MINIBOONE DETECTOR

SECTION IV CHAPTER 04 OF THE FERMILAB SAD

Revision 1 January 6, 2024

This Chapter of the Fermilab Safety Assessment Document (SAD) contains a summary of the results of the Safety Analysis for the MiniBooNE Detector segment 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 04 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *MiniBooNE Detector*, was prepared and reviewed by the staff of the Particle Physics Directorate, Neutrino Division, Technical Support Department in conjunction with the Environment, Safety & Health Division (ESH) Accelerator Safety Department.

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

☐ ______________________________________
Line Organization Owner

☐ ______________________________________
Accelerator Safety Department Head

☐ ______________________________________
SAD Review Subcommittee Chair

Revision History

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

Author	Rev. No.	Date	Description of Change
Eric McHugh	0	January 9, 2012	Initial release of the MiniBooNE Detector chapter of the Fermilab Safety Assessment Document.
Cindy Joe	1	January 6, 2024	Incorporation of Risk Matrix and hazard discussion.

Table of Contents

Acronyms and Abbreviations

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

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

HAR	Hazard Analysis Report
HCA	High Contamination Area
HCTT	Hazard Control Technology Team
HEP	High Energy Physics
HFD	Hold for Decay
HLCF	High Level Calibration Facility
HPR	Highly Protected Risk
Hr	Hour
HRA	High Radiation Area
HSSD	High Sensitivity Air Sampling Detection
HVAC	Heating, Ventilation, and Air Conditioning
HWSF	Hazardous Waste Storage Facility
Hz	Hertz
IB	Industrial Building
IBC	International Building Code
ICW	Industrial Cooling Water
IEPA	Illinois Environmental Protection Agency
IEEE	Institute of Electrical and Electronics Engineers
INFN	Istituto Nazionale di Fisica Nucleare
IMPACT	Integrated Management Planning and Control Tool
IPCB	Illinois Pollution Control Board
IQA	Integrated Quality Assurance
ISD	Infrastructure Services Division
ISM	Integrated Safety Management
ITNA	Individual Training Needs Assessment
KeV	kilo-electron volt
kg	kilo-grams
kW	kilo-watt
LBNF	Long Baseline Neutrino Facility
LCW	Low Conductivity Water
LHC	Large Hadron Collider
LLCF	Low Level Calibration Facility
LLWCP	Low Level Waste Certification Program
LLWHF	Low Level Waste Handling Facility
LOTO	Lockout/Tagout
LPM	Laser Profile Monitor
LSND	Liquid Scintillator Neutrino Detector

LSO	Laser Safety Officer
m	meter
mA	milli-amp
MABAS	Mutual Aid Box Alarm System
MARS	Monte Carlo Shielding Computer Code
MC	Meson Center
MC&A	Materials Control and Accountability
MCR	Main Control Room
MEBT	Medium Energy Beam Transport
MEI	Maximally Exposed Individual
MeV	Mega-electron volt
MI	Main Injector
MINOS	Main Injector Neutrino Oscillation Search
MMR	Material Move Request
MOI	Maximally-Exposed Offsite Individual *(Note: due to the Fermilab Batavia Site being open to the public, the location of the MOI is taken to be the location closest to the accelerator that is accessible to members of the public.)*
MP	Meson Polarized
mrad	milli-radian
mrem	milli-rem
mrem/hr	milli-rem per hour
MT	Meson Test
MTA	400 MeV Test Area
MTF	Magnet Test Facility
^{22}Na	Sodium-22
NC	Neutrino Center
NE	Neutrino East
NEC	National Electrical Code
NEPA	National Environmental Policy Act
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NM	Neutrino Muon
NMR	Nuclear Material Representative
NOvA	Neutrino Off-axis Electron Neutrino (ve) Appearance
NPH	Natural Phenomena Hazard
NRTL	Nationally Recognized Testing Laboratory
NIF	Neutron Irradiation Facility

NTSB	Neutrino Target Service Building, see also TSB
NuMI	Neutrinos at the Main Injector
NW	Neutrino West
ODH	Oxygen Deficiency Hazard
ORC	Operational Readiness Clearance
OSHA	Occupational Safety and Health Administration
pCi	pico-Curie
pCi/mL	pico-Curie per milliliter
PE	Professional Engineer
PIN	Personal Identification Number
PIP	Proton Improvement Plan
PIP-II	Proton Improvement Plan - II
PHAR	Preliminary Hazards Analysis Report
PPD	Particle Physics Directorate
PPE	Personnel Protective Equipment
QA	Quality Assurance
QAM	Quality Assurance Manual
RA	Radiation Area
RAF	Radionuclide Analysis Facility
RAW	Radioactive Water
RCT	Radiological Control Technician
RF	Radio-Frequency
RFQ	Radio-Frequency Quadrupole
RIL	RFQ Injector Line
RMA	Radioactive Material Area
RMS	Root Mean Square
RPCF	Radiation Physics Calibration Facility
RPE	Radiation Physics Engineering Department
RPO	Radiation Physics Operations Department
RRM	Repetition Rate Monitor
RSI	Reviewed Safety Issue
RSIS	Radiation Safety Interlock System
RSO	Radiation Safety Officer
RWP	Radiological Work Permit
SA	Shielding Assessment
SAA	Satellite Accumulation Areas
SAD	Safety Assessment Document

SCF	Standard Cubic Feet
SCFH	Standard Cubic Feet per Hour
SEWS	Site-Wide Emergency Warning System
SNS	Spallation Neutron Source
SR	Survey Riser
SRF	Superconducting Radio-Frequency
SRSO	Senior Radiation Safety Officer
SSB	Switchyard Service Building
SSP	Site Security Plan
SWIC	Segmented Wire Ionization Chambers
TLM	Total Loss Monitor
TLVs	Threshold Limit Values
TPC	Time Projection Chamber
TPES	Target Pile Evaporator Stack
TPL	Tagged Photon Lab
TSB	Target Service Building, see also NTSB
TSCA	Toxic Substances Control Act
TSW	Technical Scope of Work
T&I	Test and Instrumentation
UPB	Utility Plant Building
UPS	Uninterruptible Power Supply
USI	Unreviewed Safety Issue
VCTF	Vertical Cavity Test Facility
VHRA	Very High Radiation Area
VMS	Village Machine Shop
VMTF	Vertical Magnet Test Facility
VTS	Vertical Test Stand
WSHP	Worker Safety and Health Program
µs	micro-second

IV-4. MiniBooNE Detector

IV-4.1. Introduction

This Section IV, Chapter 04 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the MiniBooNE detector segment of the Fermilab Main Accelerator.

