SHORT BASELINE NEUTRINO EXPERIMENT AREAS

SECTION IV CHAPTER 07 OF THE FERMILAB SAD

Revision 1 November 16, 2023

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

SAD Chapter Review

This Section IV, Chapter 07 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *Short Baseline Neutrino Experimental Areas*, was prepared and reviewed by the staff of the Particle Physics Directorate 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

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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 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
Catherine James	1	November 16, 2023	• Rename from MicroBooNE to Short Baseline Neutrino Experimental Areas to align with current operations and organizational structure • Update to align with updated SAD Layout • Incorporation of Risk Matrix and hazard discussion • Added presence of fluorinert in the SBND HV system, section 7.2.2.3 • Modify section 7.2.10, Access & Egress, for the SBN-ND building to match recent updates to the building-specific training
Angela Aparicio Catherine James Eric McHugh	0	June 23, 2014	Initial release of the MicroBooNE Detector 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	Large 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

IV-7. Short Baseline Neutrino Experiment Areas

IV-7.1. Introduction

This Section IV, Chapter 7 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the Short Baseline Neutrino (SBN) experiment areas of the Fermilab Main Accelerator. The SBN experiment areas are four buildings located on the path of neutrinos produced by the Booster Neutrino Beam (BNB), each holding a detector used by an experiment collaboration. From south to north these are: the Accelerator Neutrino Neutron Interaction Experiment (ANNIE) in the SciBooNE building; the Short Baseline Near Detector (SBND) in the Short Baseline Neutrino Near Detector building (SBN-ND); the MicroBooNE detector in the Liquid Argon Test Facility (LArTF); and the ICARUS detector in the Short Baseline Neutrino Far Detector building (SBN-FD). Each building has below-grade levels, approximately 30-ft below surface, so the detectors can be positioned on the centerline of the BNB. The SBN detectors are not accelerators, and the buildings sit physically separate from accelerator facilities.

IV-7.1.1 Purpose/Function

The purpose of the experiments in the SBN experiment areas is to measure properties of neutrinos, as part of the Lab's intensity frontier physics program. The experiments also contribute to the development of technology for future large-scale neutrino detectors. Three of the detectors – SBND, MicroBooNE, and ICARUS – are liquid argon time projection chamber (LArTPC) detectors. The LArTPC detector technology offers extraordinarily precise event reconstruction and particle identifications. The technology is being scaled to larger (>10 kiloton) detectors for the Deep Underground Neutrino Experiment (DUNE). ANNIE studies neutrons produced by neutrino-nucleus interactions in water using advanced photosensors; these studies inform the analysis of data from other detectors which are less efficient in neutron detection, such as LArTPCs. Although the design of each SBN detector is not identical to the DUNE detectors, the SBN detectors contribute to DUNE through development of technology and through development of techniques for reconstruction and analysis of complex neutrino interactions.

IV-7.1.2 Current Status

The SBN experiment areas segment of the Fermilab Main Accelerator is currently: **operational.**

IV-7.1.3 Description

The ANNIE detector consists of a water Cerenkov sub-detector coupled with a muon range sub-detector and a veto wall for rejection of background data. The water tank holds 26 tons of pure deionized water with a 0.2% concentration of gadolinium sulfate ($Gd_2O_{12}S_3$) in solution to enhance neutron detection. The muon range detector and veto wall use plastic scintillator. All the ANNIE sub-detectors employ photosensors to detect light from particles resulting from neutrino interactions with the detector materials.

The other three detectors in the SBN experiment areas are LArTPCs. These function by using liquified argon as both the target medium for the neutrinos and the detection medium for the particles resulting from the neutrino interactions. The particles from the interactions produce both light and ionization as they pass through the liquid argon, which is collected by photosensors and wire arrays. The LArTPC detectors are fully immersed in a liquid argon volume contained within cryostats, with attached cryogenics systems to maintain temperature stability and purity. All the cryostats have

plastic scintillator detectors mounted around their exteriors to detect incoming cosmic rays which are a background to the neutrino interactions.

The SBND experiment uses 260 tons of liquid argon contained in a membrane cryostat similar to those utilized for DUNE. The MicroBooNE detector holds 170 tons of liquid argon in a steel cylinder-shape cryostat. The ICARUS detector has a pair of rectangular aluminum-walled cryostats holding a total of 760 tons of liquid argon.

IV-7.1.4 Location

The SBN experiment areas of the Fermilab Main Accelerator are within the Fermilab site in Batavia, IL.

