RADIATION PHYSICS CALIBRATION FACILITY

SECTION II CHAPTER 02 OF THE FERMILAB SAD

Revision 1 August 7, 2023

This Chapter of the Fermilab Safety Assessment Document (SAD) contains a summary of the results of the Safety Analysis for the RPCF 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 02 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), Radiation Physics Calibration Facility, was prepared and reviewed by the staff of the Environment, Safety & Health Division (ESH), Radiation Physics Engineering, Instrumentation Team 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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SAD Review Subcommittee Chair

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 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
Kathy J. Graden	0	06/12/2015	Initial release of the Radiation Physics Calibration Facility Fermilab Safety Assessment Document
Mark Zientarski	1	08/03/2023	SAD Chapter update to align with DOE O 420.2D

Table of Content

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
MCI	Maximum Credible Incident
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
NASH	Non-Accelerator Specific Hazard
^{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-2. Radiation Physics Calibration Facility

II-2.1. Introduction

This Section II, Chapter 02 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the Radiation Physics Calibration Facility (RPCF).

II-2.1.1 Purpose/Function

The purpose of the RPCF is to repair, modify, and calibrate radiation instruments. The ESH Division's Instrumentation Team conducts research, designs, develops, and constructs radiation instrumentation for Fermilab and performs related studies.

II-2.1.2 Current Status

The RPCF is currently: **Operational**.

II-2.1.3 Description

The RPCF is a two-story building located in the eastern most section of the Site 38 area of Fermilab. There are three caves at the RPCF which serve as radiation calibration facilities, neutron source storage, radioactive source storage, and instrumentation storage. Cave #1 houses various radioactive sources that are used for instrument calibrations. Cave #1 is the storage location for nuclear materials in the form of sealed neutron sources. All sealed neutron sources are stored in a concrete container called the neutron storage cave. The neutron storage cave is part of the poured concrete walls of Cave #1.

The High Level Calibration Facility (HLCF) is located in Cave #2 of the RPCF. The cave is constructed of poured concrete and consists of an outer control room and an inner irradiation room. Radioactive source projectors are used to project high intensity radiation beams into the inner irradiation room for various radiation instrument calibrations. Three projectors are located in, and operated from, the outer (control) room where operators are stationed during irradiations.

The Low Level Calibration Facility (LLCF) is located in Cave #3. The cave is constructed of poured concrete and consists of an outer room and an inner irradiation room. The radioactive projector is located in, and operated from, the inner irradiation room.

II-2.1.4 Location

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

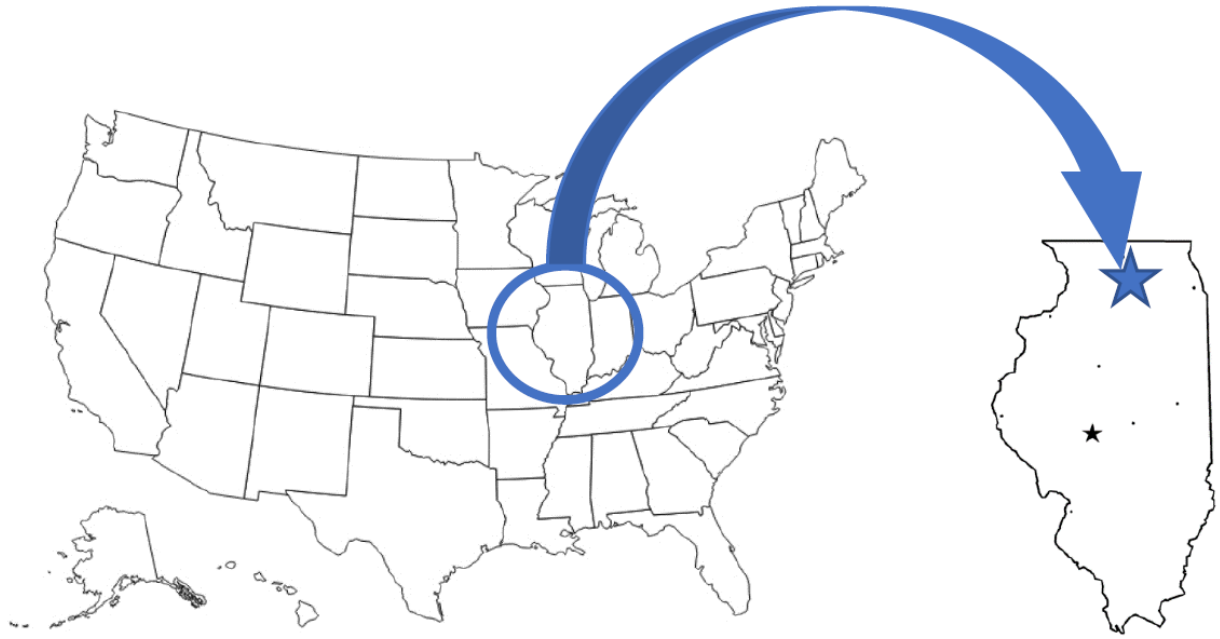

Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.

The RPCF is located in the eastern side of Site 38 on the Fermilab site.