IV-4.1.1 Purpose/Function

MiniBooNE was the first phase of the Booster Neutrino Experiment (BooNE); in this phase, neutrino oscillation measurements were made with a single detector. Previous plans had included the possibility of an upgrade to stage two BooNE with a two-detector configuration, but this did not occur.

The BooNE experiment proposed to definitively explore the neutrino oscillation signal reported by the Los Alamos Liquid Scintillator Neutrino Detector (LSND) experiment. MiniBooNE represented the first phase for the BooNE collaboration and consisted of a 1 GeV neutrino beam and a single, 800-ton mineral oil detector (the MiniBooNE detector). The MiniBooNE detector is located 500 meters downstream of the neutrino source, and was optimized to search for the LSND signal. This detector was designed to investigate the results of LSND.

MiniBooNE took data from 2002 to 2012, then for a special off-target run from 2013-2014. It was subsequently monitored and operated as a supplement to the MicroBooNE detector by the MicroBooNE experiment until 2019. At the time of this writing in January 2024, a Fermilab Laboratory Directed Research and Development (LDRD) experiment, "Prototype of a Modern Modular Bubble Chamber with Light Nuclear Targets," is actively planning to begin installation in the facility within the next year. Once additional details for this new experiment are finalized, this SAD will be updated accordingly prior to any new operations occurring within it. At this time, baseline risk assessment, evaluation of workers, co-located workers, and members of the public, with respect to this future experiment will not be considered.

IV-4.1.1.1 Current Status

The MiniBooNE Detector segment of the Fermilab Main Accelerator is currently: **not operating**. However, the facility remains an active site.

IV-4.1.2 Description

The MiniBooNE detector is approximately 500 m north of the MiniBooNE Target Hall (designated MI-12) where the neutrino beam studied in the detector is generated. The nature of the beam requires minimal physical connection between the two sites. A conduit for trigger signal cabling is the only connection between the two sites.

The MiniBooNE detector site (Figure 1) consists of:

- The MiniBooNE detector vault: a cylindrical, concrete-lined excavation, 50 ft in diameter and 45 ft deep. This vault houses the detector tank and is equipped with access hatches for personnel and equipment.

- The detector tank: a 40-ft-diameter spherical tank located in the detector vault, instrumented with a little over 1500 photomultiplier tubes, and filled with 250,000 gallons of Marcol 7 (Fermilab MSDS 16080) mineral oil. A cover gas of nitrogen, which is fed from a 1000 L liquid nitrogen dewar, is introduced in the empty space at the top of the tank to provide protection from oxidation. Oxidation degrades the desirable properties of the mineral oil that are important to the experiment [2].

- The detector support enclosure: a 50-ft-diameter circular room located (at surface level) above the detector vault which houses electronics and oil handling equipment. The support enclosure includes power, fire protection, and air handling equipment, as well as a 2-ton trolley supporting a 1-ton hoist. The scope of the MiniBooNE detector was to search for muon-neutrino to electron-neutrino oscillations in the mixing parameter space region where the LSND experiment reported a signal. The MiniBooNE experiment used a beam energy and baseline that was an order of magnitude larger than those of LSND so that the backgrounds and systematic errors were completely different.

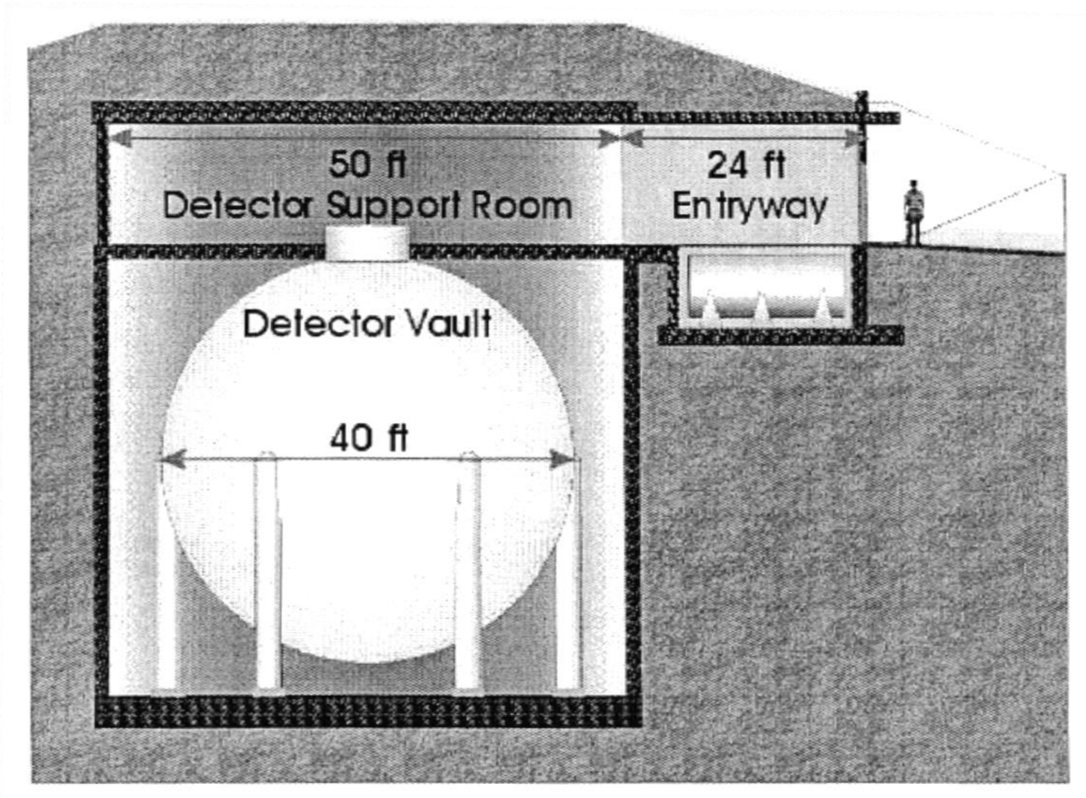

Figure 1: Layout of MiniBooNE detector vault and support room.

