# SHORT BASELINE NEUTRINO EXPERIMENT AREAS

## SECTION IV CHAPTER 07 OF THE FERMILAB SAD

Revision 01 August 09, 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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# 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 | August 9, 2023 | • Rename from MicroBooNE to Short Baseline Neutrino Experimental Areas to align with current operations and organizational structure<br>• Update to align with updated SAD Layout<br>• Incorporation of Risk Matrix and hazard discussion |
| Angela Aparicio<br>Catherine James<br>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 | Harge Hadron Collider |
| LLCF | Low Level Calibration Facility |
| LLWCP | Low Level Waste Certification Program |
| LLWHF | Low Level Waste Handling Facility |
| LOTO | Lockout/Tagout |
| LPM | Laser Profile Monitor |
| LSND | Liquid Scintillator Neutrino Detector |
| LSO | Laser Safety Officer |
| m | meter |
| mA | milli-amp |
| MABAS | Mutual Aid Box Alarm System |
| MARS | Monte Carlo Shielding Computer Code |
| MC | Meson Center |
| MC&A | Materials Control and Accountability |
| MCR | Main Control Room |
| MEBT | Medium Energy Beam Transport |
| MEI | Maximally Exposed Individual |
| MeV | Mega-electron volt |
| MI | Main Injector |
| MINOS | Main Injector Neutrino Oscillation Search |
| MMR | Material Move Request |
| MOI | Maximally-Exposed Offsite Individual *(Note: due to the Fermilab Batavia Site being open to the public, the location of the MOI is taken to be the location closest to the accelerator that is accessible to members of the public.)* |
| MP | Meson Polarized |

| | |
|---|---|
| mrad | milli-radian |
| mrem | milli-rem |
| mrem/hr | milli-rem per hour |
| MT | Meson Test |
| MTA | 400 MeV Test Area |
| MTF | Magnet Test Facility |
| $^{22}$Na | Sodium-22 |
| NC | Neutrino Center |
| NE | Neutrino East |
| NEC | National Electrical Code |
| NEPA | National Environmental Policy Act |
| NESHAPS | National Emissions Standards for Hazardous Air Pollutants |
| NFPA | National Fire Protection Association |
| NM | Neutrino Muon |
| NMR | Nuclear Material Representative |
| NOvA | Neutrino Off-axis Electron Neutrino (ve) Appearance |
| NPH | Natural Phenomena Hazard |
| NRTL | Nationally Recognized Testing Laboratory |
| NIF | Neutron Irradiation Facility |
| NTSB | Neutrino Target Service Building, see also TSB |
| NuMI | Neutrinos at the Main Injector |
| NW | Neutrino West |
| ODH | Oxygen Deficiency Hazard |
| ORC | Operational Readiness Clearance |
| OSHA | Occupational Safety and Health Administration |
| pCi | pico-Curie |
| pCi/mL | pico-Curie per milliliter |
| PE | Professional Engineer |
| PIN | Personal Identification Number |
| PIP | Proton Improvement Plan |
| PIP-II | Proton Improvement Plan - II |
| PHAR | Preliminary Hazards Analysis Report |
| PPD | Particle Physics Directorate |
| PPE | Personnel Protective Equipment |
| QA | Quality Assurance |
| QAM | Quality Assurance Manual |
| RA | Radiation Area |
| RAF | Radionuclide Analysis Facility |
| RAW | Radioactive Water |
| RCT | Radiological Control Technician |
| RF | Radio-Frequency |
| RFQ | Radio-Frequency Quadrupole |
| RIL | RFQ Injector Line |