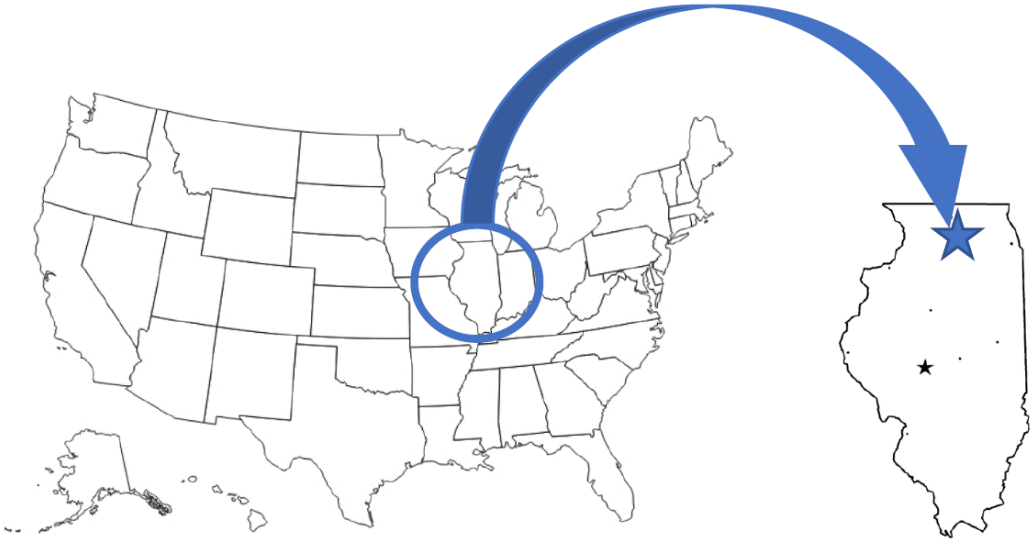

Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.

The SBN Experiment Areas are located on the west side of the Fermilab site, just north of the Main Accelerator.

Figure 2. Aerial view of the Fermilab site, indicating the location of the SBN Experiment Areas.

IV-7.1.5 Management Organization

The Neutrino Division within the Particle Physics Directorate is responsible for the commissioning, normal operations, and emergency management of the SBN Experiment Area facilities including the cryogenics systems. The experiments located in the SBN Experiment Areas are managed by their collaborations who oversee data collection and maintenance of the detectors and data collection systems.

IV-7.1.6 Operating Modes

The experiments in the SBN Experiment Area facilities operate their data collection systems 24/7 whenever the accelerator complex provides neutrinos from the BNB. The collaborations organize their personnel in shifts to monitor the operation of their detectors and data collection systems. The shifts can be performed from the Remote Operations Center (ROC)-West located in Wilson Hall on the Fermilab site or performed by connecting to experiment data collection systems from their home institutions. When the experiments are operating personnel are not required to be present in the SBN Experiment Areas buildings.

IV-7.1.7 Inventory of Hazards

The following table lists all the identified hazards found in the SBN Experiment Areas buildings. Section IV-7.9 *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 reductions and mitigations is described within Section IV-7.2 *Safety Assessment.*

Accelerator specific hazards are identified as **purple/bold** in Table 1; there are no accelerator-specific hazards in the SBN experiment areas. All hazards present in the SBN Experiment Areas 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), as described in Section I Chapter 4. These hazards are considered to be Non-Accelerator-Specific Hazards (NASH), and their specific instances in the SBN areas are summarized in this SAD Chapter.

Table 1. Hazard Inventory for SBN Experiment Areas.

	Radiological		Toxic Materials
☐	Prompt Ionizing Radiation	☐	Lead
☐	Residual Activation	☐	Beryllium
☐	Groundwater Activation	☒	Flourinert & 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
☐	Bakeouts	☒	Pumps and Motors
☐	Hot Work	☐	Motion Tables
☒	Cryogenics	☐	Mobile Shielding
	Potential Energy		**Magnetic Fields**
☒	Crane Operations	☐	Fringe Fields
☐	Compressed Gasses		**Other Hazards**
☒	Vacuum/Pressure Vessels/Piping	☒	Confined Spaces
☒	Vacuum Pumps	☐	Noise
☒	Material Handling	☐	Silica
	Access & Egress	☐	Ergonomics
☒	Life Safety Egress	☐	Asbestos
		☒	Working at Heights

IV-7.2. Safety Assessment

All hazards for the SBN Experiment Areas segment of the Fermilab Main Accelerator are summarized in this section. All are non-accelerator specific hazards (NASH); lab-wide common mitigations to these hazards are described in Section 1 Chapter 4.

IV-7.2.1 Radiological Hazards

The SBN Experiment Areas present radiological hazards in the form of non-ionizing radiation from lasers.

IV-7.2.1.1 Prompt Ionizing Radiation

N/A.

IV-7.2.1.2 Residual Activation

N/A; neutrino interactions with materials does not result in activation of the materials.

IV-7.2.1.3 Groundwater Activation

N/A; neutrino interactions with materials does not result in activation of the materials.

IV-7.2.1.4 Surface Water Activation

N/A.