IV-4.1.3 Location

The MiniBooNE Detector of the Fermilab Main Accelerator is located on the Fermilab site in Batavia, IL.

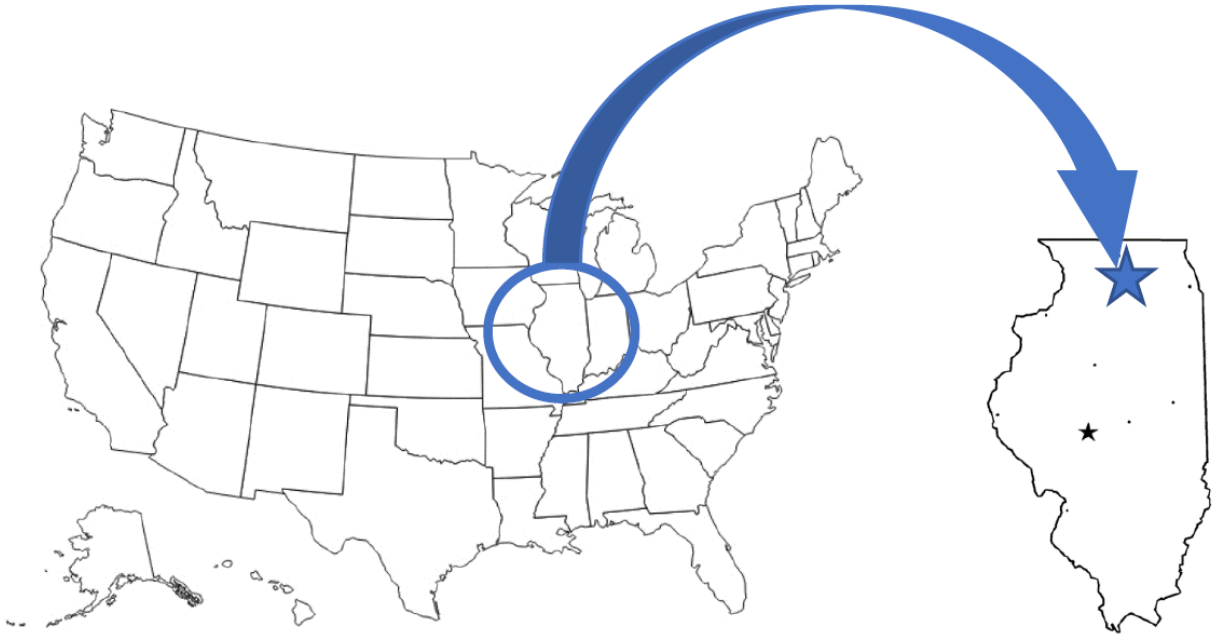

Figure 2. Regional view showing the location of the Fermilab site in Batavia, IL.

The MiniBooNE Detector is located in the MiniBooNE Service Building, in the Neutrino Campus, northwest of the Fermilab Main Accelerator on the Fermilab site. It is in the Booster Neutrino Beamline.