| | |
|---|---|
| RMA | Radioactive Material Area |
| RMS | Root Mean Square |
| RPCF | Radiation Physics Calibration Facility |
| RPE | Radiation Physics Engineering Department |
| RPO | Radiation Physics Operations Department |
| RRM | Repetition Rate Monitor |
| RSI | Reviewed Safety Issue |
| RSIS | Radiation Safety Interlock System |
| RSO | Radiation Safety Officer |
| RWP | Radiological Work Permit |
| SA | Shielding Assessment |
| SAA | Satellite Accumulation Areas |
| SAD | Safety Assessment Document |
| SCF | Standard Cubic Feet |
| SCFH | Standard Cubic Feet per Hour |
| SEWS | Site-Wide Emergency Warning System |
| SNS | Spallation Neutron Source |
| SR | Survey Riser |
| SRF | Superconducting Radio-Frequency |
| SRSO | Senior Radiation Safety Officer |
| SSB | Switchyard Service Building |
| SSP | Site Security Plan |
| SWIC | Segmented Wire Ionization Chambers |
| TLM | Total Loss Monitor |
| TLVs | Threshold Limit Values |
| TPC | Time Projection Chamber |
| TPES | Target Pile Evaporator Stack |
| TPL | Tagged Photon Lab |
| TSB | Target Service Building, see also NTSB |
| TSCA | Toxic Substances Control Act |
| TSW | Technical Scope of Work |
| T&I | Test and Instrumentation |
| UPB | Utility Plant Building |
| UPS | Uninterruptible Power Supply |
| USI | Unreviewed Safety Issue |
| VCTF | Vertical Cavity Test Facility |
| VHRA | Very High Radiation Area |
| VMS | Village Machine Shop |
| VMTF | Vertical Magnet Test Facility |
| VTS | Vertical Test Stand |
| WSHP | Worker Safety and Health Program |
| μs | micro-second |

# 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. 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 detectors in the SBN experiment areas is to measure properties of neutrinos, as well as continuing the development of technology for future large-scale Liquid Argon 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 detector coupled with a muon range 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 detector segments 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 the 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.

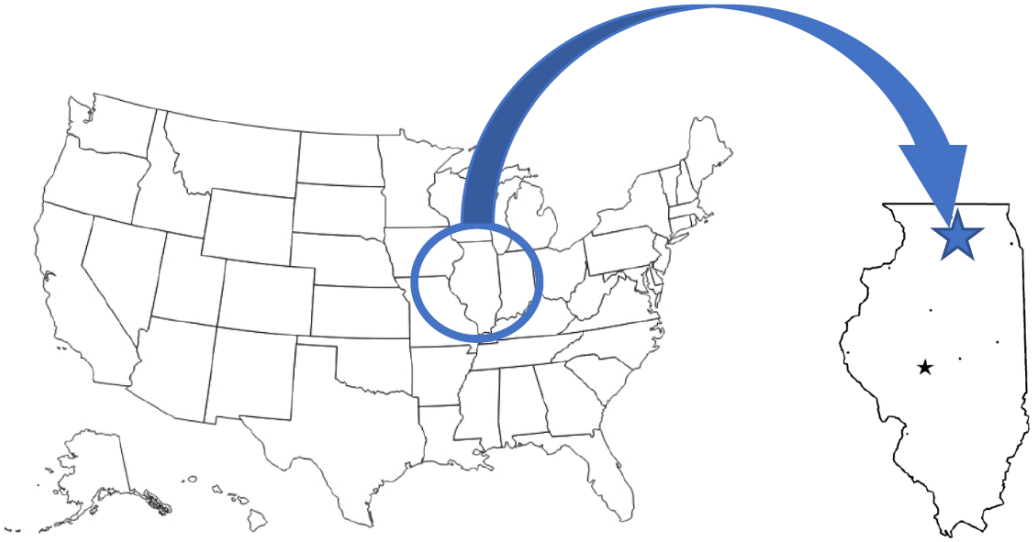

*Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.*

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

Prompt ionizing, Oxygen Deficiency Hazards due to cryogenic systems within accelerator enclosures, and fluorinert byproducts due to use of fluorinert that is subject to particle beam have been identified as accelerator specific hazards, and as such their controls are identified as Credited Controls. The analysis of these hazards and their Credited Controls will be discussed within this SAD Chapter, and

their Credited Controls summarized in the Accelerator Safety Envelope. Accelerator specific controls are identified as **purple/bold** throughout this Chapter.

