will be performed by either equivalent-static methods or dynamic analysis methods in accordance with ASCE 4 and ASCE 43, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*. The equivalent-static and dynamic seismic analysis methods are discussed below.

3.4.1.2.1 Equivalent-Static Analysis

Equivalent-static seismic analysis of commercial type structure will be performed in accordance with ASCE 7, Section 12.8.

Direction of Seismic Loading

Design of IROFS will consider seismic loads in all three directions using a combination of square-root-of-the-sum-of-squared or 100/40/40 methodologies per Regulatory Guide 1.92, *Combining Modal Responses and Spatial Components in Seismic Response Analysis*. The 100/40/40 methodology will be used in the development of the final RPF design and included as part of the Operating License Application.

3.4.1.2.2 Dynamic and Static Analysis

Dynamic analyses are only used for the evaluation of RPF structural components. A static analysis will be completed during final design by using a combination of static load computations to ensure the SSCs remain in place and intact, and a combination of existing shake table test data and existing earthquake experience to ensure that the equipment functions following the earthquake. The analysis of safety-related structures may be either completed by the:

- Linear-elastic response spectra method performed in accordance with ASCE 4, Section 3.2.3.1, and ASCE 43, Section 3.2.2
- Linear-elastic time history method performed in accordance with ASCE 4, Section 3.2.2, and ASCE 43, Section 3.2.2

Damping – The damping values used for dynamic analysis for the structural system considered will be taken from Regulatory Guide 1.61. Inelastic energy adsorption factors and damping values used for the analysis of nuclear safety-related structures will be selected from ASCE 43, Table 5-1.

Modeling – Finite element models will only be used for the RPF building structures. The mesh for plate elements and member nodes will be selected to provide adequate discretization and distribution of the mass. Further, the aspect ratio of plate elements will be limited to no greater than 4:1 to ensure accurate analysis results.

Direction of seismic loading – Three orthogonal directions of seismic loading are used in the RPF design, two horizontal and one vertical. The modal components of the dynamic analysis and the spatial components of response analysis are combined as described below.

- **Modal combinations** – The structure of the RPF is designed to be relatively stiff, and components are combined using the complete quadratic combination method.
- **Spatial component combinations** – Spatial components are calculated separately and combined using the square-root-sum-of-the-squares method to determine the combined earthquake effect and resulting demands.

3.4.2 Seismic Qualification of Subsystems and Equipment

This subsection discusses the methods by which the RPF systems and components are qualified to ensure functional integrity. Based on the characteristics and complexities of the subsystem or equipment, seismic qualification will be done by a combination of static load computations to ensure that the SSCs remain in place and intact, and a combination of existing shake table test data and existing earthquake experience to ensure that the equipment functions following the earthquake.

3.4.2.1 Qualification by Analysis

NWMI will define specific acceptable qualification methods in the procurement packages to demonstrate seismic qualifications. Seismic qualification of IROFS will include three options of: (1) calculations and verification that the main structural components of the SSC can withstand the seismic loads derived from the in-structure floor response spectra at the damping value derived from Regulatory Guide 1.61, (2) reference to available shake table testing that demonstrates the seismic capacity of the SSC or of multiple similar items, and (3) demonstration of the seismic capacity through the performance of the type of SSC in actual earthquakes.

3.4.2.1.1 Equivalent Static Analysis

The equivalent static analysis of nuclear safety-related subsystems and equipment is performed in accordance ASCE 43, Section 8.2.1.1. The equivalent static analysis of subsystems and equipment that are not relied on for nuclear safety but are designated as a component of a seismic system per IBC 2012, Chapter 17, is performed in accordance with ASCE 7, Chapter 13.

3.4.2.1.2 Static Analysis

The static analysis of non-structural, safety-related subsystems and equipment is performed in accordance ASCE 4, Section 3.2.3.1, and ASCE 43, Section 8.2.1.2. A portion of the seismic qualification process will involve simple static analysis of the main structural elements (anchorage and primary framing) of IROFS components, using seismic loads from in-structure response spectra derived from the RPF building structure dynamic response analysis. In-structure response spectra are determined using ASCE 4, Section 3.4.2, and NRC Regulatory Guide 1.122, *Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components*. In-structure floor response spectra will be developed through a finite element model of the RPF building using an artificial time history that matches or envelops the Regulatory Guide 1.60 spectrum at a peak ground acceleration = 0.20 g.

3.4.2.2 Qualification by Testing

NWMI will define specific acceptable qualification methods in the procurement packages to demonstrate seismic qualifications. Seismic qualification of IROFS will include three options of: (1) calculations and verification that the main structural components of the SSC can withstand the seismic loads derived from the in-structure floor response spectra at the damping value derived from Regulatory Guide 1.61, (2) reference to available shake table testing that demonstrates the seismic capacity of the SSC or of multiple similar items, and (3) demonstration of the seismic capacity through the performance of the type of SSC in actual earthquakes.

Per NRC Regulatory Guide 1.100, *Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants*:

- Active mechanical equipment relied on for or important to nuclear safety will be required to be seismically qualified in accordance with Regulatory Guide 1.100.
- Active electrical equipment important to or relied on for nuclear safety will be required to be seismically qualified in accordance with IEEE 344, *IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations*.

Subsystems and equipment not relied on for nuclear safety but designated as a component of a seismic system per IBC 2012, Chapter 17, will be required. Existing databases of past shake table tests will be used, such as the Office of Statewide Health Planning and Development database provided by the state of California. These tests have typically been done based on the ICC-ES AC156, "Acceptance Criteria for Seismic Certification by Shake-Table Testing of Nonstructural Components," spectrum.

The capacity of the standard support design for overhead fixtures mounted above RPF IROFS will be checked to ensure that the supports can withstand the seismic loads derived from the floor spectra (e.g., remain stable during and after postulated earthquake effects) of the attachment floor slab. This information will be provided in the FSAR as part of the Operating License Application.

The RPF seismic design will also include a check to ensure that pounding or sway impact will not occur between adjacent fixtures (e.g., rattle space). Estimates of the maximum displacement of any fixture can be derived from the appropriate floor response spectrum and an estimate of the fixture's lowest response frequency. This information will be provided as part of the Operating License Application.

3.4.3 Seismic Instrumentation

Seismic recording instrumentation will be triaxial digital systems that record accelerations versus time accurately for periods between 0 and 10 sec. Recorders will have rechargeable batteries such that if there is a loss of power, recording will still occur. All instrumentation will be housed in appropriate weather and creature-proofed enclosures. As a minimum, one recorder should be located in the free-field mounted on rock or competent ground generally representative of the site. In addition, at sites classified as Seismic Design Category D, E, or F in accordance with ASCE 7, Chapter 11, using Occupancy Category IV, recorders will be located and attached to the foundations and roofs of the RPF and in the control room. The systems will have the capability to produce motion time histories. Response spectra will be computed separately.

The purpose of the instrumentation is to (1) permit a comparison of measured responses of C-I structures and selected components with predetermined results of analyses that predict when damage might occur, (2) permit facility operators to understand the possible extent of damage within the facility immediately following an earthquake, and (3) be able to determine when an safe-shutdown earthquake event has occurred that would require the emptying of the tank(s) for inspection as specified in NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas*, Section 4.1.3.6(c).