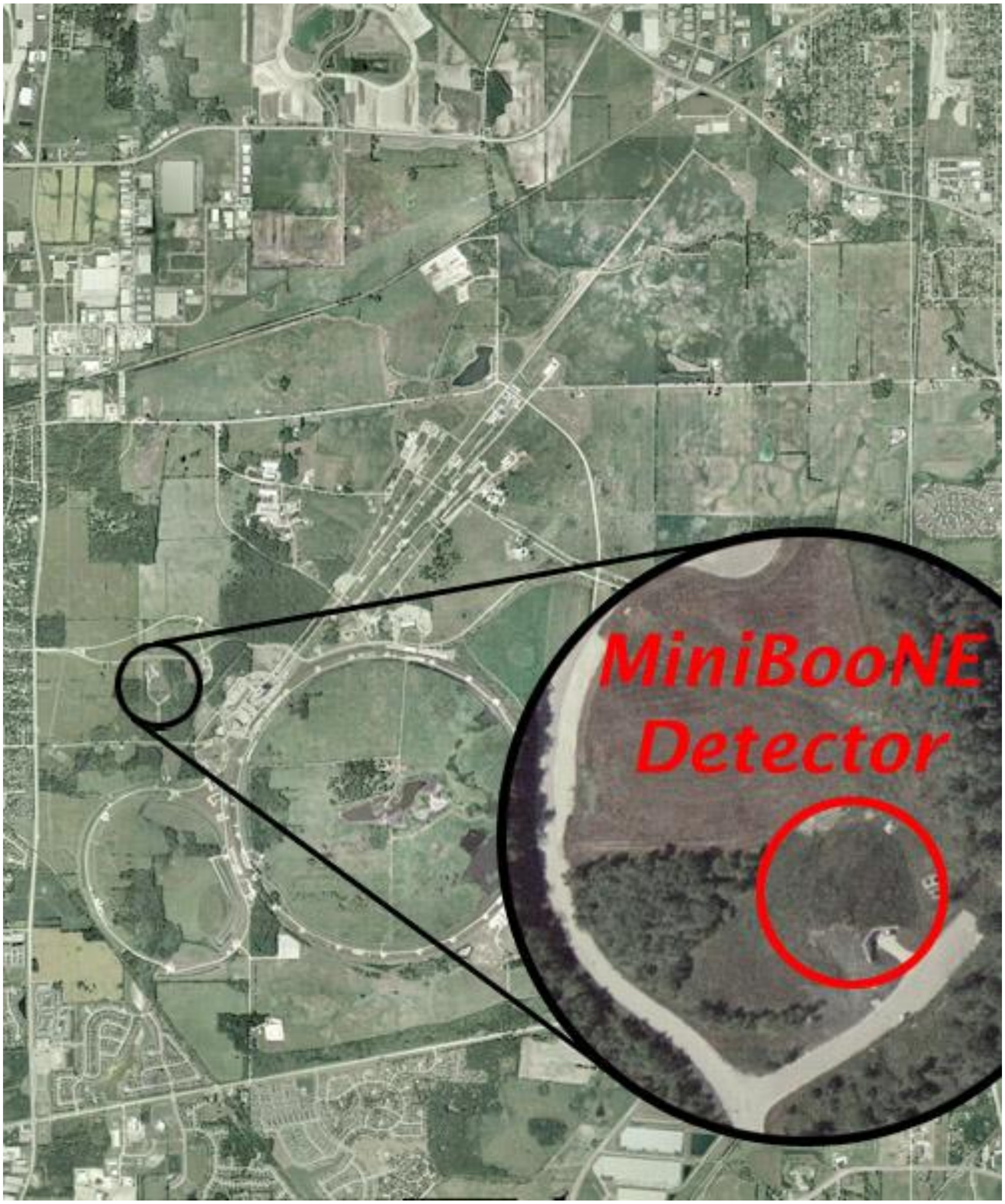

Figure 3. Aerial view of the Fermilab site, indicating the location of the MiniBooNE Detector.

IV-4.1.4 Management Organization

MiniBooNE Service Building and Detector are managed by the MiniBooNE Collaboration and Neutrino Division within the Particle Physics Directorate of Fermilab. It receives area facility management from the Infrastructure Services Division and safety support from the ES&H Division.

IV-4.1.5 Operating Modes

MiniBooNE operated as a neutrino detector in four basic modes: neutrino, anti-neutrino, beam on/horn off and beam off/horn off. None of the modes change the hazards associated with operation of the experiment.

IV-4.1.6 Inventory of Hazards

The following table lists all of the identified hazards found in the MiniBooNE enclosure and support buildings. Section IV-4.9 *Appendix – Risk Matrices* describes the baseline risk (i.e., unmitigated risk), any preventative controls and/or mitigative controls in place to reduce the risk, and residual risk (i.e., mitigated risk) for facility worker, co-located worker and Maximally Exposed Offsite Individual (MOI) (i.e., members of the public). A summary of these controls is described within Section IV-4.2 *Safety Assessment.*

Prompt ionizing, and Oxygen Deficiency Hazards due to cryogenic systems within accelerator enclosures, have been identified as accelerator specific hazards, and as such their controls are identified as Credited Controls. The analysis of these hazards and their Credited Controls will be discussed within this SAD Chapter, and their Credited Controls summarized in the applicable Accelerator Safety Envelope. Accelerator specific controls are identified as **purple/bold** throughout this Chapter. These are not applicable to the MiniBooNE Detector.

All other hazards present in the MiniBooNE Detector area are safely managed by other DOE approved applicable safety and health programs and/or processes, and their analyses have been performed according to applicable DOE requirements as flowed down through the Fermilab Environment, Safety and Health Manual (FESHM). These hazards are considered to be Non-Accelerator Specific Hazards (NASH), and their analysis will be summarized in this SAD Chapter.

Table 1. Hazard Inventory for MiniBooNE Detector.

	Radiological		**Toxic Materials**
☐	**Prompt Ionizing Radiation**	☐	Lead
☐	Residual Activation	☐	Beryllium
☐	Groundwater Activation	☐	Fluorinert & Its Byproducts
☐	Surface Water Activation	☐	Liquid Scintillator Oil
☐	Radioactive Water (RAW) Systems	☐	Ammonia
☐	Air Activation	☐	Nanoparticle Exposures
☐	Closed Loop Air Cooling		**Flammables and Combustibles**
☐	Soil Interactions	☒	Combustible Materials (e.g., cables, wood cribbing, etc.)
☐	Radioactive Waste	☒	Flammable Materials (e.g., flammable gas, cleaning materials, etc.)
☐	Contamination		**Electrical Energy**

☐	Beryllium-7	☐	Stored Energy Exposure
☐	Radioactive Sources	☐	High Voltage Exposure
☐	Nuclear Material	☐	Low Voltage, High Current Exposure
☐	Radiation Generating Devices (RGDs)		**Kinetic Energy**
☐	Non-Ionizing Radiation Hazards	☒	Power Tools
	Thermal Energy	☒	Pumps and Motors
☐	Bakeouts	☐	Motion Tables
☒	Hot Work	☐	Mobile Shielding
☐	**Cryogenics (ODH and burns)**		**Magnetic Fields**
	Potential Energy	☐	Fringe Fields
☒	Crane Operations		**Other Hazards**
☒	Compressed Gasses	☒	Confined Spaces
☐	Vacuum/Pressure Vessels/Piping	☒	Noise
☐	Vacuum Pumps	☒	Silica
☒	Material Handling	☒	Ergonomics
	Access & Egress	☐	Asbestos
☒	Life Safety Egress	☒	Working at Heights

IV-4.2. Safety Assessment

All hazards for the MiniBooNE Detector segment of the Fermilab Main Accelerator are summarized in this section, with additional details of the analyses for accelerator specific hazards.

IV-4.2.1 Radiological Hazards

The MiniBooNE detector presents no radiological hazards. An analysis [3] for the MiniBooNE Detector reveals that the expected absorbed dose is roughly 10 nanorads/year. Therefore, the neutrinos that travel to the detector (and beyond) do not present a radiological hazard.

IV-4.2.1.1 Prompt Ionizing Radiation

N/A.

IV-4.2.1.2 Residual Activation

N/A.

IV-4.2.1.3 Groundwater Activation

N/A.

IV-4.2.1.4 Surface Water Activation

N/A.