All other hazards present in the SBN Experiment Areas are safely managed by other DOE approved applicable safety and health programs and/or processes, and their analyses have been performed according to applicable DOE requirements as flowed down through the Fermilab Environment, Safety and Health Manual (FESHM). These hazards are considered to be Standard Industrial Hazards (SIH), and their analysis will be 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, with additional details of the analyses for accelerator specific hazards.

### 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

Not applicable.

#### IV-7.2.1.2 Residual Activation

Not applicable; neutrino interactions with materials does not result in activation of the materials.

#### IV-7.2.1.3 Groundwater Activation

Not applicable; neutrino interactions with materials does not result in activation of the materials.

#### IV-7.2.1.4 Surface Water Activation

Not applicable.

#### IV-7.2.1.5 Radioactive Water (RAW) Systems

Not applicable.

#### IV-7.2.1.6 Air Activation

Not applicable; neutrino interactions with materials does not result in activation of the materials.

#### IV-7.2.1.7 Closed Loop Air Cooling

Not applicable.

#### IV-7.2.1.8 Soil Interactions

Not applicable; neutrino interactions with materials does not result in activation of the materials.

#### IV-7.2.1.9 Radioactive Waste

Not applicable; neutrino interactions with materials does not result in activation of the materials.

#### IV-7.2.1.10 Contamination

Not applicable.

#### IV-7.2.1.11 Beryllium-7

Not applicable.

#### IV-7.2.1.12 Radioactive Sources

Not applicable.

#### IV-7.2.1.13 Nuclear Material

Not applicable.

#### IV-7.2.1.14 Radiation Generating Devices (RGDs)

Not applicable.

#### 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 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 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*.

### IV-7.2.2 Toxic Materials

Not applicable.

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

Not applicable.

#### IV-7.2.2.2 Beryllium

Not applicable.

#### IV-7.2.2.3 Fluorinert & Its Byproducts

Not applicable.

#### IV-7.2.2.4 Liquid Scintillator Oil

Not applicable.

#### IV-7.2.2.5 Pseudocumene

Not applicable.

#### IV-7.2.2.6 Ammonia

Not applicable.

#### IV-7.2.2.7 Nanoparticle Exposures

Not applicable.

### 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

Not applicable; very small volumes (less than 1 litre) of some flammable cleaning materials (e.g. acetone) are stored in fire-proof cabinets.

### IV-7.2.4 Electrical Energy

All the buildings in the SBN Experiment Areas contain standard electrical power distribution systems. 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 Operational Readiness Clearance process to ensure compliance with electrical safety standards.

#### IV-7.2.4.1 Stored Energy Exposure

Not applicable.

#### 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

Not applicable.

#### IV-7.2.5.2 Hot Work

Not applicable.

#### *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 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 autumn 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*.

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. All staff and users of the SBN facilities must complete building hazard awareness training that covers the potential hazards of cryogenic material.

The presence of cryogenic systems in the SBN experiment areas require ODH safety systems for monitoring of ODH hazards and broadcasting alarms when ODH conditions are detected. 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 also 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

Not applicable.

#### IV-7.2.6.4 Mobile Shielding

Not applicable.

### 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 in 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

Not applicable.

#### IV-7.2.8.1 Fringe Fields

Not applicable.

### IV-7.2.9 Other Hazards

Not applicable.

#### 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 lower-level pit surrounding the cryostat and during installation the interior of the cryostat; 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

Not applicable.

#### IV-7.2.9.3 Silica

Not applicable.

#### IV-7.2.9.4 Ergonomics

Not applicable.

#### IV-7.2.9.5 Asbestos

Not applicable.