Seismic instrumentation for the RPF site is not an IROFS; it provides no safety function and is therefore not "safety-related." Although the seismic recorders have no safety function, they must be designed to withstand any credible level of shaking to ensure that the ground motion would be recorded in the highly unlikely event of an earthquake. This capability requires verification of adequate capacity from the manufacturer (e.g., prior shake table tests of their product line), provision of adequate anchorage (e.g., manufacturer-provided anchor specifications to ensure accurate recordings), and a check for seismic interaction hazards such as water spray or falling fixtures. With these design features, the instrumentation would be treated as if it were safety-related QL-2. Additional information on seismic instruction will be provided as part of the Operating License Application.

3.4.3.1 Location and Description

Seismic instrumentation is installed for structural monitoring. The seismic instrumentation consists of solid-state digital, tri-axial strong motion recorders located in the free-field, at the structure base, and at the roof of the RPF.

3.4.3.2 Operability and Characteristics

The seismic instrumentation operates during all modes of RPF operations. The maintenance and repair procedures provide for keeping the maximum number of instruments in service during RPF operations. The instrumentation installation design includes provisions for in-service testing. The instruments selected are capable of in-place functional testing and periodic channel checks during normal facility operation.

3.5 SYSTEMS AND COMPONENTS

Certain systems and components of the RPF are considered important to safety because they perform safety functions during normal operations or are required to prevent or mitigate the consequences of abnormal operational transients or accidents. This section summarizes the design basis for design, construction, and operating characteristics of safety-related SSCs of the RPF.

3.5.1 General Design Basis Information

3.5.1.1 Classification of Systems and Components Important to Safety

The RPF systems and components will be classified according to their importance to safety, quality levels, and seismic class. The guidance used in developing these classifications during preliminary design with the support of regulatory guidance reviews, hazards and operability analysis, accident analysis, integrated safety analysis, and national consensus code requirements is presented below.

The RPF systems identified in Table 3-1 and their associated subsystems and components are discussed in the subsections that follow.

3.5.1.2 Classification Definitions

The definitions used in the classification of SSCs include the following.

In accordance with 10 CFR 50.2, "Definitions," design basis refers to information that identifies the specific functions to be performed by an SSC of a facility and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be:

- Restraints derived from generally accepted state-of-the-art practices for achieving functional goals
- Requirements derived from analysis (e.g., calculation, experiments) of the effects of a postulated accident for which a SSC must meet its functional goals

These reference bounds are to include the bounding conditions under which SSCs must perform design basis functions and may be derived from normal operation or any accident or events for which SSCs are required to function, including anticipated operational occurrences, design basis accidents, external events, natural phenomena, and other events specifically addressed in the regulations.

Design basis accident is a postulated accident that a nuclear facility must be designed and built to withstand, without loss to the SSCs necessary to ensure public health and safety.

Design basis event (DBE) is an event that is a condition of normal operation (including anticipated operational occurrences), a design basis accident, an external event, or natural phenomena for which the facility must be designed so that the safety-related functions are achievable.

Design basis accidents and transients are those DBEs that are accidents and transients and are postulated in the safety analyses. The design basis accidents and transients are used in the design of the facility to establish acceptable performance requirements for SSCs.

Single failure is considered a random failure and can include an initiating event (e.g., component failure, natural phenomenon, external man-made hazard) or consequential failures. Mechanical, instrumentation, and electrical systems and components required to perform their intended safety function in the event of a single failure are designed to include sufficient redundancy and independence. This type of design verifies that a single failure of any active component does not result in a loss of the capability of the system to perform its safety functions.

Mechanical, instrumentation, and electrical systems and components are designed to ensure that a single failure, in conjunction with an initiating event, does not result in the loss of the RPF's ability to perform its intended safety function. Design techniques such as physical separation, functional diversity, diversity in component design, and principles of operation, will be used to the extent necessary to protect against a single failure.

An initiating event is a single occurrence, including its consequential effects, that places the RPF (or some portion) in an abnormal condition. An initiating event and its resulting consequences are not considered a single failure.

Active components are devices characterized by an expected significant change of state or discernible mechanical motion in response to an imposed demand on the system or operation requirements (e.g., switches, circuit breakers, relays, valves, pressure switches, motors, dampers, pumps, and analog meters). An active component failure is a failure of the component to complete its intended safety function(s) on demand.

Passive components are devices characterized by an expected negligible change of state or negligible mechanical motion in response to an imposed design basis load demand on the system.

Defense-in-depth is an approach to designing and operating nuclear facilities that prevents and mitigates accidents that release radiation or hazardous material through the creation of multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied on. Defense-in-depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures.

The RPF structure and system designs are based on defense-in-depth practices. The RPF design incorporates:

- Preference for engineered controls over administrative controls
- Independence to avoid common mode failures
- Other features that enhance safety by reducing challenges to safety-related components and systems

Safety-related systems and components identified in this section are described in Chapters 4.0; 5.0, "Coolant Systems;" 6.0; 7.0; 8.0, "Electrical Power Systems;" and 9.0, "Auxiliary Systems," as appropriate.

3.5.1.3 Nuclear Safety Classifications for Structures, Systems, and Components

SSCs in the RPF are classified as safety-related and non-safety-related. The safety-related SSCs include IROFS to meet the performance requirement of 10 CFR 70.61 and other safety-related SSCs to meet the requirements of 10 CFR 20. The purpose of this section is to classify SSCs according to the safety function being performed.

In addition, design requirements will be placed on SSCs to ensure the proper performance of their safety function, when required.

- **Safety-related** is a classification applied to items relied on to remain functional during or following a postulated DBE to ensure the:
  - Integrity of the facility infrastructure
  - Capability to shut down the facility and maintain it in a safe shutdown condition

  - Capability to prevent or mitigate the consequences of postulated accidents identified through accident analyses that could result in potential offsite and worker exposures comparable to the applicable guideline exposures set forth in 10 CFR 70.61(b), 10 CFR 70.61(c), and 10 CFR 70.61 (d)
  - Operation of the facility without undue risk to the health and safety of workers, the public, and the environment to meet 10 CFR 20 normal release or exposure limits for radiation doses and applicable limits for chemical exposures

- **Safety-related IROFS** – SSCs identified through accident analyses that are required to meet the performance requirements of 10 CFR 70.61(b), 10 CFR 70.61(c), and 10 CFR 70.61(d) (Table 3-2).
- **Safety-related Non-IROFS** – SSCs that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of workers, the public, and environment, and includes SSCs to meet 10 CFR 20 normal release or exposure limits.
- **Non-safety-related** – SSCs related to the production and delivery of products or services that are not in the above safety classifications

3.5.1.3.1 Quality Group Classifications for Structures, Systems, and Components

The assignment of safety-related classification and use of codes and standards conforms to the requirements NWMI's Quality Assurance Program Plan (QAPP) for the development of a Quality Group classification and the use of codes and standards. The classification system provides a recognizable means of identifying the extent to which SSCs are related to safety-related and seismic requirements, including ANS nuclear safety classifications, NRC quality groups, ASME Code Section III classifications, seismic categories, and other applicable industry standards, as shown in Table 3-7.

Quality assurance (QA) requirements are defined in the NWMI QAPP (Chapter 12.0, "Conduct of Operations," Appendix C). The definitions of QA Levels 1, 2, and 3 are provided below.