IV-4.2.1.5 Radioactive Water (RAW) Systems

N/A.

IV-4.2.1.6 Air Activation

N/A.

IV-4.2.1.7 Closed Loop Air Cooling

N/A.

IV-4.2.1.8 Soil Interactions

N/A.

IV-4.2.1.9 Radioactive Waste

N/A.

IV-4.2.1.10 Contamination

N/A.

IV-4.2.1.11 Beryllium-7

N/A.

IV-4.2.1.12 Radioactive Sources

N/A.

IV-4.2.1.13 Nuclear Material

N/A.

IV-4.2.1.14 Radiation Generating Devices (RGDs)

N/A.

IV-4.2.1.15 Non-Ionizing Radiation Hazards

A Class III B laser was used in the MiniBooNE detector for calibration. The MiniBooNE laser calibration system consisted of a pulsed diode laser (Pico-Quant GmBH PDL-800-B driver and LDH 375 laser head) and four dispersion flasks installed at various locations in the detector. Short pulses (<1 ns) of laser light with wavelengths peaked at 397 nm, were transmitted via optical fibers to each of the dispersion flasks. The primary purpose was to quantify and monitor individual photo multiplier tube performance parameters. The laser also allowed for in-situ monitoring of the oil attenuation length over the lifetime of the experiment. All laser installations (class 3B or greater) were reviewed and approved by the Fermilab Laser Safety Officer (LSO) prior to commencing operations in accordance with FESHM.

The MiniBooNE laser calibration system was decommissioned in 2019 and does not present a hazard.

IV-4.2.2 Toxic Materials

Controlling industrial hygiene hazards is addressed through the application of the relevant OSHA standards and other applicable standards (such as ANSI and ACGIH). The Fermilab facilities areas have numerous industrial hygiene issues including lasers, hazardous atmospheres, confined spaces, and hazardous materials.

The Laboratory employs a professional ES&H staff that monitors industrial hygiene hazards for compliance with the national standards and the FESHM 4000 series requirements. When necessary, the ES&H staff develops additional procedures to mitigate the hazards.

MiniBooNE does not contain toxic materials as defined in the risk matrices. The liquid scintillator oil described within the matrix for MiniBooNE, presents a potential confined space hazard due to its quantity, not due to its toxicity. The material was included in the table to demonstrate that it had been considered during risk assessment activities.

IV-4.2.2.1 Lead

N/A.

IV-4.2.2.2 Beryllium

N/A.

IV-4.2.2.3 Fluorinert & Its Byproducts

N/A.

IV-4.2.2.4 Liquid Scintillator Oil

The MiniBooNE detector contains approximately 250,000 gallons of mineral oil. It does not contain any doping agents. The mineral oil itself could have mild irritating dermal, eye, or respiratory effects if it came into contact with a person but this has been evaluated by safety subject matter experts and is not considered to be a serious hazard. Risks associated with the volume, storage, combustibility/flammability of the oil, confined space encompassing the detector, and other hazards are addressed in other sections within this chapter.

As a toxic materials hazard, this is considered not applicable.

IV-4.2.2.5 Ammonia

N/A.

IV-4.2.2.6 Nanoparticle Exposures

N/A.

IV-4.2.3 Flammables and Combustibles

The accelerator and experimental areas are classified as a non-accelerator specific hazard (NASH) in terms of fire prevention. Fire prevention and protection is enhanced by independent fire department inspections, Highly Protected Risk Assessments, and prompt on-site fire department response. Continuous monitoring of systems by the AD Operations Department also contributes to quick detection of problems. Equipment is designed with the application of the criterion that minimizes or eliminates combustible material.

Service buildings and beamline enclosures are constructed primarily of non-combustible material. The primary fire hazard is from the numerous power and signal cables that are distributed throughout the buildings and tunnels. Extensive tests of fire propagation in horizontal cable trays were conducted. The results indicate that cable tray fires propagate extremely slowly, generate only low temperatures, and self-extinguish. The major concern is smoke propagation. Where possible, penetrations between services buildings or equipment galleries and enclosures are sealed.

Fire detection and suppression systems for service buildings and beamline enclosures were installed at initial construction. These systems were based on the fire loading, codes, and/or design criteria in place at the time of construction. Additional systems have been installed and upgrades to pre-existing systems have been made in conjunction with facility modifications and the application of more stringent criteria.

General housekeeping is the responsibility of line management. The Building/Area Manager Program and scheduled walk-through inspections of all areas contributes to the monitoring and minimization of excessive accumulations of flammable and combustible materials. Minimization of excess material and proper housekeeping for the enclosures is specifically addressed by radiological worker training and waste minimization practices. Flammable materials are stored in approved flammable storage cabinets. Hazardous operations, such as welding, cutting, and brazing, are regulated by appropriate permits issued by the Fermilab Fire Department.

IV-4.2.3.1 Combustible Materials

The MiniBooNE detector contains approximately 250,000 gallons of mineral oil. Mineral oil has a flash point of 420 degrees F. The interior of the tank is maintained in a nitrogen environment to protect the oil from oxidation, and to reduce the potential for fire. The exterior of the tank has a deluge spray system to maintain it at ambient temperature in the event of a fire. This system has been designed to provide a water spray to the top half and mid area of the tank at a rate of 0.25 GPM per square foot. This is in accordance with the Gage-Babcock & Associates analysis [4] and the National Fire Protection Association Pamphlet No. 15 Entitled Water Spray Fixed Systems. MiniBooNE is also protected by a Very Early Smoke

Detection and Alarm (VESDA) system that is connected to Fermilab's Fire and Utilities (FIRUS) emergency notification system.

The installation of electronics, power supplies, and all other electrical components of the experiments performed in this facility are in accordance with the guidelines of the Fermilab Environment Safety and Health Manual (FESHM) [5]. This is to ensure that they do not constitute a fire hazard. All equipment has been reviewed under the then Particle Physics Division's ES&H review process as described in their procedure, "Operational Readiness Clearance: ES&H Review of Experiments" [6].