#### 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 SBN-ND, LArTF, and SBN-FD requires completion of building-specific hazard awareness training courses. Once completed the individual's ID provides entry using via ID card reader; an ordinary door key can also be issued on request. 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. All of SBN-ND including the ground level is classified ODH-1 after the SBND cryostat is filled (expected before end of calendar 2023). LArTF and SBN-FD are classified ODH-0 on the ground level, allowing normal access to these spaces, while in both buildings the lower levels are classified ODH-1. 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.

#### 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 summer 2023, the SBND experiment is completing installation; all other experiments are operating and taking data.

#### 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-7.4.1 Passive Credited Controls

No area-specific controls.

##### IV-7.4.1.1 Shielding

Not applicable.

###### *IV-7.4.1.1.1 Permanent Shielding Including Labyrinths*

Not applicable.

#### *IV-7.4.1.1.2 Movable Shielding*

Not applicable.

#### *IV-7.4.1.1.3 Penetration Shielding*

Not applicable.

### IV-7.4.1.2 Fencing

Not applicable.

#### *IV-7.4.1.2.1 Radiation Area Fencing*

Not applicable.

#### *IV-7.4.1.2.2 Controlled Area Fencing*

Not applicable.

### IV-7.4.2 Active Engineered Credited Controls

### IV-7.4.2.1 Radiation Safety Interlock System

Not applicable.

### IV-7.4.2.2 ODH Safety System

Not applicable.

### IV-7.4.3 Administrative Credited Controls

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

### IV-7.4.3.1 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-7.4.3.2 Staffing

Not applicable.

### IV-7.4.3.3 Accelerator Operating Parameters

Not applicable.

## IV-7.5. Defense-in-Depth Controls

Not applicable.

## IV-7.6. Machine Protection Controls

Not applicable.

## IV-7.7. 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-7.8. 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-7.9. 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-7.10. Appendix – Risk Matrices

Risk Assessment methodology was developed based on the methodology described in DOE-HDBK-1163-2020. Hazards and their potential events are evaluated for likelihood and potential consequence assuming no controls in place, which results in a baseline risk. A baseline risk (i.e., an unmitigated risk) value of III and IV does not require further controls based on the Handbook. Events with a baseline risk value of I or II do require prevention and/or mitigation measures to be established in order to

reduce the risk value to an acceptable level of III or IV. Generally, preventive controls are applied prior to a loss event, reflecting a likelihood reduction, and mitigative controls are applied after a loss event, reflecting a consequence reduction. For each control put in place, likelihood or consequence can have a single “bin drop”, resulting in a new residual risk (i.e., a mitigated risk). This risk assessment process is repeated for each hazard for Facility Workers (FW), Co-Located Workers (CLW), and Maximally-Exposed Offsite Individual (MOI). At the conclusion of the risk assessments, controls that are in place for the identified accelerator specific hazards are identified as Credited Controls and further summarized in Section I-Chapter 4