QA Level 1 will implement the full measure of the QAPP and will be applied to IROFS. IROFS are QA Level 1 items in which failure or malfunction could directly result in a condition that adversely affects workers, the public, and/or environment, as described in 10 CFR 70.61. The failure of a single QA Level 1 item could result in a high or intermediate consequence. The failure of a QA Level 2 item, in conjunction with the failure of an additional item, could result in a high or intermediate consequence. All building and structural IROFS associated with credible external events are QA Level 1. QA Level 1 items also include those attributes of items that could interact with IROFS due to a seismic event and result in high or intermediate consequences, as described in 10 CFR 70.61. Examples include:

- Items to prevent nuclear criticality accidents (e.g., preventive controls and measures to ensure that under normal and credible abnormal conditions, all nuclear processes are subcritical)
- Items credited to withstand credible design-bases external events (e.g., seismic, wind)
- Items to prevent degradation of structural integrity (e.g., failure or malfunction of facility)

QA Level 2 will be applied to non-QA Level 1 safety SSCs. The QA program is important to the acceptability and suitability of the item or service to perform as specified. Acceptance methods shall be specified (including acceptance and other applicable performance criteria), documented, and verified before use of the item or service. Some of the required characteristics may be examined less rigorously than for QA Level 1. Examples of QA Level 2 items include:

- SSCs to meet 10 CFR 20 normal release or exposure limits

- Fire protection systems
- Safeguards and security systems
- Material control and accountability systems

QA Level 3 will include non-safety-related quality activities performed by NWMI that are deemed necessary to ensure the manufacture and delivery of highly reliable products and services to meet or exceed customer expectations and requirements. QA Level 3 items include those items that are not classified as QA Level 1 or QA Level 2. QA Level 3 items are controlled in accordance with standard commercial practices.

These quality activities are embodied in NWMI's QAPP and will be further specified in the Operating License Application, and when necessary.

3.5.1.3.2 Seismic Classification for Structures, Systems, and Components

SSCs identified as IROFS will be designed to satisfy the general seismic criteria to withstand the effects of natural phenomena (e.g., earthquakes, tornados, hurricanes, floods) without loss of capability to perform their safety functions. ASCE 7, Chapter 11, sets forth the criteria to which the plant design bases demonstrate the capability to function during and after vibratory ground-motion associated with the safe-shutdown earthquake conditions.

The seismic classification methodology used for the RPF complies with the preceding criteria, and with the recommendations stated in Regulatory Guide 1.29, *Seismic Design Classification*. The methodology classifies SSCs into three categories: seismic Category I (C-I), seismic Category II (C-II), and non-seismic (NS).

Seismic C-I applies to both functionality and integrity, while C-II applies only to integrity. SSCs located in the proximity of IROFS, the failure of which during a safe-shutdown earthquake could result in loss of function of IROFS, are designated as C-II. Specifically:

- C-I applies to IROFS. C-I also applies to those SSCs required to support shutdown of the RPF and maintain the facility in a safe shutdown condition

- C-II applies to SSCs designed to prevent collapse under the safe-shutdown earthquake. SSCs are classified as C-II to preclude structural failure during a safe-shutdown earthquake, or where interaction with C-I items could degrade the functioning of a safety-related SSC to an unacceptable level or could result in an incapacitating injury to occupants of the main control room.

- NS SSCs are those that are not classified seismic C-I or C-II.

3.5.2 Radioisotope Production Facility

Systems and components within the RPF are presented in Section 3.5.1. The RPF design basis evaluated the general design criteria from 10 CFR 70.64, "Requirements for New Facilities or New Processes at Existing Facilities." This evaluation is presented in Table 3-22. These general design criteria provide a rational basis from which to initiate design but are not mandatory. There are some cases where conformance to a particular criterion is not directly measurable. For each of the criteria, a specific assessment of the RPF design is made, and a complete list of references is included to identify where detailed design information pertinent to each criterion is treated. The Chapter 13.0 accident sequences for credible events define the DBE. The safety-related parameter limits ensure that the associated design basis is met for the events presented in Chapter 13.0.

Table 3-22. Design Criteria Requirements (4 pages)

Design criteria and description	Application and compliance
10 CFR 70.64, "Requirements for New Facilities or New Processes at Existing Facilities"[a]	
Quality standards and records • Develop and implement design in accordance with management measures to ensure that IROFS are available and reliable to perform their function when needed. • Maintain appropriate records of these items by or under the control of the licensee throughout the life of the facility.	• SSCs important to safety will be designed, fabricated, erected, tested, operated, and maintained to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they will be identified and evaluated to determine their applicability, adequacy, and sufficiency and will be supplemented or modified as necessary to ensure a quality product in keeping with the required safety function. • NWMI's QAPP will be established and implemented to provide adequate assurance that SSCs satisfactorily perform their safety functions. • Appropriate records of design, fabrication, erection, and testing of SSCs important to safety will be maintained by or under control of NWMI for the life of RPF. • NWMI will use a graduated QAPP that links quality classification and associated documentation to safety classification and to the manufacturing and delivery of highly reliable products and equipment. • The NWMI QAPP will provide details of the procedures to be applied, including quality and safety level classifications.
Natural phenomena hazards Provide for adequate protection against natural phenomena, with consideration of the most severe documented historical events for the site.	• SSCs important to safety will be designed, fabricated, erected, tested, operated, and maintained to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they will be identified and evaluated to determine their applicability, adequacy, and sufficiency and will be supplemented or modified as necessary to ensure a quality product in keeping with the required safety function. • The design basis for these SSCs will include: – Appropriate consideration of the most severe natural phenomena that have been historically reported for the RPF site and surrounding area, including sufficient margin for limited accuracy, quantity, and period of time for which historical data has been accumulated – Appropriate combinations of natural phenomena effects during normal and accident operating conditions – Importance of the safety functions to be performed • Specific RPF design criteria and NRC general design criteria are discussed in Sections 3.1 and 3.5, respectively.

Table 3-22. Design Criteria Requirements (4 pages)

Design criteria and description	Application and compliance
Fire protection Provide for adequate protection against fires and explosions	• SSCs important to safety will be designed and located throughout the RPF to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. • Noncombustible and heat resistant materials will be used wherever practical throughout the RPF, particularly in locations such as confinement and the control room. • Fire detection and suppression systems of appropriate capacity and capability will be provided and designed to minimize the adverse effects of fires on SSCs important to safety. • Firefighting systems will be designed to ensure that their rupture or inadvertent operation does not significantly impair the safety capability of these SSCs. • Where necessary, within zoned areas or where criticality and access are an issue, required systems will be manually initiated by operations after review of a detection signal. • RPF fire protection system will be designed such that a failure of any component will not impair the ability of safety-related SSCs to safely shut down and isolate the RPF or limit the release of radioactivity to provide reasonable assurance that the public will be protected from radiological risks resulting from RPF operations • RPF fire protection system will be designed to provide reasonable assurance that the public will be protected from radiological risks resulting from RPF operations (e.g., failure of any component will not impair the ability of safety-related SSCs to safely shutdown and isolate the RPF or limit the release of radioactivity). • Chapters 6.0 and 9.0 provide additional information.
Environmental and dynamic effects Provide for adequate protection from environmental conditions and dynamic effects associated with normal operations, maintenance, testing, and postulated accidents that could lead to loss of safety functions	• SSCs important to safety are designed to accommodate effects of, and to be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Due to low temperature and pressure RPF processes, dynamic effects due to pipe rupture and discharging fluids are not applicable to the RPF.
Chemical protection Provide for adequate protection against chemical risks produced from licensed material, facility conditions that affect the safety of licensed material, and hazardous chemicals produced from licensed material	• Chemical protection in the RPF will be provided by confinement isolation systems, liquid retention features, and use of appropriate personal protective equipment. • Chapter 6.0, Section 6.2.1, provides additional information.
Emergency capability Provide for emergency capability to maintain control of: • Licensed material and hazardous chemicals produced from licensed material • Evacuation of on-site personnel • On-site emergency facilities and services that facilitate the use of available off-site services	• Emergency procedures will be developed and maintained for the RPF to control SNM and hazardous chemicals produced from the SNM. • A preliminary Emergency Preparedness Plan is provided in Chapter 12.0, Appendix B.