The MiniBooNE detector oil plumbing system was designed to enable filling, recirculation, filtering, temperature control, and removal of the mineral oil. All oil distribution pipes are stainless steel. Oil enters the detector tank during fill or recirculation via a 7.62 cm (3 inch) pipe that attaches to the inflow penetration at the bottom of the detector tank. During decommissioning of the detector, this line will be used, together with a pump located in the bottom of the detector vault, to remove the oil.

A 9,500-liter stainless steel oil overflow tank is located beneath the detector entrance hall and provides an overflow capacity of 1% of the detector tank volume. The thermal expansion coefficient of the mineral oil was measured to be $6.1 \times 10^{-4\circ}$ C^{-1}; therefore, the tank allows an oil temperature change of 16° C, well within any expected temperature variation. Data shows that during the year the temperature of the oil varies approximately 2° C. The level is monitored for any deviation from nominal values. Any deviation outside nominal values would be remedied by increasing the flow of the circulation pumps through the heat exchanger and installing a 10kW chiller to reduce the thermal expansion if necessary**Error! Bookmark not defined.**.

IV-4.2.3.2 Flammable Materials

As discussed in the prior section IV-4.2.3.1 on Combustible Materials, the MiniBooNE detector contains approximately 250,000 gallons of mineral oil. Mineral oil has a flash point of 420 degrees F. The interior of the tank is maintained in a nitrogen environment to protect the oil from oxidation, and to reduce the potential for fire. The exterior of the tank has a deluge spray system to maintain it at ambient temperature in the event of a fire. This system has been designed to provide a water spray to the top half and mid area of the tank at a rate of 0.25 GPM per square foot. This is in accordance with the Gage-Babcock & Associates analysis [4] and the National Fire Protection Association Pamphlet No. 15 Entitled Water Spray Fixed Systems. MiniBooNE is also protected by a Very Early Smoke Detection and Alarm (VESDA) system that is connected to Fermilab's Fire and Utilities (FIRUS) emergency notification system.

As discussed in the prior section IV-4.2.3.1 on Combustible Materials, the installation of electronics, power supplies, and all other electrical components of the experiments performed in this facility are in accordance with the guidelines of the Fermilab Environment Safety and Health Manual (FESHM) [5]. This is to ensure that they do not constitute a fire hazard. All equipment has been reviewed under the Particle Physics Division's (PPD) ES&H review process as described in their procedure, "Operational Readiness Clearance: ES&H Review of Experiments" [6].

IV-4.2.4 Electrical Energy

Construction or modification of electrical equipment at Fermilab conforms to the safety and design standards of the FESHM, the Fermilab Engineering Manual [7], the National Electrical Code (NEC NFPA 70), the National Electrical Safety Code (ANSI C2-1984) and OSHA 29 CFR 1910.331-335 "Safety Related Work Practices" where applicable. FESHM describes Fermilab's Electrical Safety Program.

Training, work planning and controls, and the ORC review process provide additional protection for workers and other personnel in the area.

IV-4.2.4.1 Stored Energy Exposure

N/A.

IV-4.2.4.2 High Voltage Exposure

During the operational period of the MiniBooNE experiment, numerous high and low voltage supplies were used to power the phototubes and readout electronics. These were commercial supplies that were matched appropriately to the rating of the power distribution systems. All electrical systems complied with NEC and FESHM.

Some of these electronics remain in place and some have been removed. Since the detector is no longer operating, this hazard is considered not applicable.

IV-4.2.4.3 Low Voltage, High Current Exposure

N/A.

IV-4.2.5 Thermal Energy

Thermal energy hazards which are applicable to the MiniBooNE Detector are discussed in this section.

IV-4.2.5.1 Bakeouts

N/A.

IV-4.2.5.2 Hot Work

There are no plans to conduct hot work in this facility at the moment. However, such activities may take place during future installations in the facility or decommissioning of the MiniBooNE detector. If applicable, they would be conducted with training and work planning and controls, and in accordance with the controls specified in the Section I, Chapter 04, Non-Accelerator Specific Hazards (NASH) tables. These standard controls reduce likelihood and consequences of risks to workers, and co-located workers from a risk value of I (a major concern) to a risk value of IV (minimal concern). For member of the public, these standard controls reduce risks from level III (minor concern) to a risk level of IV (minimal concern), thus no further evaluation is necessary.

IV-4.2.5.3 Cryogenics

N/A.

IV-4.2.6 Kinetic Energy

The service buildings that support experiment operations contain rotating machinery in relatively small rooms. Mechanical guards and, in some cases, emergency stop switches are provided for personnel protection in each of these buildings.

Many service buildings and enclosures contain overhead bridge cranes, hoists, fork trucks, and aerial lifts. Infrastructure Services Division Operations & Maintenance Group maintains and inspects all cranes, hoists, and fork trucks. All crane and fork truck operators complete the appropriate training requirements as identified in their Individual Training Needs Assessments plan. Aerial lifts are maintained and lift operators are trained by the organization owning the lift.

IV-4.2.6.1 Power Tools

Power tools are sometimes used in the facility. Applicable training and work planning and controls are utilized, along with applicable PPE, to protect workers and others.

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

IV-4.2.6.2 Pumps and Motors

There are several pumps located in the MiniBooNE vault. The oil circulation and heat exchange system use a primary pump for oil circulation and a secondary pump as a spare. There is an oil removal pump installed in the inflow line at the bottom of the tank vault which will be used to remove the oil for decommissioning. A groundwater sump and pumps are installed to remove collected groundwater from the bottom of the tank vault.

Infrastructure in the form of a spiral staircase mounted along the vault wall and a freestanding workstation crane on the main level with 500 lb capacity and an access hatch aids maintenance of these pumps.

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

IV-4.2.6.3 Motion Tables

N/A.

IV-4.2.6.4 Mobile Shielding

N/A.

IV-4.2.7 Potential Energy

Potential energy hazards which are applicable to the MiniBooNE detector are discussed in this section.