**Table 2. Summary of Baseline and Residual Risks – Short Baseline Neutrino Experiment (SBNAD)**

| Risk Tables Description | | Baseline Risk | Residual Risk |
|---|---|---|---|
| 2,1 | Radiological – Onsite-1 Facility Worker | R:I/III | R:IV/III |
| 2.2 | Radiological – Onsite-2 Co-located Worker | R:I/III | R:IV/III |
| 2.3 | Radiological – MOI Offsite | R:N/A | R:N/A |
| 2.4 | Flammable & Combustible Materials – Onsite-1 Facility Worker * | R:* | R:* |
| 2.5 | Flammable & Combustible Materials – Onsite-2 Co-located worker * | R:* | R:* |
| 2.6 | Flammable & Combustible Materials – MOI Offsite * | R:* | R:* |
| 2.7 | Electrical Energy – Onsite-1 Facility Worker | R:* | R:* |
| 2.8 | Electrical Energy – Onsite-2 Co-located Worker | R:* | R:* |
| 2.9 | Electrical Energy – MOI Offsite | R:* | R:* |
| 2.10 | Thermal Energy – Onsite-1 Facility Worker | R:* | R:* |
| 2.11 | Thermal Energy – Onsite-2 Co-located Worker | R:* | R:* |
| 2.12 | Thermal Energy – MOI Offsite | R:* | R:* |
| 2.13 | Kinetic Energy – Onsite-1 Facility Worker | R:* | R:* |
| 2.14 | Kinetic Energy – Onsite-2 Co-located Worker | R:* | R:* |
| 2.15 | Kinetic Energy – MOI Offsite | R:* | R:* |
| 2.16 | Potential Energy- Onsite-1 Facility Worker | R:* | R:* |
| 2.17 | Potential Energy – Onsite-2 Co-located Worker | R:* | R:* |
| 2.18 | Potential Energy – MOI Offsite | R:* | R:* |
| 2.19 | Other Hazards – Onsite-1 Facility Worker | R:* | R:* |
| 2.20 | Other Hazards – Onsite-2 Co-located Worker | R:* | R:* |
| 2.21 | Other Hazards – MOI Offsite | R:* | R:* |
| 2.22 | Access & Egress – Onsite-1 Facility Worker | R:* | R:* |
| 2.23 | Access & Egress – Onsite-2 Co-located Worker | R:* | R:* |
| 2.24 | Access & Egress – MOI Offsite | R:* | R:* |
| 2.25 | Environmental Hazards | R:* | R:* |

*Refer to Standard Industrial Risk assessments in Section I Chapter 4

**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 2.1 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*<br>• Class 4 UV lasers (MicroBooNE and SBND)<br><br>*Hazard: Exposure to Class 3R laser*<br>• Class 3R laser (ICARUS & ANNIE) | L: A<br>C: H<br>R: I<br><br>L: A<br>C: L<br>R:III | P: Class 1 (light tight) enclosures<br>P: ORC and work planning processes<br>P: Locked/Interlocked system<br>P: LOTO procedure or other procedure approved by the LSO<br>P: Affected areas are posted<br>M: Use of PPE<br><br>No analysis required | L: BEU<br>C: M<br>R: IV<br><br>L: A<br>C: L<br>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. |
| **L** | Mild, transient adverse effects > **C** | Minor injuries; no hospitalization **>** **C** | Minor injuries; no hospitalization **>** **C** |
| **N** | Consequences less than those for Low Consequence Level | Consequences less than those for Low Consequence Level | Consequences less than those for Low Consequence Level |

**Risk Matrix**

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

**Table 2.2 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*<br>• Class 4 UV lasers (MicroBooNE and SBND) | L: A<br>C: H<br>R: I | P: Class 1 (light tight) enclosures<br>P: ORC and work planning processes<br>P: Locked/Interlocked system<br>P: LOTO procedure or other procedure approved by the LSO<br>P: Affected areas are posted<br>M: Use of PPE | L: BEU<br>C: M<br>R: IV |
| | *Hazard: Exposure to Class 3R laser*<br>• Class 3R laser (ICARUS & ANNIE) | L: A<br>C: L<br>R:III | No analysis required | L: A<br>C: L<br>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. |
| **L** | Mild, transient adverse effects > **C** | Minor injuries; no hospitalization **>** **C** | Minor injuries; no hospitalization **>** **C** |
| **N** | Consequences less than those for Low Consequence Level | Consequences less than those for Low Consequence Level | Consequences less than those for Low Consequence Level |