IV-7.2.1.5 Radioactive Water (RAW) Systems

N/A.

IV-7.2.1.6 Air Activation

N/A; neutrino interactions with materials does not result in activation of the materials.

IV-7.2.1.7 Closed Loop Air Cooling

N/A.

IV-7.2.1.8 Soil Interactions

N/A; neutrino interactions with materials does not result in activation of the materials.

IV-7.2.1.9 Radioactive Waste

N/A; neutrino interactions with materials does not result in activation of the materials.

IV-7.2.1.10 Contamination

N/A.

IV-7.2.1.11 Beryllium-7

N/A.

IV-7.2.1.12 Radioactive Sources

N/A.

IV-7.2.1.13 Nuclear Material

N/A.

IV-7.2.1.14 Radiation Generating Devices (RGDs)

N/A.

IV-7.2.1.15 Non-Ionizing Radiation Hazards

Class 4 and Class 3R lasers are utilized by the SBN experiment area detectors. Class 4 lasers present an unmitigated risk of I which is reduced by controls to a residual risk of IV, as described in the tables in Section I Chapter 4. Class 3R lasers present a Baseline Risk at acceptable level and no further analysis or controls are needed.

Class 4 UV lasers are installed in the MicroBooNE and SBND experiments for calibration of the LArTPC detectors; they are operated infrequently. Each laser and light path is fully enclosed and locked, with safety signage posted on the enclosure when the laser calibration system is in operation. The laser

light paths are entirely below grade, with no possible line-of-sight to above-grade locations either inside or outside the building. The collaborators who operate or service the lasers (SMEs) undergo laser safety training and a laser eye exam. Each laser system has a Standard Operating Procedure (SOP) for the system experts.

Class 3R laser systems are installed in the ANNIE and ICARUS experiments for calibration of their photodetectors. Both systems are located below grade, with light paths entirely contained below grade interior to the buildings. Both systems are operated on a regular periodic basis by their collaborations. The ANNIE calibration system can be operated remotely. The ICARUS calibration system is operated by its experts by accessing the equipment in the SBN-FD building.

All laser installations have been reviewed and approved by the Fermilab Laser Safety Officer (LSO) prior to operation, and meet all requirements found in Fermilab Environment, Safety and Health Manual (FESHM) Chapter *Lasers*, as stated in Section I Chapter 4.

IV-7.2.2 Toxic Materials

The gadolinium sulfate (0.2% solution) which is used by the ANNIE experiment has no occupational exposure limit as evidenced by the SDS. PPE recommendations for safe handling are specified in the material SDS and consist of gloves and safety goggles utilized during any filling/removal operation.

IV-7.2.2.1 Lead

N/A.

IV-7.2.2.2 Beryllium

N/A.

IV-7.2.2.3 Fluorinert & Its Byproducts

Fluorinert is present in the SBN-ND building as a part of the LArTPC detector high voltage sub-system. The high voltage system utilizes electrical filtering of the applied voltage. The electrical filter is contained in a cylindrical vessel, approximately 75 cm length and 20 cm diameter. There are two volumes within a filter vessel which serve to contain two types of dielectric fluid. The larger volume, which holds the main filtering resistor components, contains dielectric oil like that used in transformers. The smaller volume, where the HV cable enters and exits a filter vessel, contains fluorinert. There are two of these filter vessels connected along the length of the HV cable, one where the cable exits the HV PS at ground level north of the detector, and the other where the cable connects to the HV Feed-through, on the top of the detector below-grade at the Mezzanine level. The total volume of fluorinert present in these two filter vessels is approximately 0.6 liter and is contained in a closed system. An acceptable risk level from this hazard is assessed in Section I Chapter 4.

IV-7.2.2.4 Liquid Scintillator Oil

N/A.

IV-7.2.2.5 Pseudocumene

N/A.

IV-7.2.2.6 Ammonia

N/A.

IV-7.2.2.7 Nanoparticle Exposures

N/A.

IV-7.2.3 Flammables and Combustibles

The instances of this hazard in the SBN Experiment Areas have been evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. An unmitigated risk of I is reduced to a residual risk of IV with use of the listed controls. No further or unique controls are utilized in the SBN areas.

IV-7.2.3.1 Combustible Materials

The SBN Experiment buildings utilize the controls described in the tables in Section I Chapter 4.

IV-7.2.3.2 Flammable Materials

N/A; very small volumes (less than 1 liter) of some flammable cleaning materials (e.g. acetone) are stored in fire-proof cabinets at SBN-ND and SBN-FD.

IV-7.2.4 Electrical Energy

All the buildings in the SBN Experiment Areas contain standard electrical power distribution systems. There are no exposed conductors. The experiment detectors in each building utilize both commercial and custom-made equipment for data-taking including DC power supplies. All experiment equipment is reviewed prior to use following the Operational Readiness Clearance process to ensure compliance with electrical safety standards as listed in Section 1 Chapter 4.