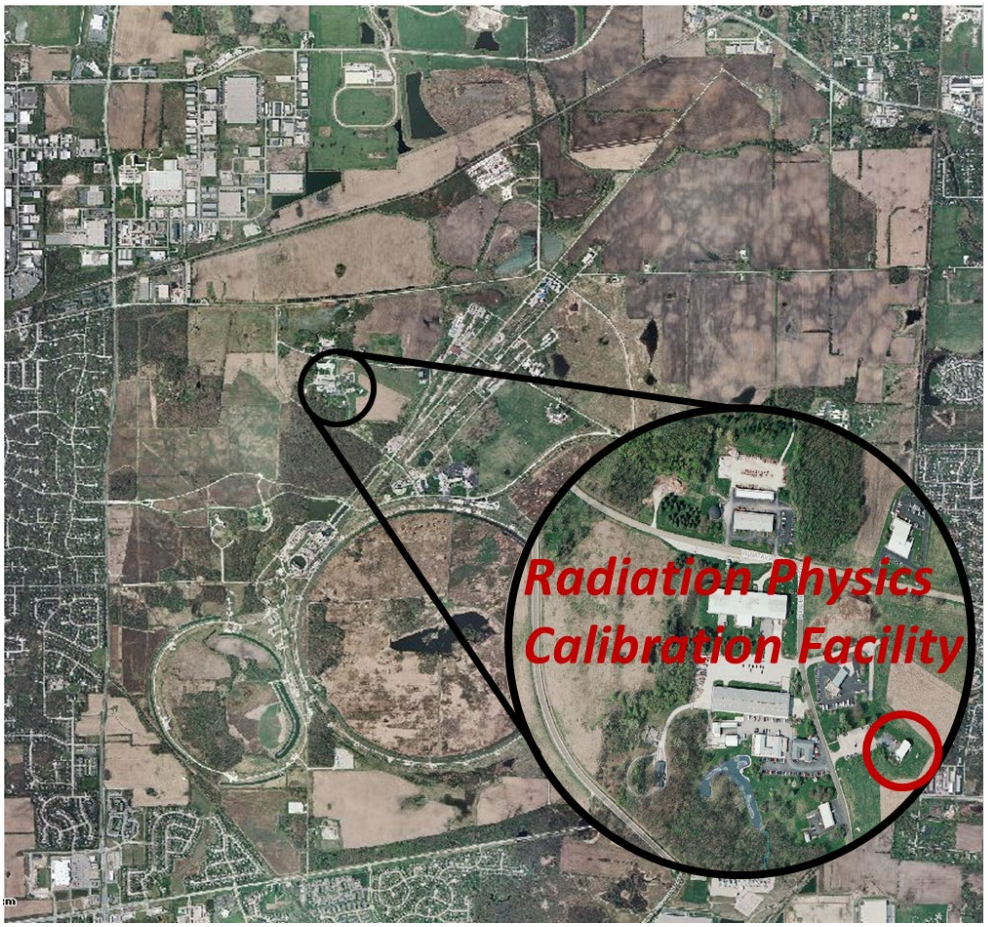

Figure 2. Aerial view of the Fermilab site, indicating the location of the RPCF.

II-2.1.5 Management Organization

The RPCF is operated by the Environment, Safety & Health (ESH) Division's Radiation Protection Group.

II-2.1.6 Operating Modes

RPCF is a support facility and is not tied to the accelerator complex or experimental operating schedules.

II-2.1.7 Inventory of Hazards

The following table lists all of the identified hazards found in the RPCF. Section II-2.10 *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 II-2.2 *Safety Assessment.*

Prompt ionizing and Oxygen Deficiency Hazards due to cryogenic systems within accelerator enclosures have been identified as accelerator specific hazards, and as such their controls are identified as Credited Controls. Accelerator specific controls are identified as **purple/bold** throughout this Chapter. These accelerator specific hazards are not present at RPCF, and Credited Controls are not applicable.

All other hazards present in the RPCF are safely managed by other 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 Non-Accelerator Specific Hazards (NASH), and their analysis will be summarized in this SAD Chapter.

Table 1. Hazard Inventory for RPCF.

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

II-2.2. Safety Assessment

All hazards for the RPCF are summarized in this section.

II-2.2.1 Radiological Hazards

Potential radiological hazards were identified at RPCF in the form of contamination, radioactive sources, and nuclear materials. Detailed facility operating manuals address these hazards and provide a detailed analysis of the facility demonstrating the required shielding, controls and interlocks.

The unmitigated risks associated with exposure to these sources have been evaluated for facility workers, co-located workers, and members of the public and preventive and mitigative measures have been identified. These measures collectively mitigate the risk involved with these hazards.

II-2.2.1.1 Prompt Ionizing Radiation

N/A

II-2.2.1.2 Residual Activation

N/A

II-2.2.1.3 Groundwater Activation

N/A

II-2.2.1.4 Surface Water Activation

N/A

II-2.2.1.5 Radioactive Water (RAW) Systems

N/A

II-2.2.1.6 Air Activation

N/A

II-2.2.1.7 Closed Loop Air Cooling

N/A

II-2.2.1.8 Soil Interactions

N/A

II-2.2.1.9 Radioactive Waste

N/A

II-2.2.1.10 Contamination

Potential skin contamination could occur from leakage of sealed sources. Sources are secured in locked pigs or approved storage cabinets when not in use. Unmounted sealed sources are stored behind locked doors and only accessible by authorized personnel. Unmounted sealed sources are under continuous monitoring when in use unless prior SRSO approval is granted. Mounted sealed

sources are wiped for leakage during repairs or calibration. Unmounted sealed sources are wiped for leakage bi-annually.

Collectively implemented measures mitigate the risk to facility workers, co-located workers, and members of the public.

II-2.2.1.11 Beryllium-7

N/A

II-2.2.1.12 Radioactive Sources

Various types of radioactive sources are located at the RPCF for instrument calibrations and related studies. These radioactive sources are stored and used in accordance with FRCM policies and the Fermilab Sealed Source Control and Accountability Program policies. Several high activity radioactive sources are contained within source projectors. The physical description of the source projector facility, including the safety features, personnel authorization requirements, and facility operating procedures are contained in the Fermilab ESH High Level Calibration Facility Operating Procedures and the Low Level Calibration Facility Operating Procedures.

