RADIONUCLIDE ANALYSIS FACILITY

SECTION II CHAPTER 03 OF THE FERMILAB SAD

Revision 1 August 6, 2023

This Chapter of the Fermilab Safety Assessment Document (SAD) contains a summary of the results of the Safety Analysis for the Radionuclide Analysis Facility (RAF) that are pertinent to understanding the risks to the workers, the public, and the environment due to its operation.

SAD Chapter Review

This Section II, Chapter 03 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *Radionuclide Analysis Facility*, was prepared and reviewed by the staff of the Environment, Safety & Health Division (ESH) Radiation Analysis Department in conjunction with the Environment, Safety & Health Division (ESH) Accelerator Safety Department.

Signatures below indicate review of this Chapter, and recommendation that it be approved and incorporated into the Fermilab SAD.

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Line Organization Owner

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Revision History

Printed versions of this Chapter of the Fermilab Safety Assessment Document (SAD) may not be the currently approved revision. The current revision of this Chapter can also be found on ESH DocDB #1066 along with all other current revisions of all Chapters of the Fermilab SAD.

Author	Rev. No.	Date	Description of Change
Matt Quinn	1	August 6, 2023	• Update to new SAD Layout • Included Risk Matrix and hazard discussion
Matt Quinn	0	June 10, 2015	Initial Release of the Radionuclide Analysis Facility chapter of the Fermilab Safety Assessment Document.

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Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ACNET	Accelerator Control Network System
AD	Accelerator Directorate
AHJ	Authority Having Jurisdiction
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
APS-TD	Applied Physics and Superconducting Technology Directorate
ARA	Airborne Radioactivity Area
ASE	Accelerator Safety Envelope
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASO	Accelerator Safety Order, referring to DOE O 420.2D *Safety of Accelerators*
^{7}Be	Beryllium-7
BLM	Beam Loss Monitor
BNB	Booster Neutrino Beam
BPM	Beam Position Monitor
BY	Boneyard
CA	Controlled Area
CA	Contamination Area
CAS	Contractor Assurance System
CC	Credited Control
CCL	Coupled Cavity Linac
CDC	Critical Device Controller
CERN	European Organization for Nuclear Research
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations (United States)
Ci	Curie
CLW	Co-Located Worker (the worker in the vicinity of the work but not actively participating)
cm	centimeter
CPB	Cryogenics Plant Building
CSO	Chief Safety Officer
CUB	Central Utility Building
CW	Continuous Wave
CX	Categorically Excluded
D&D	Decontamination and Decommissioning
DA	Diagnostic Absorber
DAE	Department of Atomic Energy India

DCS	Derived Concentration Standard
DocDB	Document Database
DOE	Department of Energy
DOT	Department of Transportation
DR	Delivery Ring
DSO	Division Safety Officer
DSS	Division Safety Specialist
DTL	Drift Tube Linac
DUNE	Deep Underground Neutrino Experiment
EA	Environmental Assessment
EA	Exclusion Area
EAV	Exhaust Air Vent
EENF	Environmental Evaluation Notification Form
EMS	Environmental Management System
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
ES&H	Environment, Safety and Health
Fermilab	Fermi National Accelerator Laboratory, see also FNAL
FESHCom	Fermilab ES&H Committee
FESHM	Fermilab Environment, Safety and Health Manual
FHS	Fire Hazard Subcommittee
FIRUS	Fire Incident Reporting Utility System
FNAL	Fermi National Accelerator Laboratory, see also Fermilab
FODO	Focus-Defocus
FONSI	Finding of No Significant Impact
FQAM	Fermilab Quality Assurance Manual
FRA	Fermi Research Alliance
FRCM	Fermilab Radiological Control Manual
FSO	Fermilab Site Office
FW	Facility Worker (the worker actively performing the work)
GERT	General Employee Radiation Training
GeV	Giga-electron Volt
^{3}H	Tritium
HA	Hazard Analysis
HAR	Hazard Analysis Report
HCA	High Contamination Area
HCTT	Hazard Control Technology Team
HEP	High Energy Physics
HFD	Hold for Decay