IV-7.2.4.1 Stored Energy Exposure

N/A.

IV-7.2.4.2 High Voltage Exposure

The instances of this hazard in the SBN Experiment Areas are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. High voltage electrical installations implement the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of IV. No additional or unique controls are applied.

IV-7.2.4.3 Low Voltage, High Current Exposure

The instances of this hazard in the SBN Experiment Areas are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Low voltage, high current electrical installations implement the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of IV. No additional or unique controls are applied.

IV-7.2.5 Thermal Energy

Cryogenic liquids are present in closed cryogenics systems.

IV-7.2.5.1 Bakeouts

N/A.

IV-7.2.5.2 Hot Work

N/A.

IV-7.2.5.3 Cryogenics

Cryogenic liquids - liquid argon and liquid nitrogen - are present in three of the SBN experiment areas buildings: SBN-ND, LArTF, and SBN-FD. Hazards from these cryogens include the potential for oxygen-deficient (ODH) atmospheres due to catastrophic failure of the cryostat vessel or cryogenic systems, and thermal (cold burn) hazards from cryogenic components and pressure hazards. An oxygen-deficient atmosphere could result from cryogenic systems failure/rupture of the vessel or piping, insulation failure, mechanical damage/failure, deficient maintenance, or improper procedures.

These hazards are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. The cryogenics installations implement the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of IV.

Liquid argon is a primary functional component of the SBND, MicroBooNE and ICARUS experiment detectors. Each of their cryogenics systems consists of the detector cryostat(s), liquid nitrogen and liquid argon storage and distribution tanks, pumps, filter systems, piping, and associated appurtenances. The cryogenics systems circulate and purify large volumes of liquid argon held in cryostats which the experiment detectors are submerged in. Liquid nitrogen is utilized by the cryogenics systems to condense argon boiling off the liquid surface inside the cryostats, a process which helps maintain temperature and pressure control of the cryostat interiors.

At SBN-ND, there is an 8,000-gallon liquid argon dewar and a 9,000-gallon liquid nitrogen dewar located outside the building. Inside, within the below-grade pit area, the SBND cryostat contains approximately 51,000 gallons of liquid argon.

At LArTF there is a 500-gallon liquid argon dewar, an 11,000-gallon liquid nitrogen dewar and an 11,000-gallon liquid argon buffer tank located outside the building. The MicroBooNE cryostat, located in the below-grade pit, contains approximately 32,000 gallons of liquid argon. Note, the MicroBooNE cryostat is being emptied by way of slow boil-off; the process is expected to complete by end of calendar 2023.

At SBN-FD, there is an 8,000-gallon liquid argon dewar and a 20,000-gallon liquid nitrogen dewar located outside the building. The two ICARUS detector cryostats, located in the below-grade pit, each contain approximately 73,000 gallons of liquid argon.

The cryogenic systems are designed and installed to comply with applicable standards per FESHM Chapters *Pressure Vessels*, *Piping Systems*, *Inert Gas Trailer Connections and Onsite Filling Guidelines*, *Gas Regulators*, *Inspection and Testing of Relief Systems*, *Cryogenic System Review, Liquid Nitrogen Dewar Installation and Operation Rules*, and *Liquid Cryogenic Targets*, as stated in Section 1 Chapter 4.1.5.3.

Portions of the distribution piping within the cryogenic systems present the potential for thermal burns; these have been marked and insulation applied to protect workers and users from inadvertent contact.

The presence of cryogenic systems in the SBN experiment areas requires analysis and calculation to determine the ODH class, as described in Section 1 Chapter 4.2.2.2. The buildings containing cryogenic systems - SBN-ND, LarTF, and SBN-FD - are all classified ODH-0 on the ground level and classified ODH-1 on the below-grade levels. All three buildings have ODH safety systems for monitoring of ODH hazards and broadcasting alarms when ODH conditions are detected, as described in Section 1

Chapter 4.3.2.2. The SBN Experiment areas hazard controls include ODH warning signals, oxygen sensors (interlocked with the Fermilab's Fire Incident Reporting and Utility System (FIRUS) alarm), and ventilation fans. The cryogenics controls systems utilize a parallel method of monitoring which reports alarms to the Neutrino Division engineering group and to collaboration personnel monitoring their detectors.

Each SBN building which holds cryogenics has an emergency generator which engages automatically in a power outage. The generators at each building provide power for critical life-safety systems - cryogenics controls, ODH alarms, ventilation of egress paths - maintaining ODH monitoring and safe exit from an ODH incident during power outages.

IV-7.2.6 Kinetic Energy

The SBN Experiment areas all have sump pump systems. SBN-ND and SBN-FD have air compressors supplying pneumatic valves in the cryogenics systems. Powered hand tools are occasionally used during experiment maintenance periods. There are no machine shop tools in the SBN buildings.