IV-4.2.7.1 Crane Operations

There is a two-ton trolley present in the MiniBooNE Service Building. It has a one-ton hoist mounted and allows the hoist position to be adjusted from the roll-up door at the entry of the building to the access hatch above the MiniBooNE detector. Its controls are kept locked when not in use.

There is also a freestanding workstation crane with a capacity of 500 lbs. It is positioned above an access point to the vault.

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

IV-4.2.7.2 Compressed Gasses

As mentioned in section IV-4.1.3 of this chapter, there is a 1000 L liquid nitrogen dewar which supplies a cover gas to the empty space at the top of the tank to provide the oil protection from oxidation. This dewar is located outside the service building behind a protective fence and refilled periodically as needed. There is no ODH hazard resulting from its presence.

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

IV-4.2.7.3 Vacuum/Pressure Vessels/Piping

N/A.

IV-4.2.7.4 Vacuum Pumps

N/A.

IV-4.2.7.5 Material Handling

Material handling may be conducted in this facility. As mentioned in prior section IV-4.2.7.1 on Crane Operations, there is a one-ton hoist with trolley and a freestanding workstation crane with a capacity of 500 lbs. There may also be use of forklifts, handtrucks, rigging, and other work.

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

IV-4.2.8 Magnetic Fields

N/A.

IV-4.2.8.1 Fringe Fields

N/A.

IV-4.2.9 Other Hazards

Other hazards which are applicable to the MiniBooNE detector are discussed in this section.

IV-4.2.9.1 Confined Spaces

MiniBooNE Vault Access/Egress

The vault is classified as a permit-required confined space. FESHM defines a confined space as:

1. Is large enough and so configured that an employee can bodily enter and perform assigned work; and
2. has limited or restricted means for entry or exit; and
3. is not designed for continuous employee occupancy.

The designation is determined by the presence of the oil, the space not meant for continuous occupancy, and the limited means of egress through hatches into the vault. Particle Physics Directorate facility management works with ES&H Directorate to maintain the space and provide equipment necessary for the permit-required entry. Entry into the vault must be approved by these groups. The requirements contained in FESHM will be adhered to for all entries into the vault.

Personnel access to and from the MiniBooNE vault is via a spiral stairway mounted on the vault wall. The entrance is covered by a hatch cover and is chained off with signs warning of the confined space. In the event of a catastrophic leak during an access to the vault, procedures for the confined space entry would be followed and all entrants extracted immediately.

This hazard has been evaluated within the common Risk Matrix table included in SAD Section I Chapter 04 *Safety Analysis*. Work at the MiniBooNE Detector involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use. The Baseline qualitative risk for workers is Risk Level I, due to the “anticipated” nature of the risks presented by confined space work activities, and a “high” consequence of injury/exposure presented by the work. Through a series of preventive and mitigative measures, the risk level is reduced to III “minor concern”, with likelihood reduced to “beyond extremely unlikely” while consequence is reduced to “low”.

IV-4.2.9.2 Noise

Typical levels of noise in this facility do not present a safety hazard. In the event of maintenance or work which produces high levels of noise, applicable training and work planning and controls are utilized, along with applicable PPE, to protect workers and others.

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

IV-4.2.9.3 Silica

Silica exposure hazards may result from drilling of concrete or similar material. In the event of work which may involve this hazard, applicable training and work planning and controls are utilized, along with applicable PPE, to protect workers and others.

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

IV-4.2.9.4 Ergonomics

All work at the MiniBooNE Detector will be conducted following good ergonomics practices and training.

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

IV-4.2.9.5 Asbestos

N/A.

IV-4.2.9.6 Working at Heights

In the event of work which may involve this hazard, applicable training and work planning and controls are utilized, along with applicable PPE, to protect workers and others.

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

IV-4.2.10 Access & Egress

As discussed in the prior section IV-4.2.9.1 on Confined Spaces, the MiniBooNE Vault is classified as a permit-required confined space and therefore has additional restrictions and protections governing entry and exit.

The designation is determined by the presence of the oil, the space not meant for continuous occupancy, and the limited means of egress through hatches into the vault. Particle Physics Directorate facility management works with ES&H Division to maintain the space and provide equipment necessary for the permit-required entry. Entry into the vault must be approved by these groups. The requirements contained in FESHM will be adhered to for all entries into the vault.

Work at the MiniBooNE Detector, involving this hazard implements the controls specified in the common Risk Matrix table. No unique controls are in use.

IV-4.2.10.1 Life Safety Egress

As discussed in the prior section IV-4.2.9.1 on Confined Spaces as well as previous section IV-4.2.10 on Access & Egress, the MiniBooNE Vault is classified as a permit-required confined space and therefore has additional restrictions and protections governing entry and exit.

Personnel access to and from the MiniBooNE vault is via a spiral stairway mounted on the vault wall. The entrance is covered by a hatch cover and is chained off with signs warning of the confined space. In the event of a catastrophic leak of scintillator oil or groundwater during an access to the vault, or any other emergency, procedures for the confined space entry would be followed and all entrants extracted immediately.

IV-4.2.11 Environmental

Environmental hazards are addressed through compliance with legal and regulatory requirements imposed by DOE Orders, Federal/State/local regulations, and FESHM 8000 series. Numerous activities at Fermilab have the potential to produce environmental impacts. These include air emission sources such as fuel combustion, component cleaning, paint spray booths, soil erosion from construction activities, oil spills from transformers and generators utilized within the electrical distribution system, and glycol spills from various cooling systems. The laboratory has an IEPA-approved air emissions permit and a Spill Prevention, Control and Countermeasures Plan (SPCC) that has been certified by a registered Professional Engineer. New activities are reviewed for potential environmental and regulatory issues as part of the NEPA process.

The environmental radiation hazards considered include off-site radiation doses from muons produced by proton interactions with targets, activation of the air in enclosures which is subsequently released to the environment, and irradiation of unprotected soil surrounding the enclosures leading to radioactivity in the groundwater or surface water.