Table 3-22. Design Criteria Requirements (4 pages)

Design criteria and description	Application and compliance
Utility services Provide for continued operation of essential utility services	• The RPF is designed for passive, safe shutdown and to prevent uncontrolled release of radioactive material if normal electric power is interrupted or lost. • A standby diesel generator will be provided for asset protection of selected RPF systems. • Uninterruptable power supplies will automatically provide power to systems that support the safety functions protecting workers and the public. • A combination of uninterruptable power supplies and a standby electrical power system will provide emergency electrical power to the RPF. A 1,000 kW (1,341 hp) diesel generator will provide facility electric power. • Chapter 8.0, Section 8.2 provides additional information.
Inspection, testing, and maintenance Provide for adequate inspection, testing, and maintenance of IROFS to ensure availability and reliability to perform their function when needed	• The RPF is designed to provide access and controls for testing, maintenance, and inspection of safety-related SSCs, as needed, throughout the RPF. • Chapters 4.0, 6.0, 7.0, and 9.0 provide additional information.
Criticality control Provide for criticality control, including adherence to the double-contingency principle	• The RPF design will provide adequate protection against criticality hazards related to the storage, handling, and processing of SNM, which will be accomplished by: – Including equipment, facilities, and procedures to protect worker and public health and to minimize danger to life or property – Ensuring that the design provides for criticality control, including adherence to the double-contingency principle – Incorporating a criticality monitoring and alarm system into the facility design • Compliance with the requirements of criticality control, including adherence to the double-contingency principle, are described in detail in Chapter 6.0, Section 6.3.
Instrumentation and control The design must provide for inclusion of I&C systems to monitor and control the behavior of items relied on for safety.	• RPF SNM processes will be enclosed predominately by hot cells and glovebox designs except for the target fabrication area. • The FPC system will provide monitoring and control of safety-related components and process systems within the RPF. • The BMS (a subset of the FPC system) will monitor the RPF ventilation system and mechanical utility systems. • ESF systems will operate independently from the FPC system or BMS. Each ESF safety function will use hard-wired analog controls/interlocks to protect workers, the public, and environment. The ESF parameters and alarm functions will be integrated into and monitored by the FPC system or BMS. • RPF designs are based on defense-in-depth practices and incorporate a preference for engineered controls over administrative controls, independence to avoid common mode failures, and incorporate other features that enhance safety by reducing challenges to safety-related components and systems. • The FPC system will provide the capability to monitor and control the behavior of safety-related SSCs. These systems ensure adequate safety of process and utility service operations in connection with their safety function. Controls are provided to maintain these variables and systems within the prescribed operating ranges under all normal conditions. • The FPC system is designed to fail to a safe-state or to assume a state demonstrated to be acceptable if conditions such as loss of signal, loss of energy or motive power, or adverse environments are experienced. • Chapter 7.0 provides additional I&C system information. Safety-related SSCs are described in Section 3.5 and Chapters 4.0, 5.0, 6.0, 7.0, and 8.0.

Table 3-22. Design Criteria Requirements (4 pages)

Design criteria and description	Application and compliance
Defense-in-depth[b] Base facility and system design and facility layout on defense-in-depth practices. The design must incorporate, to the extent practicable: • Preference for the selection of engineered controls over administrative controls to increase overall system reliability • Features that enhance safety by reducing challenges to IROFS	• Defense-in-depth is a design philosophy that NWMI has applied from the beginning of the project and will continue through completion of a design that is based on providing successive levels of protection such that health and safety are not wholly dependent on any single element of the design, construction, maintenance, or operation of the RPF. • NWMI's risk insights obtained through performance of the accident analysis will be used to supplement the final design by focusing attention on the prevention and mitigation of the higher risk potential accidents. • Chapter 6.0 and 13.0 provide additional information.

[a] 10 CFR 70.64, "Requirements for New Facilities or New Processes at Existing Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.

[b] As used in 10 CFR 70.64, requirements for new facilities or new processes at existing facilities, defense-in-depth practices means a design philosophy, applied from the outset and through completion of the design, that is based on providing successive levels of protection such that health and safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of the facility. The net effect of incorporating defense-in-depth practices is a conservatively designed facility and system that will exhibit greater tolerance to failures and external challenges.

BMS	=	building management system.	NRC	=	U.S. Nuclear Regulatory Commission.
CFR	=	Code of Federal Regulations.	NWMI	=	Northwest Medical Isotopes, LLC.
ESF	=	engineered safety feature.	QAPP	=	quality assurance program plan.
FPC	=	facility process control.	RPF	=	Radioisotope Production Facility.
I&C	=	instrumentation and control.	SNM	=	special nuclear material.
IROFS	=	items relied on for safety.	SSC	=	structures, systems, and components.

The criteria are generic in nature and subject to a variety of interpretations; however, they also establish a proven basis from which to provide for and assess the safety of the RPF and develop principal design criteria. The general design criteria establish the necessary design, fabrication, construction, testing, and performance requirements for SSCs important to safety (i.e., SSCs that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of workers, the public, and environment).

Safety-related SSCs that are determined to have safety significance for the RPF will be designed, fabricated, erected, and tested as required by the NWMI QAPP, described in Chapter 12.0, Appendix C. In addition, appropriate records of the design, fabrication, erection, procurement, testing, and operations of SSCs will be maintained throughout the life of the plant.

The RPF design addresses the following:

- Radiological and chemical protection
- Natural phenomena hazards
- Fire protection
- Environmental and dynamic effects
- Emergency capability (e.g., licensed material, hazardous chemicals, evacuation of on-site personnel, on-site emergency facilities/off-site emergency facilities)
- Utility services
- Inspection, testing, and maintenance
- Criticality safety

- Instrumentation and controls
- Defense-in-depth

Safety-related systems and components will be qualified using the applicable guidance in the Institute of Electrical and Electronics Engineers (IEEE) Standard IEEE 323, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*. The qualification of each safety-related system or component needs to demonstrate the ability perform the associated safety function:

- Under environmental and dynamic service conditions in which they are required to function
- For the length of time the function is required

Additionally, non-safety-related components and systems will be qualified to withstand environmental stress caused by environmental and dynamic service conditions under which their failure could prevent satisfactory accomplishment of the safety-related functions.

The RPF instrumentation and control (I&C) system (also known as the facility process control [FPC] system) will provide monitoring and control of the process systems within the RPF that are significant to safety over anticipated ranges for normal operations and abnormal operations. The FPC system will perform as the overall production process controller. This system will monitor and control the process instrumented functions within the RPF, including monitoring of process fluid transfers and controlled inter-equipment pump transfers of process fluids.