IV-7.2.6.1 Power Tools

The hazards from powered hand tools are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Usage of powered hand tools implement the controls specified in the common Risk Matrix table., which reduce an unmitigated risk of I to a residual risk of IV. No additional or unique controls are applied.

IV-7.2.6.2 Pumps and Motors

The hazards from pumps and motors are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Work performed on and with pumps and motors implement the controls specified in the common Risk Matrix table., which reduce an unmitigated risk of I to a residual risk of III. No additional or unique controls are applied.

IV-7.2.6.3 Motion Tables

N/A.

IV-7.2.6.4 Mobile Shielding

N/A.

IV-7.2.7 Potential Energy

Overhead cranes are found within the SBN-ND, LArTF, and SBN-FD buildings. A mobile crane must be utilized for moving heavy equipment in/out of the SciBooNE building.

Compressed gases can be present at all the SBN buildings.

The cryostats and cryogenics systems at SBN-ND, LArTF, and SBN-FD utilize vacuum and pressure vessels, and vacuum/pressure piping; all are designed, installed, reviewed, and approved following FESHM. The ANNIE experiment water tank is not a pressure vessel. Vacuum pumps are found in SBN-ND and SBN-FD.

Materials handling occurs as needed at all the SBN Experiment Areas.

IV-7.2.7.1 Crane Operations

The hazards in crane operations are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Work involving crane operations implements the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of IV. No additional or unique controls are applied.

IV-7.2.7.2 Compressed Gasses

A non-flammable argon/hydrogen gas mixture (2.5% hydrogen, balance argon) is used for regeneration of the argon filtering systems at SBN-ND and SBN-FD. This gas mixture is supplied by a tube trailer located outside of the building. The tube trailer conforms to ASME and DOT standards per FESHM chapters *Pressure Piping Systems*, *Inert Gas Trailer Connections and Onsite Filling Guidelines*, and *Retesting Procedures for DOT Gas Storage Cylinders Including Tube Trailers*. Personnel utilizing the gas trailer have completed Compressed Gas Cylinder Safety training. The mixture does not pose unique hazards. Note – the tube trailer serving SBN-ND is moved from LArTF circa summer 2023.

Standard compressed gas bottles may be present at any of the buildings for incidental work; gas bottle racks are available for storage at all SBN buildings. The hazards in the use of compressed gas in bottles are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Work involving compressed gas bottles implements the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of IV. No additional or unique controls are applied.

IV-7.2.7.3 Vacuum/Pressure Vessels/Piping

The hazards due to the presence of vacuum/pressure vessels/piping operations are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Work involving vacuum/pressure vessels/piping implements the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of IV. No additional or unique controls are applied.

IV-7.2.7.4 Vacuum Pumps

The hazards due to the presence of vacuum pumps are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Work involving vacuum pumps implements the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of III. No additional or unique controls are applied.

IV-7.2.7.5 Material Handling

The hazards due to material handling operations are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Materials handling work implements the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of III. No additional or unique controls are applied.

IV-7.2.8 Magnetic Fields

N/A.

IV-7.2.8.1 Fringe Fields

N/A.

IV-7.2.9 Other Hazards

N/A.

IV-7.2.9.1 Confined Spaces

Confined spaces exist in the SBN Experiment areas. These are: in SciBooNE the lower level surrounding the detectors; in SBN-ND the interior of the cryostat during the installation period before the cryostat top is welded; in LArTF the platform catwalk; in SBN-FD the pipe chase between lower levels and ground level. In all the SBN Experiment areas buildings, the sump pump pits are also confined spaces.

Each of these confined spaces is included on the laboratory's confined space inventory, and require permits for entry, following FESHM Chapter *Confined Spaces*. The hazards in entering these confined spaces are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Entry into the confined spaces implements the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of III. No additional or unique controls are applied.

IV-7.2.9.2 Noise

N/A.

IV-7.2.9.3 Silica

N/A.

IV-7.2.9.4 Ergonomics

N/A.

IV-7.2.9.5 Asbestos

N/A.

IV-7.2.9.6 Working at Heights

Working at heights is periodically necessary in the SBN Experiment areas. These instances are evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. All work at heights implements the controls specified in the common Risk Matrix table, which reduce an unmitigated risk of I to a residual risk of III. No additional or unique controls are applied.

IV-7.2.10 Access & Egress

Access to all the SBN Experimental Areas requires completion of building-specific hazard awareness training courses. Once completed the individual's ID provides entry using via ID card reader into SBN-ND, LarTF, and SBN-FD; an ordinary door key can also be issued to trained personnel. Entry to SciBooNE is only via a key.