**Risk Matrix**

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

**Table 2.3 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* | L:<br>C:<br>R: | | L:<br>C:<br>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 2.4 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• No unique combustible materials in SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.5 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• No unique combustible materials in SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.6 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• No unique combustible materials in SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.7 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• No unique electrical systems in SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.8 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• No unique electrical systems in SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.9 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• No unique electrical systems in SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.10 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Cryogenics are located at SBN-ND, LArTF, and SBN-FD<br>• no cryogenics at SciBooNE | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.11 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Cryogenics at SBN-ND, LArTF, and SBN-FD<br>• no cryogenics at SciBooNE | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.12 Thermal Energy – MOI Offsite**

| Hazard | Hazard Description | Baseline Qualitative Risk (without controls) | Preventative (P)/ Mitigative (M) | Residual Qualitative Risk (with controls) |
|---|---|---|---|---|
| Cryogenics | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Cryogenics systems at SBN-ND, LArTF, and SBN-FD<br>• no cryogens at SciBooNE | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.13 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:*<br>• Similar to those listed in Standard Industrial Hazards table<br>• There are no machine-shop tools in the SBN Buildings | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Pumps and Motors | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• no unique pumps or motors in the SBN Buildings | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.14 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• There are no machine-shop tools in the SBN Buildings | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Pumps and Motors | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• no unique pumps or motors in the SBN Buildings | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |

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

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

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

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

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

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

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

**Risk Matrix**

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

**Table 2.15 Kinetic Energy – MOI Offsite**

| Hazard | Hazard Description | Baseline Qualitative Risk (without controls) | Preventative (P)/ Mitigative (M) | Residual Qualitative Risk (with controls) |
|---|---|---|---|---|
| Power tools | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• There are no machine-shop tools in the SBN Buildings | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Pumps and Motors | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• no unique pumps or motors in the SBN Buildings | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |

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

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

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

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

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

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

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

**Risk Matrix**

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

**Table 2.16 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Overhead cranes are found in SBN-ND, LArTF and SBN-FD | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Vacuum/ Pressure Vessels/Piping | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Vacuum and/or pressure vessels and piping are found in all SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Vacuum Pumps | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Vacuum pumps are found in SBN-ND and SBN-FD | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Material Handling | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Material handling is performed in all SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.17 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Overhead cranes are found in SBN-ND, LArTF and SBN-FD | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Vacuum/ Pressure Vessels/Piping | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Vacuum and/or pressure vessels are found in all SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Vacuum Pumps | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Vacuum pumps are found in SBN-ND and SBN-FD | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Material Handling | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Material handling is performed in all SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.18 Potential Energy – MOI Offsite**

| Hazard | Hazard Description | Baseline Qualitative Risk (without controls) | Preventative (P)/ Mitigative (M) | Residual Qualitative Risk (with controls) |
|---|---|---|---|---|
| Crane Operations | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Overhead cranes are found in SBN-ND, LArTF and SBN-FD | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Vacuum/ Pressure Vessels/Piping | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Vacuum and/or pressure vessels are found in all SBN | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Vacuum Pumps | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Vacuum pumps are found in SBN-ND and SBN-FD | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>R: |
| Material Handling | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• Material handling is performed in all SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.19 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• There are confined spaces in all SBN areas | L:<br>C<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.20 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:*<br>• Similar to those listed in Standard Industrial Hazards<br>• There are confined spaces in all SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.21 Other hazards – MOI Offsite**

| Hazard | Hazard Description | Baseline Qualitative Risk (without controls) | Preventative (P)/ Mitigative (M) | Residual Qualitative Risk (with controls) |
|---|---|---|---|---|
| Confined Spaces | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards<br>• There are confined spaces in all SBN areas | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.22 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:*<br>• Similar to those listed in Standard Industrial Hazards | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.23 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:*<br>• Similar to those listed in Standard Industrial Hazards | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.24 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:*<br>• Similar to those listed in Standard Industrial Hazards | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>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 2.25 Environmental**

| Hazard | Hazard Description | Baseline Qualitative Risk (without controls) | Preventative (P)/ Mitigative (M) | Residual Qualitative Risk (with controls) |
|---|---|---|---|---|
| Airborne | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>**R:** |
| Water | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>**R:** |
| Soil | *Hazard:*<br>• Similar to those listed in Standard Industrial Hazards | L:<br>C:<br>R: | See Section I Chapter 4 | L:<br>C:<br>**R:** |