Radioactive sources installed in three J.L. Shepard source projectors located in Cave #2 are as follows:

- Cesium-137 radioactive source identified as 137-3.2-12 (2 milliCuries)
- Cesium-137 radioactive source identified as 137-4.2-3 (20 milliCuries)
- Cesium-137 radioactive source identified as 137-5.2-1 (200 milliCuries)
- Cesium-137 radioactive source identified as 137-6.2-1 (2 Curies)
- Cesium-137 radioactive source identified as 137-7.2-1 (22 Curies)
- Cesium-137 radioactive source identified as 137-8.2-1 (225 Curies)

Radioactive sources installed in the J.L. Shepard quad source projector located in Cave #3 is as follows:

- Cesium-137 radioactive source identified as 137-5.6-4 (600 milliCuries)
- Cesium-137 radioactive source identified as 137-4.5-2 (50 milliCuries)
- Cesium-137 radioactive source identified as 137-3.4-4 (4 milliCuries)
- Cesium-137 radioactive source identified as 137-2.4-3 (0.35 milliCuries)

Collectively-implemented measures described in the operating procedures, mitigate the risk to facility workers, co-located workers, and members of the public.

II-2.2.1.13 Nuclear Material

Nuclear materials at RPCF are stored and used in accordance with FRCM policies and the Fermilab Nuclear Materials Control and Accountability (MC&A) Plan policies. The following sealed neutron sources are located in the neutron storage cave located in Cave #1:

- Americium-241 Beryllium neutron source identified as 241Be-5.2-1 (96 milliCuries)
- Americium-241 Beryllium neutron source identified as 241Be-6.7-1 (3 Curies)
- Americium-241 Beryllium neutron source identified as 241Be-7.2-1 (10 Curies)
- Americium-241 Beryllium neutron source identified as 241Be-7.6-1 (24 Curies)
- Calfornium-252 neutron source identified as 252-7.2-1 (5 microCuries)

- Calfornium-252 neutron source identified as 252-7.2-2 (36 microCuries)

Collectively implemented measures mitigate the risk to facility workers, co-located workers, and members of the public.

II-2.2.1.14 Radiation Generating Devices (RGDs)

N/A

II-2.2.1.15 Non-Ionizing Radiation Hazards

Positioning lasers are used in both HLCF and LLCF to align detectors to source projector ports. All positioning lasers are Class II and pose a negligible risk and is covered in Section I, Chapter 4.

II-2.2.2 Toxic Materials

Potential toxic material hazard was identified at RPCF in the form of lead shielding.

The unmitigated risk associated with exposure to lead have been evaluated for facility workers, co-located workers, and members of the public and preventive and mitigative measures have been identified. These measures collectively mitigate the risk involved with these hazards.

II-2.2.2.1 Lead

Lead exists in the form of coated lead sheet and coated source projectors. Lead handling is conducted in accordance with FESHM polices and is covered in Section I, Chapter 4.

Collectively implemented measures mitigate the risk to facility workers, co-located workers, and members of the public.

II-2.2.2.2 Beryllium

N/A

II-2.2.2.3 Fluorinert & Its Byproducts

N/A

II-2.2.2.4 Liquid Scintillator Oil

N/A

II-2.2.2.5 Pseudocumene

N/A

II-2.2.2.6 Ammonia

N/A

II-2.2.2.7 Nanoparticle Exposures

N/A

II-2.2.3 Flammables and Combustibles

Potential flammables and combustibles hazards were identified at RPCF in the form of wood stock, cleaners, and solvents.

The unmitigated risks associated with exposure to these sources have been evaluated for facility workers, co-located workers, and members of the public and preventive and mitigative measures have been identified. These measures collectively mitigate the risk involved with these hazards.

II-2.2.3.1 Combustible Materials

Combustible materials exist at RPCF in the form of various forms of raw wood supplies located in the facilities Tech Shop. Materials are used for construction and fabrication activities.

This hazard has been evaluated within the common Risk Matrix table included in the SAD Section I Chapter 04 safety analysis. Work in RPCF involving this hazard implements applicable controls specified in the common Risk Matrix table.

II-2.2.3.2 Flammable Materials

Flammable materials exist at RPCF in the form of various forms of approved cleaners and solvents. Chemicals are located in designated locations. Tech shop chemicals are stored in a marker metal cabinet away from sparking sources. General chemicals are stored on mezzanine in flammable storage cabinet.

This hazard has been evaluated within the common Risk Matrix table included in the SAD Section I Chapter 04 safety analysis. Work in RPCF involving this hazard implements applicable controls specified in the common Risk Matrix table.

II-2.2.4 Electrical Energy

N/A

II-2.2.4.1 Stored Energy Exposure

N/A

II-2.2.4.2 High Voltage Exposure

N/A

II-2.2.4.3 Low Voltage, High Current Exposure

N/A

II-2.2.5 Thermal Energy

N/A

II-2.2.5.1 Bakeout

N/A

II-2.2.5.2 Hot Work

N/A

II-2.2.5.3 Cryogenics

N/A

II-2.2.6 Kinetic Energy

Potential kinetic energy hazards were identified at RPCF in the form of power tools, motion tables and mobile shielding.

The unmitigated risks associated with kinetic energy have been evaluated for facility workers, co-located workers, and members of the public and preventive and mitigative measures have been identified. These measures collectively mitigate the risk involved with these hazards.

II-2.2.6.1 Power Tools

This hazard has been evaluated within the common Risk Matrix table included in the SAD Section I Chapter 04 safety analysis. Work in RPCF involving this hazard implements applicable controls specified in the common Risk Matrix table.

Collectively implemented measures mitigate the risk to facility workers, co-located workers, and members of the public.

II-2.2.6.2 Pumps and Motors

N/A

II-2.2.6.3 Motion Tables

Motion tables are used in the HLCF and LLCF for instrumentation distance positioning in the irradiation rooms. Baseline risks were found to be of acceptable risk. Additional prevention and mitigation measures were put in place to further reduce this hazard.

Collectively implemented measures mitigate the risk to facility workers, co-located workers, and members of the public.