When cryogens are present in SBN-ND, LArTF, and SBN-FD then completion of ODH training and medical qualifications is required for entry to ODH-1 classified spaces. These three buildings are classified ODH-0 on their ground levels, allowing normal access to these spaces, and are classified ODH-1 in the below-grade levels. Access to the below-grade mezzanine and pit areas in SBN-ND is via gates at the top of the mezzanine stairs and at the top of the ship-ladder to the pit; ID card access for personnel with ODH training is planned to be installed at the mezzanine gate in 2024. Access to the stairwells and lower levels of LArTF is controlled via a key-tree interlock system; only personnel who have current ODH training are given access codes to the key-tree. Gates at the below-

grade stairwell landings in SBN-FD provide ID card access only for personnel with current ODH training; keys to the gates are available for emergency access.

Each SBN building which holds cryogenics has an emergency generator which engages automatically in a power outage. The generators at each building provide power for critical life-safety systems - cryogenics controls, ODH alarms, ventilation of egress paths - maintaining ODH monitoring and safe exit from an ODH incident during power outages.

In all SBN Experiment Areas buildings, two-person work rules are in effect for any work performed in the ODH-1 classified areas, and for SciBooNE any work below grade.

IV-7.2.10.1 Life Safety Egress

Life safety egress in all SBN Experiment Areas buildings is evaluated within the common Risk Matrix table included in SAD Section I Chapter 4 Safety analysis. Egress design and maintenance implements the controls specified in the common Risk Matrix table, which reduces an unmitigated risk of I to a residual risk of IV.

All the SBN Experiment Areas buildings have multiple exits at ground level, except SciBoone which has only one entrance/exit for the enclosure. SBN-ND has one stairway path from below grade to ground level. Both LArTF and SBN-FD have two stairway paths from below grade to ground level. SBN-ND and LArTF have 4 exit doors at ground level. SBN-FD has 7 exit doors at ground level. Exit through any of the doors controlling entrance to ODH-1 areas does not require key or card reader.

At SBN-FD the designated tornado shelter is the ODH-0 classified below-grade stairwell landing. At LArTF the designated tornado shelter is the nearby MiniBooNE enclosure; a key for emergency entry is located next to the key tree in LArTF. The designated tornado shelter for both SBN-ND and SciBooNE is MI-10; a key for emergency entry to MI-10 is available in SBN-ND. MI-10 is approximately 100 yards from SciBooNE and SBN-ND.

Occupancy at the SBN Experiment Areas buildings during operations is low, generally less than 5 persons. Operation of the experiments does not require personnel to be present in the buildings; monitoring of the experiment and data-taking equipment is performed from remote locations both on and off the Laboratory site. Alarm systems on both the data-taking systems and cryogenics systems alert personnel to deviations from normal status. During installation and commissioning phases the occupancy level of any area can increase but seldom to more than 20 persons. As of autumn 2023, the SBND experiment is completing installation, ICARUS is operating, and MicroBooNE is in the process of decommissioning.

IV-7.2.11 Environmental

No area-specific hazards; see Section I Chapter 4.

IV-7.2.11.1 Hazard to Air

No area-specific hazards; see Section I Chapter 4.

IV-7.2.11.2 Hazard to Water

No area-specific hazards; see Section I Chapter 4.

IV-7.2.11.3 Hazard to Soil

No area-specific hazards; see Section I Chapter 4.

IV-7.3. Summary of Hazards to Members of the Public

No area-specific hazards to the general public; see Section I Chapter 4.

IV-7.4. Summary of Credited Controls

There are no area-specific credited controls.

IV-7.5. Defense-in-Depth Controls

IV-7.5.1 Administrative Controls

Administrative procedures have been put in place to ensure safe operations at the SBN Detector sites.

IV-7.5.1.1 Operation Authorization Document

Operational readiness clearance (ORC) of the experiments is governed by FESHM Chapter 2005 *Operational Readiness Clearance*. Subject matter experts review each aspect of the experiment prior to operations to ensure safe operations. The review includes procedure, hazard analysis and document reviews and walk-throughs of the experiment components. Division head(s) of the area(s) in which experiment components reside grant approval for operations.

IV-7.6. Decommissioning

The SBN buildings may be utilized for future experiments. Decommissioning of the currently operating SBN experiments will follow the requirements of FESHM Chapter 7050, *Rules for Demolition* and FESHM Chapter 8070, *Decontamination and Decommissioning*. DOE Field Element Manager approval shall be obtained prior to the start of any decommissioning activities for the SBN Experiment Areas.

IV-7.7. Summary and Conclusion

This chapter of the Fermilab SAD identifies and assesses specific hazards associated with commissioning and operation of the SBN Experiment Areas. The chapter identifies and describes designs, controls, and procedures to mitigate specific hazards for the ANNIE, SBND, MicroBooNE, and ICARUS experiment detectors. In addition to the specific safety considerations presented in this chapter, the ANNIE, SBND, MicroBooNE, and ICARUS experiments are subject to the global and more general safety requirements, controls, and procedures outlined in Section I of this Fermilab SAD.