HLCF	High Level Calibration Facility
HPR	Highly Protected Risk
Hr	Hour
HRA	High Radiation Area
HSSD	High Sensitivity Air Sampling Detection
HVAC	Heating, Ventilation, and Air Conditioning
HWSF	Hazardous Waste Storage Facility
Hz	Hertz
IB	Industrial Building
IBC	International Building Code
ICW	Industrial Cooling Water
IEPA	Illinois Environmental Protection Agency
IEEE	Institute of Electrical and Electronics Engineers
INFN	Istituto Nazionale di Fisica Nucleare
IMPACT	Integrated Management Planning and Control Tool
IPCB	Illinois Pollution Control Board
IQA	Integrated Quality Assurance
ISD	Infrastructure Services Division
ISM	Integrated Safety Management
ITNA	Individual Training Needs Assessment
KeV	kilo-electron volt
kg	kilo-grams
kW	kilo-watt
LBNF	Long Baseline Neutrino Facility
LCW	Low Conductivity Water
LHC	Harge Hadron Collider
LLCF	Low Level Calibration Facility
LLWCP	Low Level Waste Certification Program
LLWHF	Low Level Waste Handling Facility
LOTO	Lockout/Tagout
LPM	Laser Profile Monitor
LSND	Liquid Scintillator Neutrino Detector
LSO	Laser Safety Officer
m	meter
mA	milli-amp
MABAS	Mutual Aid Box Alarm System
MARS	Monte Carlo Shielding Computer Code
MC	Meson Center
MC&A	Materials Control and Accountability

MCR	Main Control Room
MEBT	Medium Energy Beam Transport
MEI	Maximally Exposed Individual
MeV	Mega-electron volt
MI	Main Injector
MINOS	Main Injector Neutrino Oscillation Search
MMR	Material Move Request
MOI	Maximally-Exposed Offsite Individual *(Note: due to the Fermilab Batavia Site being open to the public, the location of the MOI is taken to be the location closest to the accelerator that is accessible to members of the public.)*
MP	Meson Polarized
mrad	milli-radian
mrem	milli-rem
mrem/hr	milli-rem per hour
MT	Meson Test
MTA	400 MeV Test Area
MTF	Magnet Test Facility
^{22}Na	Sodium-22
NC	Neutrino Center
NE	Neutrino East
NEC	National Electrical Code
NEPA	National Environmental Policy Act
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NM	Neutrino Muon
NMR	Nuclear Material Representative
NOvA	Neutrino Off-axis Electron Neutrino (ve) Appearance
NPH	Natural Phenomena Hazard
NRTL	Nationally Recognized Testing Laboratory
NIF	Neutron Irradiation Facility
NTSB	Neutrino Target Service Building, see also TSB
NuMI	Neutrinos at the Main Injector
NW	Neutrino West
ODH	Oxygen Deficiency Hazard
ORC	Operational Readiness Clearance
OSHA	Occupational Safety and Health Administration
pCi	pico-Curie
pCi/mL	pico-Curie per milliliter
PE	Professional Engineer

PIN	Personal Identification Number
PIP	Proton Improvement Plan
PIP-II	Proton Improvement Plan - II
PHAR	Preliminary Hazards Analysis Report
PPD	Particle Physics Directorate
PPE	Personnel Protective Equipment
QA	Quality Assurance
QAM	Quality Assurance Manual
RA	Radiation Area
RAF	Radionuclide Analysis Facility
RAW	Radioactive Water
RCT	Radiological Control Technician
RF	Radio-Frequency
RFQ	Radio-Frequency Quadrupole
RIL	RFQ Injector Line
RMA	Radioactive Material Area
RMS	Root Mean Square
RPCF	Radiation Physics Calibration Facility
RPE	Radiation Physics Engineering Department
RPO	Radiation Physics Operations Department
RRM	Repetition Rate Monitor
RSI	Reviewed Safety Issue
RSIS	Radiation Safety Interlock System
RSO	Radiation Safety Officer
RWP	Radiological Work Permit
SA	Shielding Assessment
SAA	Satellite Accumulation Areas
SAD	Safety Assessment Document
SCF	Standard Cubic Feet
SCFH	Standard Cubic Feet per Hour
SEWS	Site-Wide Emergency Warning System
SNS	Spallation Neutron Source
SR	Survey Riser
SRF	Superconducting Radio-Frequency
SRSO	Senior Radiation Safety Officer
SSB	Switchyard Service Building
SSP	Site Security Plan
SWIC	Segmented Wire Ionization Chambers
TLM	Total Loss Monitor