II-2.2.6.4 Mobile Shielding

Mobile shielding in utilized in HLCF in the form of three J.L. Shepherd self-contained source projectors. The projectors are permanently secured to a welded stand frame and positioning requires two-handed operation by trained personnel.

Collectively implemented measures mitigate the risk to facility workers, co-located workers, and members of the public.

II-2.2.7 Potential Energy

N/A

II-2.2.7.1 Crane Operations

N/A

II-2.2.7.2 Compressed Gasses

N/A

II-2.2.7.3 Vacuum/Pressure Vessels/Piping

N/A

II-2.2.7.4 Vacuum Pumps

N/A

II-2.2.7.5 Material Handling

N/A

II-2.2.8 Magnetic Fields

N/A

II-2.2.8.1 Fringe Fields

N/A

II-2.2.9 Other Hazards

N/A

II-2.2.9.1 Confined Spaces

N/A

II-2.2.9.2 Noise

N/A

II-2.2.9.3 Silica

N/A

II-2.2.9.4 Ergonomics

N/A

II-2.2.9.5 Asbestos

N/A

II-2.2.9.6 Working at Heights

N/A

II-2.2.10 Access & Egress

N/A

II-2.2.10.1 Life Safety Egress

N/A

II-2.2.11 Environmental

N/A

II-2.2.11.1 Hazard to Air

N/A

II-2.2.11.2 Hazard to Water

N/A

II-2.2.11.3 Hazard to Soil

N/A

II-2.3. Summary of Hazards to Members of the Public

RPCF has implemented access controls to ensure minimal residual risk is present to members of the public.

The unmitigated risks associated with members of the public have been evaluated for all identified hazards and preventive and mitigative measures have been identified. The RPCF hazards are confined to the facility footprint, and therefore, do not directly affect members of the public. The measures collectively identified mitigate the risk involved with these hazards.

II-2.4. Summary of Credited Controls

Credited Control are not required for RPCF.

II-2.4.1 Passive Credited Controls

N/A

II-2.4.1.1 Shielding

N/A

II-2.4.1.1.1 Permanent Shielding Including Labyrinths

N/A

II-2.4.1.1.2 Movable Shielding

N/A

II-2.4.1.1.3 Penetration Shielding

N/A

II-2.4.1.2 Fencing

N/A

II-2.4.1.2.1 Radiation Area Fencing

N/A

II-2.4.1.2.2 Controlled Area Fencing

N//A

II-2.4.2 Active Engineered Credited Controls

N/A

II-2.4.2.1 Radiation Safety Interlock System

N/A

II-2.4.2.2 ODH Safety System

N/A

II-2.4.3 Administrative Credited Controls

N/A

II-2.4.3.1 Operation Authorization Document

N/A

II-2.4.3.2 Staffing

N/A

II-2.4.3.3 Accelerator Operating Parameters

N/A

II-2.5. Defense-in-Depth Controls

N/A

II-2.6. Machine Protection Controls

N/A

II-2.7. Decommissioning

DOE Field Element Manager approval shall be obtained prior to the start of any decommissioning activities for the Radiation Physics Calibration Facility.

II-2.8. Summary and Conclusion

This chapter of the Fermilab SAD identifies specific hazards associated with the RPCF operations. This chapter describes designs, controls and procedures that mitigate specific hazards and enhance safety security at the RPCF. In addition to these specific safety considerations, the RPCF is subject to the global and more generic safety requirements, controls, and procedures outlined in Section I Chapter 04.

II-2.9. References

[1] Fermilab Radiological Control Manual
[2] High Level Calibration Facility Operating Procedures (ESH DocDB Document #7291)
[3] Low Level Calibration Facility Operating Procedures (ESH DocDB Document #7294)

II-2.10. 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 RPCF specific hazards are identified.

Table 2. Summary of Baseline and Residual Risks Radiological Physics Calibration Facility (RPCF)

Risk Tables Description		Baseline Risk	Residual Risk
2.1	Radiological – Onsite-1 Facility Worker	R:I	R:IV
2.2	Radiological – Onsite-2 Co-located Worker	R:I	R:IV
2.3	Radiological – MOI Offsite	R:I	R:IV
2.4	Toxic Materials – Onsite-1 Facility Worker	R:II	R:IV
2.5	Toxic Materials – Onsite-2 Co-located Worker	R:III	R:IV
2.6	Toxic Materials – MOI Offsite	R:N/A	R:N/A
2.7	Kinetic Energy – Onsite-1 Facility Worker	R:I	R:IV
2.8	Kinetic Energy – Onsite-2 Co-located Worker	R:I	R:IV
2.9	Kinetic Energy – MOI Offsite	R: N/A	R: N/A
2.10	Flammables and Combustibles – Onsite-1 Facility Worker	R:I	R:IV
2.11	Flammables and Combustibles – Onsite-2 Co-located Worker	R:II	R:IV
2.12	Flammables and Combustibles – MOI Offsite	R:III	R: IV

NOTE:
Per DOE-HDBK-1163-2020, Appendix C, "Risk Assessment Methodology":
"Events with an unmitigated risk value of III or IV would not require additional control assignments to provide reasonable assurance of adequate protection. Whereas, for events with an unmitigated risk value of I or II, controls would need to be assigned to either reduce the likelihood or the consequence, and therefore the overall mitigated risk. 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. Each control is credited for a single "bin drop" either in likelihood or consequence; not both. Following a standard hierarchy of controls, controls are applied until the residual risk is acceptable – reflecting a mitigated risk value of III or IV. After controls are credited, events with a remaining unacceptable residual risk (i.e., I or II) are candidates for additional analyses and additional controls, often quantitative in nature." For Fermilab, these controls for accelerator-specific hazards are identified as Credited Controls and further summarized in the Accelerator Safety Envelope (ASE).