The FPC system will also ensure that process and utility systems operate in accordance with their safety function. Controls will be provided to maintain variables and systems within the prescribed operating ranges under all normal conditions. In addition, the FPC system is designed to fail into a safe state or to assume a state demonstrated to be acceptable if conditions such as loss of signal, loss of energy or motive power, or adverse environments are experienced.

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

ESF systems will operate independently from the FPC system or BMS. Each ESF safety function will use hard-wired analog controls/interlocks to protect workers, the public, and environment. The ESF parameters and alarm functions will be integrated into and monitored by the FPC system or BMS.

The fire protection system will have its own central alarm panel. The fire protection system will report the status of the fire protection equipment to the central alarm station and the RPF control room.

This integrated control system will be isolated from safety-related components consistent with IEEE 279, *Criteria for Protection Systems for Nuclear Power Generating Stations*. In addition, the RPF is designed to meet IEEE 603, *Standard Criteria for Safety Systems for Nuclear Power Generating Stations*, for separation and isolation of safety-related systems and components. Chapter 7.0 provides additional details on the integrated control system.

3.5.2.1 System Classification

The RPF is classified as a non-reactor nuclear production facility per 10 CFR 50. In addition, a portion of the RPF will fabricate LEU targets, similar to fuel fabrication per 10 CFR 70. Due to the nature of the work performed within facility, a hazardous occupancy applies. Table 3-23 provides the RPF classification for hazards occupancy, construction, risk, and seismic design categories.

Table 3-23. System Classifications

Classification description	Classification	Source
Hazard category	Intermediate hazard	NRC
Occupancy type	Mixed, A-2, B, F-1, H-3 and H-4	IBC 2012[a]
Construction type	II-B	IBC 2012[a]
Risk category	IV	ASCE 7[b]
Seismic design category	C	ASCE 7[b]

[a] IBC 2012, "International Building Code," as amended, International Code Council, Inc., Washington, D.C., February 2012.

[b] ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2013.

NRC = U.S. Nuclear Regulatory Commission.

3.5.2.2 Classification of Systems and Components Important to Safety

RPF SSCs, including their foundations and supports, designed to remain functional in the event of a DBE are designated as C-I. SSCs designated IROFS are also classified as C-I. SSCs co-located with C-I systems are reviewed and supported in accordance with II over I criteria. This avoids any unacceptable interactions between SSCs.

C-I structures should be designed using dynamic analysis procedures, or when justified, equivalent static procedures using both horizontal and vertical input ground motions. For dynamic analyses, either response spectra or time history analyses approaches may be used. Dynamic analysis should be performed in accordance with the procedures of ASCE 4, with the exception of the damping limitations presented in Section 3.4.1.

Table 3-24 lists the RPF SSCs and associated safety and seismic classifications and quality level group for the top-level systems. Subsystems within these systems may be identified with lower safety classifications. For example, the day tanks of the chemical supply system are IROFS, while the rest of the chemical supply system is classified as safety-related or not-safety-related.

Table 3-24. System Safety and Seismic Classification and Associated Quality Level Group (2 pages)

System name (code)	Highest safety classification[a]	Seismic classification[b]	Quality level group
Facility structure (RPF)	IROFS	C-I	QL-1
Target fabrication (TF)	IROFS	C-I	QL-1
Target receipt and disassembly (TD)	IROFS	C-I	QL-1
Target dissolution (DS)	IROFS	C-I	QL-1
Mo recovery and purification (MR)	IROFS	C-I	QL-1
Uranium recovery and recycle (UR)	IROFS	C-I	QL-1
Waste handling (WH)	IROFS	C-I	QL-1
Criticality accident alarm (CA)	IROFS	C-I	QL-1
Radiation monitoring (RM)	IROFS	C-I	QL-1
Standby electrical power (SEP)	IROFS	C-I	QL-1
Normal electrical power (NEP)	SR	C-I	QL-1

Table 3-24. System Safety and Seismic Classification and Associated Quality Level Group (2 pages)

System name (code)	Highest safety classification[a]	Seismic classification[b]	Quality level group
Process vessel ventilation (PVV)	IROFS	C-I	QL-1
Facility ventilation (FV)[c]	IROFS	C-I/II	QL-1/2
Fire protection (FP)	SR	C-II	QL-2
Plant and instrument air (PA)	NSR	C-II	QL-2
Emergency purge gas (PG)	IROFS	C-I	QL-1
Gas supply (GS)	NSR	C-II	QL-2
Process chilled water (PCW)	IROFS	C-I	QL-1
Facility chilled water (FCW)	NSR	C-II	QL-2
Facility heated water (HW)	NSR	C-II	QL-2
Process steam	IROFS	C-I	QL-1
Demineralized water (DW)	NSR	C-II	QL-2
Chemical supply (CS)	IROFS	C-I	QL-1
Biological shield (BS)	IROFS	C-I	QL-1
Facility process control (FPC)	SR	C-II	QL-2

[a] Safety classification accounts for highest classification in the system. Systems that are classified as safety-related may include both safety-related and non-safety-related components. Only safety-related components will be used to satisfy the safety functions of the system, whereas non-safety-related components can be used to perform non-safety functions. For example, there are non-safety-related components, such as fans, within the safety-related ventilation systems that perform non-safety-related functions.

[b] Seismic category may be locally revised to account for II over I design criteria and to eliminate potential system degradation due to seismic interactions.

[c] Ventilation zone classifications vary –Ventilation Zone I and II are considered safety-related, C-I and QL-1; Ventilation Zone III and IV are considered non-safety-related, C-II and QL-2.

IROFS = items relied on for safety.
NSR = non-safety related.
RPF = Radioisotope Production Facility.
SR = safety-related (not IROFS).

SSCs that must maintain structural integrity post-DBE, but are not required to remain functional are C-II. All other SSCs that have no specific NRC-regulated requirements are designed to local jurisdictional requirements for structural integrity and are C-III. All C-I SSCs are analyzed under the loading conditions of the DBE and consider margins of safety appropriate for that earthquake. The margin of safety provided for safety-class SSCs for the DBE are sufficient to ensure that their design functions are not put at risk. Table 3-25 presents the likelihood index limit guidelines and associated event frequency and risk index limits.

Table 3-25. Likelihood Index Limit Guidelines

	Likelihood category	Event frequency limits	Risk index limits
Likely normal facility process condition	4	Multiple events per year	> or = 0
Not unlikely (frequent facility process condition)	3	More than 10^{-4} per event, per year	>-4 <0
Unlikely (infrequent facility process condition)	2	Between 10^{-4} and 10^{-5} per event, per year	-4 to 5
Highly unlikely (limiting facility process condition)	1	Less than 10^{-5} per event, per year	< -5

3.5.2.3 Design Basis Functions, Values, and Criteria

The design basis for systems and components required for safe operation and shutdown of the RPF are established in three categories, which are described below. The preliminary design basis functions and values for each major system are provided in the following subsections.