The SBN experiments have been/will be constructed, commissioned, and operated within the specific and general considerations of this safety assessment. The preceding discussion of the hazards and their mitigations presented by the SBN Experiment Area operations demonstrate that the experiments can be operated in a manner that will produce minimal hazards to the health and safety of Fermilab workers, researchers, members of the public, as well as to the environment.

IV-7.8. References

[1] Fermilab Radiological Control Manual

[2] MicroBooNE Ground Floor ODH Analysis – The current link is: http://microboone-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=2346

[3] MicroBooNE Hazard Analysis – The current link is: http://microboone-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=1612

[4] MicroBooNE ODH Analysis – The current link is: http://microboone-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=2322

[5] SBN Hazard Analysis – The current link is: https://sbn-docdb.fnal.gov/cgi-bin/cert/ShowDocument?docid=1518

[6] SBN-FD ODH Analysis – EN02219

[7] SBN-ND ODH Analysis – EN02218

IV-7.9. 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 IV-7.4

Table 11. Summary of Baseline and Residual Risks – SBN Experiment Areas

Risk Tables Description		Baseline Risk	Residual Risk
11.1	Radiological – Onsite-1 Facility Worker	R:I/III	R:IV/III
11.2	Radiological – Onsite-2 Co-located Worker	R:I/III	R:IV/III
11.3	Radiological – MOI Offsite	R:N/A	R:N/A
11.4	Flammable & Combustible Materials – Onsite-1 Facility Worker *	R:*	R:*
11.5	Flammable & Combustible Materials – Onsite-2 Co-located worker *	R:*	R:*
11.6	Flammable & Combustible Materials – MOI Offsite *	R:*	R:*
11.7	Electrical Energy – Onsite-1 Facility Worker	R:*	R:*
11.8	Electrical Energy – Onsite-2 Co-located Worker	R:*	R:*
11.9	Electrical Energy – MOI Offsite	R:*	R:*
11.10	Thermal Energy – Onsite-1 Facility Worker	R:*	R:*
11.11	Thermal Energy – Onsite-2 Co-located Worker	R:*	R:*
11.12	Thermal Energy – MOI Offsite	R:*	R:*
11.13	Kinetic Energy – Onsite-1 Facility Worker	R:*	R:*
11.14	Kinetic Energy – Onsite-2 Co-located Worker	R:*	R:*
11.15	Kinetic Energy – MOI Offsite	R:*	R:*
11.16	Potential Energy- Onsite-1 Facility Worker	R:*	R:*
11.17	Potential Energy – Onsite-2 Co-located Worker	R:*	R:*
11.18	Potential Energy – MOI Offsite	R:*	R:*
11.19	Other Hazards – Onsite-1 Facility Worker	R:*	R:*
11.20	Other Hazards – Onsite-2 Co-located Worker	R:*	R:*
11.21	Other Hazards – MOI Offsite	R:*	R:*
11.22	Access & Egress – Onsite-1 Facility Worker	R:*	R:*
11.23	Access & Egress – Onsite-2 Co-located Worker	R:*	R:*
11.24	Access & Egress – MOI Offsite	R:*	R:*
11.25	Environmental Hazards	R:*	R:*

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

NOTE:
Per DOE-HDBK-1163-2020, Appendix C, "Risk Assessment Methodology":
"Events with an unmitigated risk values 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 11.1 Radiological – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Non-ionizing Radiation Hazards Lasers*	*Hazard: Exposure to Class 4 lasers* • Class 4 UV lasers (MicroBooNE and SBND)	L: A C: H R: I	P: Class 1 (light tight) enclosures P: ORC and work planning processes P: Locked/Interlocked system P: LOTO procedure or other procedure approved by the LSO P: Affected areas are posted M: Use of PPE	L: BEU C: M R: IV
	Hazard: Exposure to Class 3R laser • Class 3R laser (ICARUS & ANNIE)	L: A C: L R:III	No analysis required	L: A C: L R: III

***NON-Ionizing Radiation follows rule for "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.

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

	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	

Table 11.2 Radiological – Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Non-ionizing Radiation Hazards Lasers*	*Hazard: Exposure to Class 4 lasers* • Class 4 UV lasers (MicroBooNE and SBND)	L: A C: H R: I	P: Class 1 (light tight) enclosures P: ORC and work planning processes P: Locked/Interlocked system P: LOTO procedure or other procedure approved by the LSO P: Affected areas are posted M: Use of PPE	L: BEU C: M R: IV
	Hazard: Exposure to Class 3R laser • Class 3R laser (ICARUS & ANNIE)	L: A C: L R:III	No analysis required	L: A C: L R: III