Furthermore, a baseline qualitative risk assessment was performed for environmental hazards which indicated that although hazards to air, water and soil are anticipated, the consequences of releases to these media from the MiniBooNE Detector have been deemed to be “negligible”. Furthermore, controls that are implemented and documented within the common Risk Matrix table included in SAD Section I Chapter 04 *Safety Analysis,* indicate that the likelihood of occurrence of “negligible” release events of this nature is reduced from “anticipated” to “extremely unlikely”, and risk level IV is maintained, meaning that such releases are events of “minimal concern”.

IV-4.2.11.1 Hazard to Air

Locations where there is a potential for the release of airborne radionuclides in measurable concentrations are identified and appropriately monitored to ensure compliance with applicable standards. There is no hazard to air resulting from the MiniBooNE Detector.

IV-4.2.11.2 Hazard to Water

Groundwater and surface water are monitored on an as needed basis by the assigned RSO or the ES&H Section to ensure compliance with the FRCM [1] and applicable standards.

The MiniBooNE vault is surrounded by an impermeable membrane for groundwater control and mineral oil secondary containment. There is no hazard to water resulting from the MiniBooNE Detector.

IV-4.2.11.3 Hazard to Soil

There is no radiation or chemical hazard to soil resulting from the MiniBooNE detector.

The detector is housed in a concrete vault which also serves as the secondary containment for the full capacity of the detector. The drainage paths into the main sumps are physically isolated from the vault region so that no oil can get into the sump even in the event of a catastrophic leak or rupture of the detector itself. A secondary monitoring sump provides the ability to check for major oil leaks without entering the vault area. Both sump systems have been designed and built to be serviceable from outside of the concrete vault.

In the event of a serious mineral oil spill from the detector, the vault and sumps are designed to avoid the possibility of oil being able to leak outside the vault. The MiniBooNE vault is surrounded by an impermeable membrane for groundwater control and mineral oil secondary containment.

IV-4.3. Summary of Hazards to Members of the Public

The MiniBooNE Detector presents no specific hazards to members of the public. The potential release of mineral oil from the main tank is controlled by secondary spill containment and sump activation. Couple these controls with the innocuous properties of the mineral oil itself, means that the release of mineral oil results only in a negligible consequence to the public, and a risk of minimal concern, thus no additional evaluations of these hazards are necessary.

IV-4.4. Summary of Credited Controls

As described in Chapters 1-10 of the Fermilab SAD, credited controls are designed to reduce the risk of accelerator operations hazards to an acceptable level. The MiniBooNE Detector does not require active controls due to the nature of the detector. The MiniBooNE Detector site is geographically separated (approximately 500 m) from the accelerator components with the exception of a small signal cable chase that traverses through the earth. The MiniBooNE Detector does not have any accelerator components and thus does not require credited controls.

IV-4.5. Defense-in-Depth Controls

Commissioning, normal operations, and emergency management of the MiniBooNE Detector site are all conducted under the auspices of the Neutrino Division, Particle Physics Directorate Headquarters, and the Environment Safety & Heath Division.

IV-4.6. Decommissioning

The MiniBooNE detector completed data taking in 2019. Some systems have been decommissioned but most of the detector, including the oil vessel, remains intact and in place.

The MiniBooNE detector oil plumbing system was designed to enable filling, recirculation, filtering, temperature control, and removal of the mineral oil. All oil distribution pipes are stainless steel. Oil enters the detector tank during fill or recirculation via a 7.62 cm (3 inch) pipe that attaches to the inflow penetration at the bottom of the detector tank. During decommissioning of the detector, this line will be used, together with a pump located in the bottom of the detector vault, to remove the oil. However, there are no firm plans to do this yet.

At the time of this writing in January 2024, a Fermilab Laboratory Directed Research and Development (LDRD) experiment, "Prototype of a Modern Modular Bubble Chamber with Light Nuclear Targets," is actively planning to begin installation in the facility within the next year.

Once additional details for this new experiment are finalized, this SAD will be updated accordingly prior to any new operations occurring within it. At this time, baseline risk assessment, evaluation of workers, co-located workers, and members of the public, with respect to this experiment will not be considered.

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

IV-4.7. Summary and Conclusion

Specific hazards associated with commissioning and operation of the MiniBooNE detector are identified and assessed in this chapter of the Fermilab Safety Assessment Document. The designs, controls, and procedures to mitigate MiniBooNE specific hazards are identified and described. In addition to these specific safety considerations, the MiniBooNE experiment is subject to the requirements, controls and procedures outlined in Section I of this Fermilab Safety Assessment Document.

Within the specific and generic considerations of this assessment, the MiniBooNE experiment can be constructed, commissioned, and operated with a level of safety that is equal to or exceeding that currently prescribed by DOE orders and Fermilab regulations as put forth in the FESHM and the Fermilab Radiological Control Manual[i] (FRCM), and 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-4.8. References

[1] Fermilab Radiological Control Manual - The current web link is: http://esh.fnal.gov/xms/FRCM

[2] The MiniBooNE Detector, A. A. Aguilar-Arevalo et.al., June 25, 2008. http://arxiv.org/pdf/0806.4201v1

[3] An Analysis of Dose from Neutrinos Arriving in the MiniBooNE Detector, P.S. Martin, MiniBooNE Technical Note 17, July 23, 1999.
[4] Gage-Babcock & Associates, Fire Protection/Life Safety Analysis for the Fermilab MiniBooNE Project, June 30, 1999.
[5] Fermilab Environment, Safety, and Health Manual. – The current web link is: http://esh.fnal.gov/xms/FESHM
[6] PPD ESH Procedure 006, Operational Readiness Clearance: ES&H Review of Experiments, Projects, and R&D Efforts. – The current web link is: http://www-ppd.fnal.gov/ESHBMGOffice-w/ESH%20Management/ESH_Manual/PPD_ESH_006.pdf
[7] Fermilab Engineering Manual. The current web link is: https://directorate-docdb.fnal.gov/cgi-bin/sso/ShowDocument?docid=34

IV-4.9. Appendix – Risk Matrices

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