TLVs	Threshold Limit Values
TPC	Time Projection Chamber
TPES	Target Pile Evaporator Stack
TPL	Tagged Photon Lab
TSB	Target Service Building, see also NTSB
TSCA	Toxic Substances Control Act
TSW	Technical Scope of Work
T&I	Test and Instrumentation
UPB	Utility Plant Building
UPS	Uninterruptible Power Supply
USI	Unreviewed Safety Issue
VCTF	Vertical Cavity Test Facility
VHRA	Very High Radiation Area
VMS	Village Machine Shop
VMTF	Vertical Magnet Test Facility
VTS	Vertical Test Stand
WSHP	Worker Safety and Health Program
μs	micro-second

II-3. Radionuclide Analysis Facility

II-3.1. Introduction

This Section V, Chapter 04 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the RAF facility located in the Site 39 Annex.

II-3.1.1 Purpose/Function

Fermilab has had a Radionuclide Analysis Facility (RAF), formerly known as the Activation Analysis Laboratory and the Nuclear Counting Laboratory, since 1971. The work activity was moved to the present Annex at Site 39 in 2000. The RAF has played a vital role in environmental sample analysis, waste stream characterizations, calibrations of beam intensity monitoring devices, beam absorber monitoring, cross calibrations of other types of instrumentation, and material activation studies1. RAF has not been required to hold outside certifications.

Environmental samples are analyzed as part of a continuing on-site surveillance and National Pollutant Discharge Elimination Systems (NPDES) monitoring programs. Waste samples are analyzed primarily for the purpose of characterizing their radionuclide content to meet disposal facility requirements. Results of RAF analyses are also used for screening purposes in cases where a waste generator is unsure of the origin of radioactivity in a waste stream2. Activated materials are analyzed to evaluate hadron intensities, specific radionuclide activities, activation cross sections, Monte Carlo computer model predictions, and to assist in establishing correlations between specific radionuclide activities and detectors operating in single channel modes.

II-3.1.2 Current Status

The RAF is currently: operational.

II-3.1.3 Description

The RAF uses several commercial high-purity germanium detectors, liquid scintillation counters, and gas proportional counters to measure the activity of samples. Lead shields are in or around most of these devices. Additionally, a chemistry lab at RAF is used to prepare samples for analysis. A liquid nitrogen tank is situated outside the southwest entrance to the RAF.

II-3.1.4 Location

The RAF is located on the Fermilab site in Batavia, IL.

Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.

The RAF is located in the Site 39 Annex. The RAF is operated by the Environment, Safety, Health, & Quality (ESH&Q) Section Radiation Protection Group as a building tenant of the Facilities Engineering Services Section (FESS). FESS supplies the Building Management functions for this building. The map below shows the location on the Fermilab site.

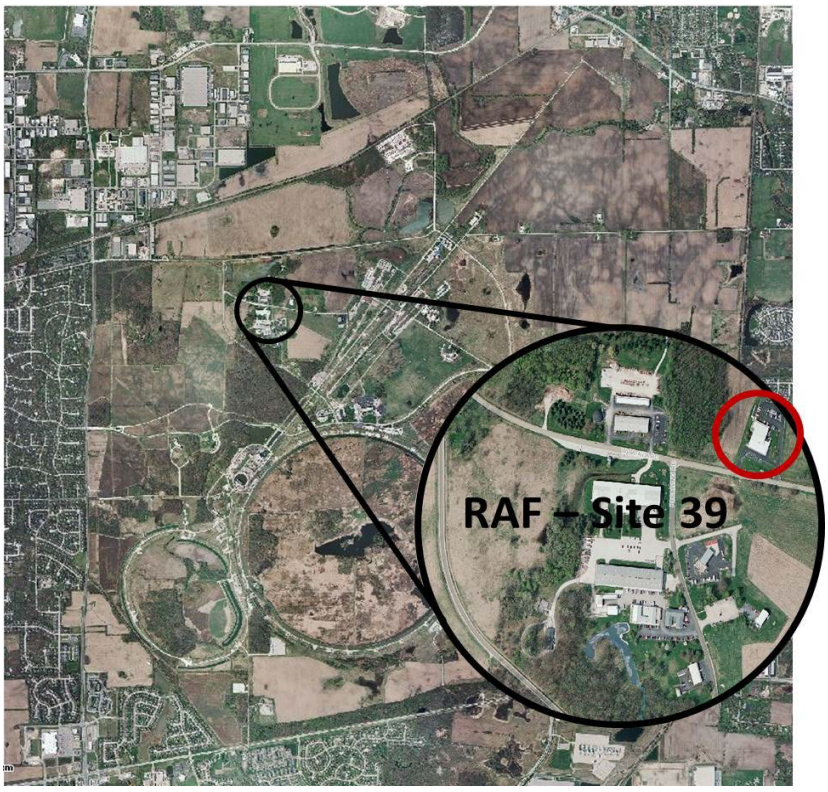

Figure 2. Aerial view of the Fermilab site, indicating the location of the RAF.