***NON-Ionizing Radiation follows rule for "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.

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

	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	

Table 11.3 Radiological – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Non-ionizing Radiation Hazards*	*Hazard: N/A. Laser light does not reach any public areas.*	L: C: R:		L: C: R:

***NON-Ionizing Radiation follows rule for "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 11.4 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:*	L: C: R:	See Section I Chapter 4	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**
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 11.5 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:*	L: C: R:	See Section I Chapter 4	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**
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 11.6 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:*	L: C: R:	See Section I Chapter 4	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**
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 11.7 Electrical Energy – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
High Voltage Exposure	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.8 Electrical Energy 1 Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
High Voltage Exposure	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.9 Electrical Energy – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
High Voltage Exposure	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.10 Thermal Energy – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Cryogenics	*Hazard:* • Cryogenics are located at SBN-ND, LArTF, and SBN-FD • no cryogenics at SciBooNE	L: C: R:	See Section I Chapter 4	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**
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 11.11 Thermal Energy – Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Cryogenics	*Hazard:* • Cryogenics at SBN-ND, LArTF, and SBN-FD • no cryogenics at SciBooNE	L: C: R:	See Section I Chapter 4	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**
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 11.12 Thermal Energy – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Cryogenics	*Hazard:* • Cryogenics systems at SBN-ND, LArTF, and SBN-FD • no cryogens at SciBooNE	L: C: R:	See Section I Chapter 4	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**
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 11.13 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:*	L: C: R:	See Section I Chapter 4	L: C: R:
Pumps and Motors	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.14 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:*	L: C: R:	See Section I Chapter 4	L: C: R:
Pumps and Motors	*Hazard:*	L: C: R:	See Section I Chapter 4	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 11.15 Kinetic Energy – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Power tools	*Hazard:*	L: C: R:	See Section I Chapter 4	L: C: R:
Pumps and Motors	*Hazard:*	L: C: R:	See Section I Chapter 4	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 11.16 Potential Energy – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Crane Operations	*Hazard:* Overhead cranes are found in SBN-ND, LArTF and SBN-FD	L: C: R:	See Section I Chapter 4	L: C: R:
Vacuum/ Pressure Vessels/Piping	*Hazard:*	L: C: R:	See Section I Chapter 4	L: C: R:
Vacuum Pumps	*Hazard:* Vacuum pumps are found in SBN-ND and SBN-FD	L: C: R:	See Section I Chapter 4	L: C: R:
Material Handling	*Hazard:*	L: C: R:	See Section I Chapter 4	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.

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

	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	

Table 11.17 Potential Energy – Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Crane Operations	*Hazard:* Overhead cranes are found in SBN-ND, LArTF and SBN-FD	L: C: R:	See Section I Chapter 4	L: C: R:
Vacuum/ Pressure Vessels/Piping	*Hazard:*	L: C: R:	See Section I Chapter 4	L: C: R:
Vacuum Pumps	*Hazard:* Vacuum pumps are found in SBN-ND and SBN-FD	L: C: R:	See Section I Chapter 4	L: C: R:
Material Handling	*Hazard:*	L: C: R:	See Section I Chapter 4	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.

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

	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	

Table 11.18 Potential Energy – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Crane Operations	*Hazard:* Overhead cranes are found in SBN-ND, LArTF and SBN-FD	L: C: R:	See Section I Chapter 4	L: C: R:
Vacuum/ Pressure Vessels/Piping	*Hazard:*	L: C: R:	See Section I Chapter 4	L: C: R:
Vacuum Pumps	*Hazard:* Vacuum pumps are found in SBN-ND and SBN-FD	L: C: R:	See Section I Chapter 4	L: C: R:
Material Handling	*Hazard:*	L: C: R:	See Section I Chapter 4	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.

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

	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	

Table 11.19 Other hazards – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Confined Spaces	*Hazard:*	L: C R:	See Section I Chapter 4	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**
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 11.20 Other hazards – Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Confined Spaces	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.21 Other hazards – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Confined Spaces	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.22 Access & Egress – Onsite-1 Facility Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Life Safety Egress	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.23 Access & Egress – Onsite-2 Co-located Worker

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Life Safety Egress	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.24 Access & Egress – MOI Offsite

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Life Safety Egress	*Hazard:*	L: C: R:	See Section I Chapter 4	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**
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 11.25 Environmental

Hazard	Hazard Description	Baseline Qualitative Risk (without controls)	Preventative (P)/ Mitigative (M)	Residual Qualitative Risk (with controls)
Airborne	*Hazard:*	L: C: R:	See Section I Chapter 4	L: C: **R:**
Water	*Hazard:*	L: C: R:	See Section I Chapter 4	L: C: **R:**
Soil	*Hazard:*	L: C: R:	See Section I Chapter 4	L: C: **R:**