Table 2.1 Radiological – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Contamination	*Hazard: Potential skin contamination from leakage of a sealed check source*	L: A C: N R: IV	P- Sources are kept in a secure building and behind locked doors P- Unmounted sources are wiped for leakage bi-annually M- Employees must complete training to minimize exposure time	L:EU C: N R: IV
Radioactive Sources	*Hazard: HLCF - Potential direct radiation exposure due to open projector*	L: A C: H R: I	P- Employees must complete training to use facility P- Visual warning devices indicate sources are exposed P- Control room is separate from irradiation room M- Sources are shielded preventing dose to operator M- A multilayer interlock system prevents access when sources are exposed	L: BEU C: L R: IV
	Hazard: LLCF - Potential direct radiation exposure due to open projector	L: A C: M R:II	P- Employees must complete training to use facility P- Visual warning devices indicate sources are exposed M- Sources are shielded preventing dose to operator	L:EU C:L R:IV

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Nuclear Material	*Hazard: Potential direct radiation exposure due to neutron sources*	L: A C: H R: I	P- Employees must complete training to use facility P- Sources are stored behind locked door P- Sources are stored behind padlocked door P- Sources are inside concrete storage cave M- Sources are transported in polyethylene	L: BEU C: M R: IV
Non-ionizing radiation-Laser	*Hazard: Exposure to Class 1 and 2 Lasers*	L: A C: N R: IV	No analysis required	L: A C: N R:IV

Radiological Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
A = Anticipated (L > 1.0E-02)
U = Unlikely (1.0E-02> L >1.0E-04)
EU = Extremely Unlikely (1.0E-04 > L >1.0E-06)
BEU = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
H = High
M = Moderate
L = Low
N = Negligible

Risk (R, Qualitative Ranking)
I = situation (event) of major concern
II = situation (event) of concern
III = situation (event) of minor concern
IV = situation (event) of minimal concern

Control(s) Type
P = Preventive (reduce event occurrence likelihood)
M = Mitigative (reduces event consequences)

Acronyms
MOI = Maximally-exposed Offsite Individual
rem = Roentgen equivalent man

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ 25.0 rem	**C** ≥ 100 rem	**C** ≥ 100 rem
M	25.0 rem > **C** ≥ 5 rem	100 rem > **C** ≥ 25 rem	100 rem > **C** ≥ 25 rem
L	5 rem > **C**	25 rem > **C**	25 rem > **C**
N	0.5 rem > **C**	5 rem > **C**	5 rem > **C**

Risk Matrix

Consequences \ Likelihood	A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.2 Radiological – Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Contamination	*Hazard: Potential skin contamination from leakage of a sealed source*	L: A C: N R: IV	P- Sources are kept in a secure building and behind locked door P- Unmounted sources are wiped for leakage bi-annually M- Employees must complete training to minimize exposure time	L:EU C: N R: IV
Radioactive Sources	*Hazard: HLCF - Potential direct radiation exposure due to open projector*	L: U C: H R: I	P- Employees must complete training to use facility P- Visual warning devices indicate sources are exposed P- Control room is separate from irradiation room M- Sources are shielded preventing dose to operator M- A multilayer interlock system prevents access when sources are exposed	L: BEU C: L R: IV
	Hazard: LLCF - Potential direct radiation exposure due to open projector	L: A C: M R:II	P- Employees must complete training to use facility P- Visual warning devices indicate sources are exposed M- Sources are shielded preventing dose to operator	L:EU C:L R:IV
Nuclear Material	*Hazard: Potential direct radiation exposure due to neutron sources*	L: A C: H R: I	P- Warning devices active when sources are in use P- Employees must complete training to use facility P- Sources are stored behind locked door P- Sources are stored behind padlocked door P- Sources are inside concrete storage cave M- Is transported in polyethylene	L: BEU C: M R: IV

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Non-ionizing radiation-Laser	*Hazard: Exposure to Class 1 and 2 Lasers*	L: A C: N R: IV	No analysis required	L: A C: N R:IV

Radiological Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **MOI** = Maximally-exposed Offsite Individual
- **rem** = Roentgen equivalent man

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ 25.0 rem	**C** ≥ 100 rem	**C** ≥ 100 rem
M	25.0 rem > **C** ≥ 5 rem	100 rem > **C** ≥ 25 rem	100 rem > **C** ≥ 25 rem
L	5 rem > **C**	25 rem > **C**	25 rem > **C**
N	0.5 rem > **C**	5 rem > **C**	5 rem > **C**

Risk Matrix

Consequences	Likelihood: A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.3 Radiological – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Contamination	*Hazard: Potential skin contamination from leakage of a sealed source*	L: U C: N R: IV	P- Building is restricted from public access P- Sealed source are kept behind locked door P- Unmounted sources are wiped for leakage bi-annually M- Visitors are escorted at all times	L:BEU C: N R: IV
Radioactive Sources	*Hazard: HLCF - Potential direct radiation exposure due to open projector* *Hazard: LLCF - Potential direct radiation exposure due to open projector*	L: U C: N R: III L: BEU C: N R:IV	P- Off hour exposures require SRSO approval and extra security surveillance P- Sources are not left unattended P- Off hour exposures require SRSO approval and extra security surveillance P- Sources are not lef	L: BEU C: N R: IV L:BEU C:N R:IV

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Nuclear Material	*Hazard: Potential direct radiation exposure due to neutron sources*	L: A C: H R: I	P- Warning devices active when sources are in use P- Sources are stored behind locked doors P- Sources are stored behind padlocked cave door P- Sources are inside concrete storage cave P- Building is restricted from public access P- Visitors are escorted at all times. M- Sources are transported in polyethylene	L: BEU C: M R: IV
Non-ionizing radiation-Laser	*Hazard: N/A*	L: C: R:	No analysis required	L: C: R:

Radiological Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **MOI** = Maximally-exposed Offsite Individual
- **rem** = Roentgen equivalent man