II-3.1.5 Management Organization

The RAF is operated by the ES&H Division. It is the landlord of the Site 39 Annex building.

II-3.1.6 Operating Modes

The RAF is a support facility that operates in the same manner regardless of accelerator operational modes.

II-3.1.7 Inventory of Hazards

The following table lists all of the identified hazards found in the RAF. Section I-1.10 *Appendix – Risk Matrices* describes the baseline risk (i.e., unmitigated risk), any preventative controls and/or mitigative controls in place to reduce the risk, and residual risk (i.e., mitigated risk) for facility worker, co-located worker and Maximally Exposed Offsite Individual (MOI) (i.e., members of the public). A summary of these controls is described within Section I-1.2 *Safety Assessment.*

All hazards present in the RAF are safely managed by DOE approved applicable safety and health programs and/or processes, and their analyses have been performed according to applicable DOE requirements as flowed down through the Fermilab Environment, Safety and Health Manual (FESHM). These hazards are considered to be Standard Industrial Hazards (SIH), and their analysis will be summarized in this SAD Chapter.

Table 1. Hazard Inventory for RAF.

	Radiological		Toxic Materials
☐	**Prompt Ionizing Radiation**	☒	Lead Shielding
☒	Residual Activation	☐	Beryllium
☐	Groundwater Activation	☐	**Fluorinert & Its Byproducts**
☐	Surface Water Activation	☒	Liquid Scintillator Oil
☐	Radioactive Water (RAW) Systems	☐	Pseudocumene
☐	Air Activation	☐	Ammonia
☐	Closed Loop Air Cooling	☐	Nanoparticle Exposures
☐	Soil Interactions		**Flammables and Combustibles**
☒	Radioactive Waste	☒	Combustible Materials (e.g., cables, wood cribbing, etc.)
☒	Contamination	☒	Flammable Materials (e.g., flammable gas, cleaning materials, etc.)
☐	Beryllium-7		**Electrical Energy**
☒	Radioactive Sources	☐	Stored Energy Exposure
☐	Nuclear Material	☒	High Voltage Exposure
☐	Radiation Generating Devices (RGDs)	☐	Low Voltage, High Current Exposure
☐	Non-Ionizing Radiation Hazards		**Kinetic Energy**
	Thermal Energy	☐	Power Tools
☐	Magnet Bakeouts	☐	Pumps and Motors
☐	Hot Work	☐	Motion Tables
☒	**Cryogenic Liquids**	☒	Mobile Shielding
	Potential Energy		**Magnetic Fields**
☐	Crane Operations	☐	Fringe Fields
☒	Compressed Gasses		**Other Hazards**
☐	Vacuum/Pressure Vessels	☐	Confined Spaces
☒	Vacuum Pumps	☐	Noise
☐	Material Handling	☐	Silica
	Access & Egress	☒	Ergonomics
☐	Life Safety Egress	☐	Asbestos

II-3.2. Safety Assessment

All hazards for the RAF are summarized in this section, with additional details of the analyses for accelerator specific hazards.

II-3.2.1 Radiological Hazards

The RAF presents radiological hazards in the form of radiological materials, radioactivated material, sealed radioactive sources, and radioactive waste. Radiological hazards are not directly associated with accelerator operations and are managed in accordance with the requirements of the FRCM that implement 10 CFR 835.

Safety controls at Fermilab are in the form of prescribed procedures and protective measures detailed in the following guidance documents: Fermilab Environment, Safety, and Health Manual[3] (FESHM), Fermilab Radiological Control Manual[4] (FRCM), Fermilab Sealed Source Control and Accountability Program[5], Fermilab Nuclear Materials Control and Accountability (MC&A) Plan[6], Fermilab Site Security Plan[7], and Low-Level Waste Certification Program[2].

The baseline risk level of R III is reduced to a residual risk level of R IV through the control measures currently implemented for workers, co-located workers and the public.