Design Basis Functions

- License conditions, orders, or technical specifications
- Functions credited in the safety analysis to ensure safe shutdown of the facility is achieved and maintained, prevent potential accidents, or mitigate the potential consequences of accidents that could result in consequences greater than applicable NRC exposure guidelines

Design Basis Values

- Values or ranges of values of controlling parameters established as reference bounds for RPF design to meet design basis function requirements
- Values may be established by an NRC requirement, derived from or confirmed by the safety analysis, or selected by the designer from an applicable code, standard, or guidance document

Design Basis Criteria

- Code-driven requirements established for the RPF fall into seven categories, including fabrication, construction, operations, testing, inspection, performance, and quality
- Codes include national consensus codes, national standards, and national guidance documents
- Design of safety-related systems (including protection systems) is consistent with IEEE 379, *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems*, and Regulatory Guide 1.53, *Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems*
- Protection system is designed to provide two or three channels for each protective systems and functions and two logic train circuits:
  - Redundant channels and trains will be electrically isolated and physically separated in areas outside of the RPF control room
  - Redundant design will not prevent protective action at the system level

3.5.2.4 System Functions/Safety Functions

The NWMI RPF will provide protection against natural phenomena hazards for the personnel, SNM, and systems within the facility. The facility will also provide protection against operational and accident hazards to personnel and the public. Table 3-2 lists the IROFS defined by the preliminary hazards analysis.

3.5.2.5 Systems and Components

3.5.2.5.1 Mechanical

RPF C-I mechanical equipment and components (identified in Table 3-24) will be qualified for operation under the design basis earthquake (DBEQ) seismic conditions by prototype testing, operating experience, or appropriate analysis. The C-I mechanical equipment is also designed to withstand loadings due to the DBEQ, vibrational loadings transmitted through piping, and operational vibratory loading, such as floor vibration due to other operating equipment, without loss of function or fluid boundary. This analysis considers the natural frequency of the operating equipment, the floor response spectra at the equipment location, and loadings transmitted to the equipment and the equipment anchorage.

The qualification documents and all supporting analysis and test reports will be maintained as part of the permanent plant record in accordance with the requirements of the NWMI QAPP.

The safety-related equipment and components within the RPF will be required to function during normal operations and during and following DBEs. This equipment will be capable of functioning in the RPF environmental conditions associated with normal operations and design basis accidents. Certain systems and components used in the ESF systems will be located in a controlled environment. This controlled environment is considered an integral part of the ESF systems.

3.5.2.5.2 Instrumentation and Electrical

C-I instrumentation and electrical equipment (identified in Table 3-24) is designed to resist and withstand the effects of the postulated DBEQ without functional impairment. The equipment will remain operable during and after a DBEQ. The magnitude and frequency of the DBEQ loadings that each component experiences will be determined by its location within the RPF. In-structure response curves at various building elevations will be developed to support design. The equipment (e.g., batteries and instrument racks, control consoles) has test data, operating experience, and/or calculations to substantiate the ability of the components and systems to not suffer loss of function during or after seismic loadings due to the DBEQ. This information will be completed during final design of the RPF and provided in the Operating License Application.

This certification of compliance with the specified seismic requirements, including compliance with the requirements of IEEE 344, is maintained as part of the permanent plant record in accordance with the NWMI QAPP.

3.5.2.6 Qualification Methods

Environmental qualification of safety-related mechanical, instrumentation, and electrical systems and components is demonstrated by tests, analysis, or reliance on operating experience. Qualification method testing will be accomplished either by tests on the particular equipment or by type tests performed on similar equipment under environmental conditions at least as severe as the specified conditions. The equipment will be qualified for normal and accident environments. Qualification data will be maintained as part of the permanent plant record in accordance with the NWMI QAPP.

3.5.2.7 Radioisotope Production Facility Specific System Design Basis Functions and Values

The design basis functions and values for each system identified in Table 3-1 are discussed in the following subsections. Additional details for each system described below will be updated during the development of the Operating License Application.

3.5.2.7.1 Target Fabrication System

An overview and detailed description of the target fabrication system are provided in Chapter 4.0, Sections 4.1.3.1 and 4.4, respectively.

Design Basis Functions

- Store fresh LEU, LEU target material, and new LEU targets
- Produce LEU target material from fresh and recycled LEU material
- Assemble, load, and fabricate LEU targets
- Reduce or eliminate the buildup of static electricity
- Minimize uranium losses through target fabrication
- Safety-related functions:

  - Maintain subcriticality conditions within target fabrication system
  - Prevent flammable gas composition within target fabrication system
  - Limit personnel exposure to hazardous chemicals and offgases

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs

3.5.2.7.2 Target Receipt and Disassembly System

An overview and detailed description of the target receipt and disassembly system are provided in Chapter 4.0, Section 4.1.3.2, and Sections 4.3.2/4.3.3, respectively.

Design Basis Functions

- Handle irradiated target shipping cask, including all opening, closing, and lifting operations
- Retrieve irradiated targets from a shipping cask
- Disassemble targets and retrieving irradiated target material from targets
- Reduce or eliminate the buildup of static electricity
- Safety-related functions:
  - Provide radiological shielding during receipt and disassembly activities
  - Maintain subcriticality conditions within target receipt and disassembly system
  - Prevent radiological materials from being released during target receipt and disassembly operations to limit the exposure of workers, the public, and environment to radioactive material
  - Maintain positive control of radiological materials (LEU target material and radiological waste)
  - Protect personnel and equipment from industrial hazards associated with system equipment (e.g., moving parts)

Design Basis Values

- 30-year design life
- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs
- Crane designed for anticipated load (e.g., hot cell cover block) of approximately 68 metric tons (MT) (75 ton)

3.5.2.7.3 Replace Target Dissolution (DS)

An overview and detailed description of the target dissolution system are provided in Chapter 4.0, Sections 4.1.3.3 and 4.3.4, respectively.

Design Basis Functions

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

- Safety-related functions:
  - Provide radiological shielding during target dissolution activities
  - Control and prevent flammable gas from reaching lower flammability limit conditions
  - Maintain subcriticality conditions through inherently safe design of target dissolution equipment
  - Maintain positive control of radiological materials (LEU target material and radiological waste)

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs
- Prevent radiological materials from being released during target dissolution operations to limit the exposure of workers, the public, and environment to radioactive material per 10 CFR 20

3.5.2.7.4 Molybdenum Recovery and Purification (MR)

An overview and detailed description of the Mo recovery and purification system are provided in Chapter 4.0, Sections 4.1.3.4 and 4.3.5, respectively.

Design Basis 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
- Safety-related functions:
  - Maintain subcriticality conditions through inherently safe design of components that could handle high-uranium content fluid
  - Prevent radiological materials from being released by containing fluids in appropriate tubing, valves, and other components
  - Control and prevent flammable gas from reaching lower flammability limit conditions
  - Maintain positive control of radiological materials (^{99}Mo product, intermediate streams, and radiological waste)
  - Provide appropriate containers and handling systems to protect personnel from industrial hazards such as chemical exposure (e.g., nitric acid, caustic, etc.)

Design Basis Values

- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs
- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Replace consumables after each batch

3.5.2.7.5 Uranium Recovery and Recycle (UR)

An overview and detailed description of the uranium recovery and recycle system are provided in Chapter 4.0, Sections 4.1.3.5 and 4.3.6, respectively.

Design Basis Functions

- Receive and decay impure LEU solution
- Recover and purify impure LEU solution
- Decay and recycle LEU solution
- Transfer process waste
- Safety-related functions:
  - Provide radiological shielding during uranium recovery and recycle system activities
  - Prevent radiological release during uranium recovery and recycle system activities
  - Maintain subcriticality conditions through inherently safe design of the uranium recovery and recycle equipment
  - Control and preventing flammable gas from reaching lower flammability limit conditions
  - Maintain positive control of radiological materials
  - Protect personnel and equipment from industrial hazards associated with the system equipment, such as moving parts, high temperatures, and electric shock

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs

3.5.2.7.6 Waste Handling

An overview and detailed description of the waste handling system are provided in Chapter 4.0, Section 4.1.3.6 and Chapter 9.0, Section 9.7.2, respectively.

Design Basis Functions

- Receive liquid waste that is divided into high-dose source terms and low-dose source terms to lag storage
- Transfer remotely loaded drums with high-activity solid waste via a solid waste drum transit system to a waste encapsulation cell
- Encapsulate solid waste drums
- Load drums with solidification agent and low-dose liquid waste
- Load high-integrity containers with solidification agent and high-dose liquid waste
- Handle and load a waste shipping cask with radiological waste drums/containers
- Safety-related functions:
  - Maintain subcriticality conditions through mass limits
  - Prevent spread of contamination to manned areas of the facility that could result in personnel exposure to radioactive materials or toxic chemicals
  - Provide shielding, distance, or other means to minimize personnel exposure to penetrating radiation

Design Basis Values

- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs
- 30-year design life with the exception of common replaceable parts (e.g., pumps)

3.5.2.7.7 Criticality Accident Alarm System

Chapter 6.0, Section 6.3.3.1, and Chapter 7.0, Section 7.3.7, provide descriptions of the criticality accident alarm system.

Design Basis Functions

- Provide analysis for criticality accident alarm system coverage in all areas where SNM is handled, processed, or stored
- Provide for continuous monitoring, indication, and recording of neutron or gamma radiation levels in areas where personnel may be present and wherever an accidental criticality event could result from operational processes.
- Provide both local and remote annunciation of a criticality excursion
- Remain operational during DBEs

Design Basis Values

- 30-year design life
- Capable of detecting a criticality accident that produces an absorbed dose in soft tissue of 20 absorbed radiation dose (rad) of combined neutron or gamma radiation at an unshielded distance of 2 m from reacting material within one minute

3.5.2.7.8 Continuous Air Monitoring System

Chapter 7.0, Section 7.6, and Chapter 11.0, Section 11.1.4, provide detailed descriptions of the RPF continuous air monitoring system.

Design Basis Functions

- Provide real-time local and remote annunciation of airborne contamination in excess of preset limits
- Provide real-time local and remote annunciation of radiological dose of excess of preset limits
- Provide environmental monitoring of nuclear radioactive stack releases
- Provide the capability to collect continuous samples
- Remain operational during DBEs

Design Basis Values

- Activate when airborne radioactivity levels exceed predetermined limits
- Activate when radiological dose levels exceed predetermined limits
- Adjust volume of air sampled to ensure adequate sensitivity with minimum sampling time

3.5.2.7.9 Standby Electrical Power

Chapter 8.0, Section 8.2 provides a detailed description of the RPF standby electrical power (SEP) system.

Design Basis Functions

SEP includes two types of components: uninterruptible power supplies (UPS) and a standby diesel generator:

- **UPS** – Provides power when normal power supplies are absent
- **Standby diesel generator** – Provides power when normal power supplies are absent to allow continued RPF processing

Design Basis Values

- 30-year design life
- Maintain power availability for a minimum of 120 min post-accident (UPS)
- Maintain power availability for 12 hr (diesel generator)

3.5.2.7.10 Normal Electrical Power

Chapter 8.0, Section 8.1 provides a detailed description of the RPF normal electrical power (NEP) system.

Design Basis Functions

- Provide facility power during normal operations

Design Basis Values

- 30-year design life

3.5.2.7.11 Process Vessel Ventilation System

Chapter 9.0, Section 9.1 provides a detailed description of the process vessel ventilation system.

Design Basis Functions

- Provide primary system functions to protect on-site and off-site personnel from radiological and other industrial related hazards
- Collect air in-leakage sweep from each of the numerous vessels and other components in main RPF processes and maintain hydrogen concentration process tanks and piping below lower flammability limit
- Minimize reliance on administrative or complex active engineering controls to provide a confinement system as simple and fail-safe as reasonably possible

Design Basis Values

- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs
- 30-year design life
- Contain and store noble gases generated in the RPF to meet 10 CFR 20 requirements

3.5.2.7.12 Facility Ventilation System

Chapter 9.0, Section 9.1 provides a detailed description of the facility ventilation system.

Design Basis Functions

- Provide confinement of hazardous chemical fumes and airborne radiological materials and conditioning of RPF environment for facility personnel and equipment
- Prevent release and dispersal of airborne radioactive materials (e.g., maintain pressure gradients to ensure proper flow of air from least potentially contaminated areas to most potentially contaminated areas) to protect health and minimize danger to life or property
- Maintain dose uptake through ingestion to levels as low as reasonably achievable (ALARA)
- Provide makeup air and condition the RPF environment for process and electrical equipment
- Process exhaust flow from the process vessel ventilation system

- Provide confinement of airborne radioactive materials by providing for the rapid, automatic closure of isolation dampers within confinement zones for various accident conditions
- Provide conditioned air to ensure suitable environmental conditions for personnel and equipment in RPF

Design Basis Values

- Maintain primary fission product boundary during and after normal operations, shutdown conditions, and DBEs
- Provide an integrated leak rate for confinement boundaries that meets the requirements of accident analyses that complies with 10 CFR 10.61
- 30-year design life
- Maintain occupied space at 24 degrees Celsius (°C) (75 degrees Fahrenheit [°F]) (summer) and 22°C (72°F) (winter), with active ventilation to support workers and equipment
- Maintain air quality that complies with 10 CFR 20 dose limits for normal operations and shutdown

3.5.2.7.13 Fire Protection System

Chapter 9.0, Section 9.3 provides a detailed description of the RPF fire protection system.

Design Basis Functions

- Provide detection and suppression of fires
- Generate alarm signals indicating presence and location of fire
- Execute commands appropriate for the particular location of the fire (e.g., provide varying levels of notification of a fire event and transmitting notification to RPF central alarm station and RPF control room)
- Provide fire detection in RPF and initiate fire-rated damper closures
- Remain functional during DBEs

Design Basis Values

- 30-year design life
- Provide a constant flow of water to an area experiencing a fire for a minimum of 120 min based on the size of the area per International Fire Code (IFC, 2012)
- Provide sprinkler systems, when necessary, per National Fire Protection Association (NFPA) 13, *Standard for the Installation of Sprinkler Systems*

3.5.2.7.14 Plant and Instrument Air System

Chapter 9.0, Section 9.7.1 provides a detailed description of the RPF plant and instrument air system.

Design Basis Functions

- Provide small, advective flows of plant air for several RPF activities (e.g., tool operation, pump power, purge gas in tanks, valve actuation, and bubbler tank level measurement)
- Provide plant air receiver buffer capacity to make up difference between peak demand and compressor capacity

- Provide plant air to instrument air subsystem for bubblers and valve actuation
- Provide instrument air receiver buffer capacity to make up difference between peak demand and compressor capacity

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Provide instrument air dried in regenerable desiccant beds to a dew point of no greater than -40°C (-40°F) and filtered to a maximum 40 micron (μ) particle size

3.5.2.7.15 Emergency Purge Gas System

Chapter 6.0, Section 6.2.1.7.5 provides a detailed description of the emergency purge gas system.