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ 25.0 rem	**C** ≥ 100 rem	**C** ≥ 100 rem
M	25.0 rem > **C** ≥ 5 rem	100 rem > **C** ≥ 25 rem	100 rem > **C** ≥ 25 rem
L	5 rem > **C**	25 rem > **C**	25 rem > **C**
N	0.5 rem > **C**	5 rem > **C**	5 rem > **C**

Risk Matrix

Consequences \ Likelihood	A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.4 Toxic Materials – Onsite 1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Lead	*Hazard: Potential exposure to lead dust during manual handling of un-encased lead bricks, lead shot, and lead sheets*	L:A C:M R:II	P- Contained in painted surfaces P- Behind locked doors P- Administrative policy (Lead handling training) M- Caution lead signs	L:BEU C:L R:IV

Chemical Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **IDLH** = Immediately Dangerous to Life and Health
- **MOI** = Maximally-exposed Offsite Individual
- **PAC** = Protective Action Criteria
- **PEL** = Permissible Exposure Limit
- **TLV_c** = Threshold Limit Value (ceiling)

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ PAC-2	**C** ≥ PAC-3	**C** ≥ IDLH
M	PAC-2 > **C** ≥ PAC-1	PAC-3 > **C** ≥ PAC-2	IDLH > **C** ≥ PEL or TLV_c
L	PAC-1 > **C**	PAC-2 > **C**	PEL or TLV_c > **C**
N	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level

Risk Matrix

Consequences \ Likelihood	A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.5 Toxic Materials – Onsite 2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Lead	*Hazard: Potential exposure to lead dust during manual handling of un-encased lead bricks, lead shot, and lead sheets*	L:A C:L R:III	P- Contained in painted surfaces P- Behind locked doors M- "Caution lead" signs	L:UE C:N R:IV

Chemical Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **IDLH** = Immediately Dangerous to Life and Health
- **MOI** = Maximally-exposed Offsite Individual
- **PAC** = Protective Action Criteria
- **PEL** = Permissible Exposure Limit
- **TLV_c** = Threshold Limit Value (ceiling)

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ PAC-2	**C** ≥ PAC-3	**C** ≥ IDLH
M	PAC-2 > **C** ≥ PAC-1	PAC-3 > **C** ≥ PAC-2	IDLH > **C** ≥ PEL or TLV_c
L	PAC-1 > **C**	PAC-2 > **C**	PEL or TLV_c > **C**
N	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level

Risk Matrix

Consequences \ Likelihood	A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.6 Toxic Materials – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Lead	*Hazard: N/A*	L: C: R:	Public is prevented from having access to work areas	L: C: R:

Chemical Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Risk Matrix

Consequences	Likelihood: A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **IDLH** = Immediately Dangerous to Life and Health
- **MOI** = Maximally-exposed Offsite Individual
- **PAC** = Protective Action Criteria
- **PEL** = Permissible Exposure Limit
- **TLV_c** = Threshold Limit Value (ceiling)

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ PAC-2	**C** ≥ PAC-3	**C** ≥ IDLH
M	PAC-2 > **C** ≥ PAC-1	PAC-3 > **C** ≥ PAC-2	IDLH > **C** ≥ PEL or TLV_c
L	PAC-1 > **C**	PAC-2 > **C**	PEL or TLV_c > **C**
N	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level

Table 2.7 Kinetic Energy – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Power tools	*Hazard: Potential pinch or abrasion hazards*	L: C: R: I	*See Section I Chapter 04	L: C: R: IV
Motion Tables	*Hazard: HLCF -Personnel injury due to pinch points, tip-overs, caught in between, crushing.* *Hazard: LLCF -Personnel injury due to pinch points, tip-overs, caught in between, crushing.*	L:U C:L R:III L:U C:L R:III	P- Employees must complete training to use facility P- Distance crank is located in control room away from motion table P- Motion chain is recessed into guide system M- Trolly construction prevents table from reaching the wall P- Employees must complete training to use facility P- Table is operated by computer located away from motion table M- Emergency stop switch M- Current sensing stop override M- Trolly construction prevents table from reaching the wall	L:BEU C:N R: IV L:BEU C: N R: IV
Mobile Shielding	*Hazard: Personnel injury due to pinch points, tip-overs, caught in between, crushing.*	L:A C:H R:I	P- Employees must complete training to use facility P- Securing shielding prevents tip overs and pinch points P- Two handed operation is required to slide shielded projectors M- Rubber bumpers prevent over movement	L:BEU C:M R:IV

Other Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **MOI =** Maximally-exposed Offsite Individual

C	**Offsite (MOI)**	**Onsite-2 (co-located worker)**	**Onsite-1 (facility worker)**
H	**C** ≥ Irreversible, other serious effects, or symptoms which could impair an individual's ability to take protective action.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.
M	**C** ≥ Mild, transient adverse effects.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.
L	Mild, transient adverse effects > **C**	Minor injuries; no hospitalization **> C**	Minor injuries; no hospitalization **> C**
N	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level

Risk Matrix

Consequences \ Likelihood	A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.8 Kinetic Energy – Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Power tools	*Hazard: Potential pinch or abrasion hazards*	L: C: R: I	*See Section I Chapter 04	L: C: R: IV
Motion Tables	*Hazard: HLCF -Personnel injury due to pinch points, tip-overs, caught in between, crushing.* *Hazard: LLCF -Personnel injury due to pinch points, tip-overs, caught in between, crushing.*	L:U C:L R:III L:U C:L R:III	P- Trolly is manually operated P- Distance crank is located in control room away from motion table P- Motion chain is recessed into guide system M- Trolly construction prevents table from reaching the wall P- Employees must complete training to use facility P- Table is operated by computer located away from motion table M- Emergency stop switch M- Current sensing stop override M- Trolly construction prevents table from reaching the wall	L:BEU C:N R: IV L:BEU C: N R: IV
Mobile Shielding	*Hazard: Personnel injury due to pinch points, tip-overs, caught in between, crushing.*	L:EU C:H R:II	P- Employees must complete training to use facility P- Securing shielding prevents tip overs and pinch points P- Only Facility Workers would need to position projectors M- Rubber bumpers prevent over movement	L:BEU C:M R:IV