II-3.2.1.1 Prompt Ionizing Radiation

Not applicable

II-3.2.1.2 Residual Activation

The RAF produces no residual activation. Activated materials are brought to RAF for isotopic analysis. As indicated in the FRCM Article 555, *Collection and Analysis of Analytical Samples*, no radioactive material above Fermilab radioactive material Class 1 may be brought into RAF without ESH&Q Section approval. Work at the RAF is performed according to approved procedures including requisite safety precautions that include consideration of radiation protection or an approved Radiological Work Permit (RWP) if the need for an RWP arises.

II-3.2.1.3 Groundwater Activation

not applicable

II-3.2.1.4 Surface Water Activation

not applicable

II-3.2.1.5 Radioactive Water (RAW) Systems

not applicable

II-3.2.1.6 Air Activation

not applicable

II-3.2.1.7 Closed Loop Air Cooling

not applicable

II-3.2.1.8 Soil Interactions

not applicable

II-3.2.1.9 Radioactive Waste

Radioactive waste produced in the course of RAF operations will be managed within the established Radiological Protection Program (RPP) and as prescribed in the Fermilab Radiological Control Manual (FRCM).

Radioactive waste is a standard radiological hazard that is managed within the established Radiological Protection Program (RPP) and as prescribed in the Fermilab Radiological Control Manual (FRCM). Waste

minimization is an objective of the equipment design and operational procedures. Reuse of activated items will be carried out when feasible. Activated items that cannot be reused will be disposed of as radioactive waste in accordance with the FRCM requirements.

The majority of samples return to the original requestor, who initiates proper disposal in accordance with FESHM 8021including FRCM Chapter 4, *Radioactive Material, Part 4, Radioactive Waste Management.* Sample aliquots drawn for tritium analysis have a scintillator cocktail added. In accordance with Department of Energy (DOE) order 458.1[8] and 40 CFR Part 141[9], all aliquots are disposed of as mixed waste in accordance with FRCM requirements.

II-3.2.1.10 Contamination

RAF does not routinely have contamination present. However, contamination may be present if there is a spill of a sample being analyzed at the lab. RAF has specific sample handling and spill response procedures in place to prevent and mitigate contamination events.

II-3.2.1.11 Beryllium-7

See residual activation and contamination sections.

II-3.2.1.12 Radioactive Sources

Radioactive sources used at RAF are issued and used in accordance with FRCM Chapter 4, Part 3 *Radioactive Source Controls.*

II-3.2.1.13 Nuclear Material

not applicable

II-3.2.1.14 Radiation Generating Devices (RGDs)

not applicable

II-3.2.1.15 Non-Ionizing Radiation Hazards

not applicable

II-3.2.2 Toxic Materials

II-3.2.2.1 Lead

RAF has lead shielding for detectors and sample storage. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.2.2 Beryllium

not applicable

II-3.2.2.3 Fluorinert & Its Byproducts

not applicable

II-3.2.2.4 Liquid Scintillator Oil

RAF has liquid scintillator cocktail for liquid scintillation counting analysis. The LSC cocktail is handled according to standard operating procedures. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.2.5 Pseudocumene

not applicable

II-3.2.2.6 Ammonia

not applicable

II-3.2.2.7 Nanoparticle Exposures

not applicable

II-3.2.3 Flammables and Combustibles

II-3.2.3.1 Combustible Materials

RAF has combustible materials such as cables, boxes, and paper. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.3.2 Flammable Materials

This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.4 Electrical Energy

RAF uses high voltage to bias detectors used for sample analysis. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.4.1 Stored Energy Exposure

not applicable

II-3.2.4.2 High Voltage Exposure

No unique controls are in use.

II-3.2.4.3 Low Voltage, High Current Exposure

not applicable

II-3.2.5 Thermal Energy

II-3.2.5.1 Bakeouts

not applicable

II-3.2.5.2 Hot Work

not applicable

II-3.2.5.3 Cryogenics

RAF uses liquid nitrogen to cool High Purity Germanium detectors. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.6 Kinetic Energy

II-3.2.6.1 Power Tools

not applicable

II-3.2.6.2 Pumps and Motors

not applicable

II-3.2.6.3 Motion Tables

not applicable

II-3.2.6.4 Mobile Shielding

not applicable

II-3.2.7 Potential Energy

RAF has compressed gasses for use in some of its detectors. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

RAF has vacuum pumps used in sample preparation. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.7.1 Crane Operations

not applicable

II-3.2.7.2 Compressed Gasses

No unique controls are in use.

II-3.2.7.3 Vacuum/Pressure Vessels/Piping

not applicable

II-3.2.7.4 Vacuum Pumps

No unique controls are in use.

II-3.2.7.5 Material Handling

not applicable

II-3.2.8 Magnetic Fields

II-3.2.8.1 Fringe Fields

not applicable

II-3.2.9 Other Hazards

II-3.2.9.1 Confined Spaces

not applicable

II-3.2.9.2 Noise

not applicable

II-3.2.9.3 Silica

not applicable

II-3.2.9.4 Ergonomics

No unique controls are in use.

II-3.2.9.5 Asbestos

not applicable

II-3.2.9.6 Working at Heights

not applicable

II-3.2.10 Access & Egress

II-3.2.10.1 Life Safety Egress

not applicable

II-3.2.11 Environmental

RAF has potential environmental hazards through possible spills of radioactive material. This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 Safety Analysis. Work in RAF involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

II-3.2.11.1 Hazard to Air

No unique controls are in use.

II-3.2.11.2 Hazard to Water

No unique controls are in use.

II-3.2.11.3 Hazard to Soil

No unique controls are in use.

II-3.3. Summary of Hazards to Members of the Public

Hazards to members of the public at RAF are mitigated by the building being a locked facility, preventing access by members of the public.

II-3.4. Summary of Credited Controls

There are no credited controls that qualify for inclusion in the Accelerator Safety Envelope at RAF.

II-3.4.1 Passive Credited Controls

not applicable

II-3.4.1.1 Shielding

not applicable

II-3.4.1.1.1 Permanent Shielding Including Labyrinths

not applicable

II-3.4.1.1.2 Movable Shielding

not applicable

II-3.4.1.1.3 Penetration Shielding

not applicable

II-3.4.1.2 Fencing

not applicable

II-3.4.1.2.1 Radiation Area Fencing

not applicable

II-3.4.1.2.2 Controlled Area Fencing

not applicable

II-3.4.2 Active Engineered Credited Controls

not applicable

II-3.4.2.1 Radiation Safety Interlock System

not applicable

II-3.4.2.2 ODH Safety System

not applicable

II-3.4.3 Administrative Credited Controls

not applicable

II-3.4.3.1 Operation Authorization Document

not applicable

II-3.4.3.2 Staffing

not applicable

II-3.4.3.3 Accelerator Operating Parameters

not applicable

II-3.5. Defense-in-Depth Controls

not applicable

II-3.6. Machine Protection Controls

not applicable

II-3.7. Decommissioning

DOE Field Element Manager approval shall be obtained prior to the start of any decommissioning activities for RAF.

II-3.8. Summary and Conclusion

Specific hazards associated with RAF operations are identified and assessed in this chapter of the Fermilab SAD. The designs, controls, and procedures to mitigate RAF specific hazards are identified and described. In addition to these specific safety considerations, the RAF is subject to the standard industrial hazard controls and procedures outlined in Section 1 of this Fermilab SAD.

Within the specific and generic considerations of this assessment RAF can be operated with a level of safety that will protect people and property and is equal to or exceeding that currently prescribed by DOE orders and Fermilab regulations as put forth in the FESHM including FRCM, and the Fermilab Quality Assurance Manual.

II-3.9. References

[1] Fermilab Radiological Control Manual

II-3.10. Appendix – Risk Matrices

Risk Assessment methodology was developed based on the methodology described in DOE-HDBK-1163-2020. Hazards and their potential events are evaluated for likelihood and potential consequence assuming no controls in place, which results in a baseline risk. A baseline risk (i.e., an unmitigated risk) value of III and IV does not require further controls based on the Handbook. Events with a baseline risk value of I or II do require prevention and/or mitigation measures to be established in order to reduce the risk value to an acceptable level of III or IV. Generally, preventive controls are applied prior to a loss event, reflecting a likelihood reduction, and mitigative controls are applied after a loss event, reflecting a consequence reduction. For each control put in place, likelihood or consequence can have a single “bin drop”, resulting in a new residual risk (i.e., a mitigated risk). This risk assessment process is repeated for each hazard for Facility Workers (FW), Co-Located Workers (CLW), and Maximally-Exposed Offsite Individual (MOI). At the conclusion of the risk assessments, controls that are in place for the identified accelerator specific hazards are identified as Credited Controls and further summarized in Section I-1.4 of this .