Design Basis Functions

- Provide >12 hr of nitrogen to the emergency purge gas system
- Emergency purge gas system to provide nitrogen to the required process tanks
- Remain functional during DBEs

Design Basis Values

- 30-year design life with the exception of common replaceable parts
- Maintain hydrogen gas (H_2) concentrations less than 25% of the lower flammability limit

3.5.2.7.16 Gas Supply System

Chapter 9.0, Section 9.7.1 provides a detailed description of the gas supply system.

Design Basis Functions

- Provide helium, hydrogen, and oxygen in standard gas bottles
- Provide nitrogen from a tube truck to the chemical supply room where manifold piping will be used to distribute the gas
- Provide adequate flow to ensure that the accumulation of combustible gases is below hazardous concentrations and reduces radiological hazards due to accumulation of gaseous fission products

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Provide standard gas bottles, with capacity of approximately 8,495 L (300 cubic feet [ft^3])

3.5.2.7.17 Process Chilled Water System

Chapter 9.0, Section 9.7.1 provides a detailed description of the RPF chilled water system.

Design Basis Functions

- Provide process chilled water loop for three secondary loops heat exchangers
  - One large geometry secondary loop in hot cell
  - One criticality-safe geometry secondary loop in hot cell
  - One criticality-safe geometry secondary loop in target fabrication area
- Provide monitoring of chilled water loops for loss of primary containment

- Provide cover gas to prevent flammable conditions in secondary loops

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Chilled water to various process equipment at no greater than 10°C (50°F) during normal operations
- Maintain the hydrogen concentration in the coolant system at less than 25 percent of the lower flammability limit of 5 percent H_2

3.5.2.7.18 Facility Chilled Water System

Chapter 9.0, Section 9.7.1.2.2 provides a detailed description of the RPF facility chilled water system.

Design Basis Functions

- Provide cooling media to heating, ventilation, and air conditioning (HVAC) system
- Supply HVAC system with cooling water that is circulated through the chilled water coils in air-handling units

Design Basis Values

- Provide cooling water at a temperature of 9°C (48°F) to the HVAC air-handling unit cooling coils
- 30-year design life with the exception of common replaceable parts (e.g., pumps)

3.5.2.7.19 Facility Heated Water System

Chapter 9.0, Section 9.7.1.2.2 provides a detailed description of the RPF heated water system.

Design Basis Functions

- Provide heated media to HVAC system
- Supply the HVAC system with heated water that is circulated through the heated water coils in the air-handling units

Design Basis Values

- Provide heated water at a temperature of 82°C (180°F) to HVAC air-handling unit heating coils and reheat coil
- 30-year design life with the exception of common replaceable parts (e.g., pumps)

3.5.2.7.20 Process Steam System – Boiler

Chapter 9.0, Section 9.7.1 provides a detailed description of the RPF process steam system for the boiler.

Design Basis Functions

- Generate low- and medium-pressure steam using a natural gas-fired package boiler
- Provide a closed loop steam system for the hot cell secondary loops that meets criticality control requirements
- Provide monitoring of steam condensate for loss of primary containment
- Limit sludge or dissolved solids content with automatic and makeup water streams in the boiler

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Provide saturated steam at 1.7 kg/square centimeters (cm^2) (25 lb/square inch [$in.^2$]) and 4.2 kg/cm^2 (60 $lb/in.^2$) gauge to various process equipment

3.5.2.7.21 Process Steam System – Hot Cell Secondary Loops

Chapter 9.0, Section 9.7.1 provides a detailed description of the RPF process steam system for the hot cell secondary loops.

Design Basis Functions

- Provide a closed loop steam system for the hot cell secondary loops
- Generate low-pressure steam using a vertical shell-and-tube heat exchanger
- Provide monitoring of steam condensate for loss of primary containment

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)

3.5.2.7.22 Demineralized Water System

Chapter 9.0, Section 9.7.1 provides a detailed description of the RPF demineralized water system.

Design Basis Functions

- Provide demineralized water to RPF except for administration and truck bay areas
- Remove mineral ions from municipal water through an ion exchange (IX) process and accumulate in a storage tank
- Provide regenerable IX media using a strong acid and a strong base
- Feed acids and bases from local chemical drums by toe pumps

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)
- Provide the water at 4.2 kg/cm^2 (60 $lb/in.^2$) gauge

3.5.2.7.23 Supply Air System

Chapter 9.0, Section 9.1.2 provides a detailed description of the supply air system. The design basis functions and values are identified in Section 3.5.2.7.12.

3.5.2.7.24 Chemical Supply System

Chapter 9.0, Section 9.7.4 provides a detailed description of the chemical supply system.

Design Basis Functions

- Provide storage capability for nitric acid, sodium hydroxide, reductant, and nitrogen oxide absorber solutions, hydrogen peroxide, and fresh uranium IX resin
- Segregate incompatible chemicals (e.g., acids from bases)
- Provide transfer capability for chemical solutions mixed to required concentrations and used in target fabrication, target dissolution, Mo recovery and purification, and waste management systems

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., pumps)

3.5.2.7.25 Biological Shielding System

Chapter 4.0, Section 4.2, provides a detailed description of the RPF biological shielding.

Design Basis Functions

- Provide biological shielding from radiation sources in the hot cells for workers in occupied areas of the RPF
- Limit physical access to hot cells
- Remain functional through DBEs without loss of structural integrity

Design Basis Values

- 30-year design life
- Provide dose rates consistent with ALARA goals for normally occupied areas

3.5.2.7.26 Facility Process Control System

Chapter 7.0, Section 7.2.3 provides a description of the FPC system.

Design Basis Functions

- Perform as overall production process controller
- Monitor and control process instrumented functions within the RPF (e.g., process fluid transfers, controlled inter-equipment pump transfers of process fluids)
- Provide monitoring of safety-related components while BMS (a subset of the FPC system) monitors ventilation system and mechanical utility systems
- Ensure ESF systems operate independently from FPC system or BMS
- Use hard-wired analog controls/interlocks for each ESF safety function to protect workers, public, and environment
- Integrate into and monitor ESF parameters and alarm functions by FPC system or BMS
- Initiate actuation of isolation dampers for hot cell area or analytical area on receipt of signals from fire protection system

Design Basis Values

- 30-year design life with the exception of common replaceable parts (e.g., controllers)

3.6 REFERENCES

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10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," *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 50.2, "Definitions," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 50.31, "Combining Applications," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 50.32, "Elimination of Repetition," *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.

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

10 CFR 70.64, "Requirements for New Facilities or New Processes at Existing Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 71, "Energy: Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 73, "Physical Protection of Plants and Materials," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 74, "Material Control and Accounting of Special Nuclear Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 851, "Worker Safety and Health Program," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CSR 10-6.01, "Ambient Air Quality Standards," *Missouri Code of State Regulations*, as amended.

20 CSR 2030, "Missouri Board for Architects, Professional Engineers, Professional Land Surveyors, and Landscape Architects," *Code of State Regulations*, Jefferson City, Missouri, as amended.

21 CFR 210, "Current Good Manufacturing Practice in Manufacturing, Processing, Packaging, or Holding of Drugs," *Code of Federal Regulations*, Office of the Federal Register, as amended.

21 CFR 211, "Current Good Manufacturing Practice for Finished Pharmaceuticals," *Code of Federal Regulations*, Office of the Federal Register, as amended.

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40 CFR 141, "National Primary Drinking Water Regulations," Code of Federal Regulations, Office of the Federal Register, as amended.

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