Other Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **MOI =** Maximally-exposed Offsite Individual

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ Irreversible, other serious effects, or symptoms which could impair an individual's ability to take protective action.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.
M	**C** ≥ Mild, transient adverse effects.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.
L	Mild, transient adverse effects > **C**	Minor injuries; no hospitalization **>** **C**	Minor injuries; no hospitalization **>** **C**

Risk Matrix

Consequences	Likelihood: A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.9 Kinetic Energy – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Power tools	*Hazard: N/A*	L: C: R:	Public is prevented from having access to work areas	L: C: R:
Motion Tables	*Hazard: N/A*	L: C: R:	Public is prevented from having access to work areas	L: C: R:
Mobile Shielding	*Hazard: N/A*	L: C: R:	Public is prevented from having access to work areas	L: C: R:

Other Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
- **A** = Anticipated (L > 1.0E-02)
- **U** = Unlikely (1.0E-02> L >1.0E-04)
- **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06)
- **BEU** = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
- **H** = High
- **M** = Moderate
- **L** = Low
- **N** = Negligible

Risk (R, Qualitative Ranking)
- **I** = situation (event) of major concern
- **II** = situation (event) of concern
- **III** = situation (event) of minor concern
- **IV** = situation (event) of minimal concern

Control(s) Type
- **P** = Preventive (reduce event occurrence likelihood)
- **M** = Mitigative (reduces event consequences)

Acronyms
- **MOI =** Maximally-exposed Offsite Individual

C	**Offsite (MOI)**	**Onsite-2 (co-located worker)**	**Onsite-1 (facility worker)**
H	**C** ≥ Irreversible, other serious effects, or symptoms which could impair an individual's ability to take protective action.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.
M	**C** ≥ Mild, transient adverse effects.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.
L	Mild, transient adverse effects > **C**	Minor injuries; no hospitalization **>** **C**	Minor injuries; no hospitalization **>** **C**

Risk Matrix

Consequences	**Likelihood** A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.10 Flammable and Combustible Materials – Onsite -1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Combustible materials (cables, boxes, paper, wood cribbing, etc.)	*Hazard:* *This hazard is a potential facility fire.* *The presence of excessive combustible materials can pose a hazard stemming from inadequate housekeeping practices.* *This hazard can add to the fuel load of a potential facility fire.* *Poor housekeeping can also lead to life safety concerns, such as egress obstructions and tripping hazards.* *The exposure of the hazard to the facility worker is of major concern.*	L:A C:H R:I	P - Fire Safety and Life Safety Inspections are performed by the Fire Protection Group and the Fire Department P – Fire alarm systems ITM is performed at prescribed frequencies M – Smoke, heat, sprinklers, are monitored by a sitewide monitoring system with notification to the emergency dispatch center that is constantly staffed, 24/7, 365 days M – Fire detection and/or suppression is present M – Manual fire suppression services are provided, i.e., fire extinguisher throughout the complex M – Building is constructed of concrete slowing the spread of fire M – On-site fire department trained in radiological environments	L:EU C:N R:IV

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Flammable Materials (Flammable gas, cleaning materials, etc.)	*Hazard:* *The presence of flammable gases in cylinders or storage containers pose an inherent hazard due to their flammability/combustibility properties.* *Exposure to hot work provides a dangerous situation where flammable liquids will ignite. Unmitigated this could lead to an explosion and subsequent fire.* *The exposure of the hazard to the facility worker is of major concern.*	L:A C:H R:I	P - Fire Safety and Life Safety Inspections are performed by the Fire Protection Group and the Fire Department P – Fire alarm systems ITM is performed at prescribed frequencies M – Smoke, heat, sprinklers, are monitored by a sitewide monitoring system with notification to the emergency dispatch center that is constantly staffed, 24/7, 365 days M – Fire detection and/or suppression is present M – Manual fire suppression services are provided, i.e., fire extinguishers, throughout the complex M – Building is constructed of concrete slowing the spread of fire M – On-site fire department trained in radiological environments	L:EU C:N R:IV

Other Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
A = Anticipated (L > 1.0E-02)
U = Unlikely (1.0E-02> L >1.0E-04)
EU = Extremely Unlikely (1.0E-04 > L >1.0E-06)
BEU = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
H = High
M = Moderate
L = Low
N = Negligible

Risk (R, Qualitative Ranking)
I = situation (event) of major concern
II = situation (event) of concern
III = situation (event) of minor concern
IV = situation (event) of minimal concern

Control(s) Type
P = Preventive (reduce event occurrence likelihood)
M = Mitigative (reduces event consequences)
Acronyms
MOI = Maximally-exposed Offsite Individual

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ Irreversible, other serious effects, or symptoms which could impair an individual's ability to take protective action.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.
M	**C** ≥ Mild, transient adverse effects.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.
L	Mild, transient adverse effects > **C**	Minor injuries; no hospitalization > **C**	Minor injuries; no hospitalization > **C**
N	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level

Risk Matrix

Consequences \ Likelihood	A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.11 Flammable and Combustible Materials – Onsite -2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Combustible materials (cables, Boxes, Paper, wood cribbing, etc.)	*Hazard:* *The presence of excessive combustible materials can pose a hazard stemming from inadequate housekeeping practices.* *This hazard can add to the fuel load of a potential fire.* *Poor housekeeping can also lead to life safety concerns, such as egress obstructions and tripping hazards.* *The exposure of the hazard to the co-located worker is of concern.*	L:A C:M R:II	P - Fire Safety and Life Safety Inspections are performed by the Fire Protection Group and the Fire Department P – Fire alarm systems ITM is performed at prescribed frequencies M – Smoke, heat, sprinklers, are monitored by a sitewide monitoring system with notification to the emergency dispatch center that is constantly staffed, 24/7, 365 days M – Fire detection and/or suppression is present M – Manual fire suppression services are provided, i.e., fire extinguisher, throughout the complex M – Building is constructed of concrete slowing the spread of fire M – On-site fire department trained in radiological environments	L:EU C:N R:IV

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Flammable Materials (Flammable gas, cleaning materials, etc.)	*Hazard:* *The presence of flammable gases in cylinders or storage containers pose an inherent hazard due to their flammability/combustibility properties.* *The exposure of the hazard to the co-located worker is of concern.*	L: A C:M R:II	P - Fire Safety and Life Safety Inspections are performed by the Fire Protection Group and the Fire Department P – Fire alarm systems ITM is performed at prescribed frequencies M – Smoke, heat, sprinklers, are monitored by a sitewide monitoring system with notification to the emergency dispatch center that is constantly staffed, 24/7, 365 days M – Fire detection and/or suppression is present M – Manual fire suppression services are provided, i.e., fire extinguishers, throughout the complex M – Building is constructed of concrete slowing the spread of fire M – On-site fire department trained in radiological environments	L:EU C:N R:IV

Other Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
A = Anticipated (L > 1.0E-02)
U = Unlikely (1.0E-02> L >1.0E-04)
EU = Extremely Unlikely (1.0E-04 > L >1.0E-06)
BEU = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
H = High
M = Moderate
L = Low
N = Negligible

Risk (R, Qualitative Ranking)
I = situation (event) of major concern
II = situation (event) of concern
III = situation (event) of minor concern
IV = situation (event) of minimal concern

Control(s) Type
P = Preventive (reduce event occurrence likelihood)
M = Mitigative (reduces event consequences)
Acronyms
MOI = Maximally-exposed Offsite Individual

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ Irreversible, other serious effects, or symptoms which could impair an individual's ability to take protective action.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.
M	**C** ≥ Mild, transient adverse effects.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.
L	Mild, transient adverse effects > **C**	Minor injuries; no hospitalization **> C**	Minor injuries; no hospitalization **> C**
N	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level

Risk Matrix

Consequences	Likelihood: A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Table 2.12 Flammable and Combustible Materials – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Combustible materials (cables, Boxes, Paper, wood cribbing, etc.)	*Hazard:* *The presence of excessive combustible materials can pose a hazard stemming from inadequate housekeeping practices.* *This hazard can add to the fuel load of a potential fire.* *Poor housekeeping can also lead to life safety concerns, such as egress obstructions and tripping hazards.* *The exposure of the hazard to the public is of minimal concern.*	L:U C:L R:III	P – Public is screened at Fermi site boundary, and Fermilab restricts public access to accelerator complex. P - Fire Safety and Life Safety Inspections are performed by the Fire Protection Group and the Fire Department P – Fire alarm systems ITM is performed at prescribed frequencies P- EPHS demonstrates no risk of off-site releases to the public M – Smoke, heat, sprinklers, are monitored by a sitewide monitoring system with notification to the emergency dispatch center that is constantly staffed, 24/7, 365 days M – Fire detection and/or suppression is present M – Manual fire suppression services are provided, i.e., fire hydrants, throughout the complex M – Building is constructed of concrete slowing the spread of fire M – On-site fire department trained in radiological environments M – In the event of a fire, site security prohibits access to the public	L:BEU C:N R:IV

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Flammable Materials (Flammable gas, cleaning materials, etc.)	*Hazard:* *The presence of flammable gases in cylinders or storage containers pose an inherent hazard due to their flammability/combustibility properties.* *The exposure of the hazard to the public is of minor concern.*	L: U C:L R:III	P – Public is screened at Fermi site boundary, and Fermilab restricts public access to accelerator complex. P - Fire Safety and Life Safety Inspections are performed by the Fire Protection Group and the Fire Department P – Fire alarm systems ITM is performed at prescribed frequencies M – Smoke, heat, sprinklers, are monitored by a sitewide monitoring system with notification to the emergency dispatch center that is constantly staffed, 24/7, 365 days M – Fire detection and/or suppression is present M – Manual fire suppression services are provided, i.e., fire hydrants, throughout the complex M – Building is constructed of concrete slowing the spread of fire M – On-site fire department trained in radiological environments M – In the event of a fire, site security prohibits access to the public	L:BEU C:N R:IV

Other Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year
A = Anticipated (L > 1.0E-02)
U = Unlikely (1.0E-02> L >1.0E-04)
EU = Extremely Unlikely (1.0E-04 > L >1.0E-06)
BEU = Beyond Extremely Unlikely (1.0E-06> L)

Consequence (C, of event)/year
H = High
M = Moderate
L = Low
N = Negligible

Risk (R, Qualitative Ranking)
I = situation (event) of major concern
II = situation (event) of concern
III = situation (event) of minor concern
IV = situation (event) of minimal concern

Control(s) Type
P = Preventive (reduce event occurrence likelihood)
M = Mitigative (reduces event consequences)
Acronyms
MOI = Maximally-exposed Offsite Individual

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ Irreversible, other serious effects, or symptoms which could impair an individual's ability to take protective action.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.	**C** ≥ Prompt worker fatality or acute injury that is immediately life-threatening or permanently disabling.
M	**C** ≥ Mild, transient adverse effects.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.	**C** ≥ Serious injury, no immediate loss of life no permanent disabilities; hospitalization required.
L	Mild, transient adverse effects > **C**	Minor injuries; no hospitalization **>** **C**	Minor injuries; no hospitalization **>** **C**
N	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level	Consequences less than those for Low Consequence Level

Risk Matrix

Consequences	Likelihood: A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV