NUMI OFF-AXIS ELECTRON NEUTRINO APPEARANCE (NOVA) EXPERIMENT NEAR DETECTOR

SECTION IV CHAPTER 05 OF THE FERMILAB SAD

Revision 1 February 14, 2024

This chapter of the Fermilab Safety Assessment Document (SAD) contains a summary of the results of the Safety Analysis for the NOvA Near 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.

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SAD Chapter Review

This Section IV Chapter 05 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *NuMI Off-Axis Electron Neutrino Appearance (NOvA) Experiment Near 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 (ES&H) Accelerator Safety Department.

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

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SAD Review Subcommittee Chair

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Revision History

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

Author	Rev. No.	Date	Description of Change
Eric McHugh, TJ Sarlina	0	March 21, 2014	Initial release of the NOvA Near Detector chapter of the Fermilab Safety Assessment Document.
Cindy Joe Zarko Pavlovic, Madeleine O'Keefe	1	January 6, 2024	Incorporation of risk matrix and hazard discussion. Consistency and QA edits, minor corrections, addition of hazard risk levels.

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Acronyms and Abbreviations

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

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

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

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

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

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

IV-5. NuMI Off-Axis Electron Neutrino Appearance Experiment Near Detector

IV-5.1. Introduction

This Section IV Chapter 05 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the NuMI Off-Axis Electron Neutrino Appearance (NOvA) Near Detector segment of the Fermilab Main Accelerator.

IV-5.1.1 Purpose/Function

The NOvA experiment uses a neutrino beam to study the strange properties of neutrinos, especially the transition of muon neutrinos into electron neutrinos. The neutrino beam interacts with the "Near Detector" located on the Fermilab site. Beyond the detector, the neutrino beam travels through the earth from Fermilab to a laboratory in Ash River, Minn., that houses the so-called "Far Detector." Due to the physical interaction properties of the neutrino beam, no tunnel or other physical connection is needed between Fermilab and the Far Detector. Indeed, there is no detectable ionizing radiation due to the neutrino beam at either detector. The safety assessment of the beamline is addressed in the Neutrinos at the Main Injector (NuMI) Beam Line SAD Chapter.

The Far Detector is operated by the University of Minnesota and is located near Ash River, Minn. Safety assessments of the Far Detector are addressed by the University of Minnesota and are beyond the scope of this chapter. The experiment will help answer some of the most important scientific questions about neutrino masses, neutrino oscillations and the role neutrinos may have played in the evolution of the universe.

IV-5.1.2 Current Status

The NOvA Near Detector segment of the Fermilab Main Accelerator is currently: **operational.**

IV-5.1.3 Description

The NOvA Near Detector resides approximately 350 feet underground in a cavern adjacent to the MINOS detector hall. The NuMI beamline transports protons from Fermilab's Main Injector accelerator (left in Figure 1) 1,000 feet down the beam line, where the protons interact with a graphite target to create muon neutrinos that interact with the Near Detector. The NOvA Near Detector site consists of:

- An underground NOvA Near Detector cavern measuring 75'L X 20'W X 22'H, located adjacent to the existing underground cavern that housed the Main Injector Neutrino Oscillation Search (MINOS) experiment. The cavern is outfitted with an automatic water mist fire suppression system, a Very Early Smoke Detection and Alarm (VESDA) detection system, and secondary containment for the liquid contained within the detector. The cavern also houses the electronics for the detector;
- The NOvA Near Detector, which is an approximately 294- metric-ton structure constructed of modules made of polyvinyl chloride (PVC) and steel. The rigid PVC cellular extrusions are

filled with liquid scintillator, which comprises 70% of the total detector mass. The detector contains approximately 41,200 gallons of liquid scintillator oil. Included in this design is 100% secondary containment for the liquid scintillator.

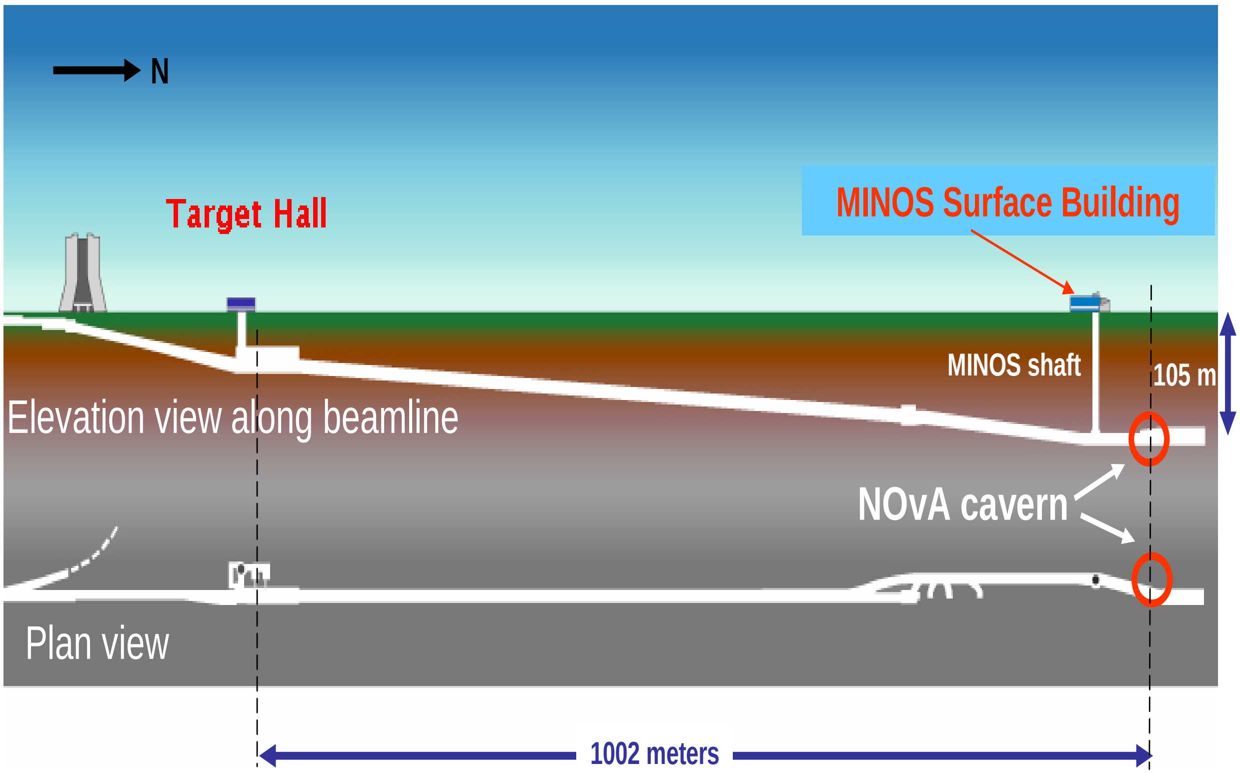

Figure 1. – Neutrino transport path to NOvA Near Detector Hall.

IV-5.1.4 Location

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

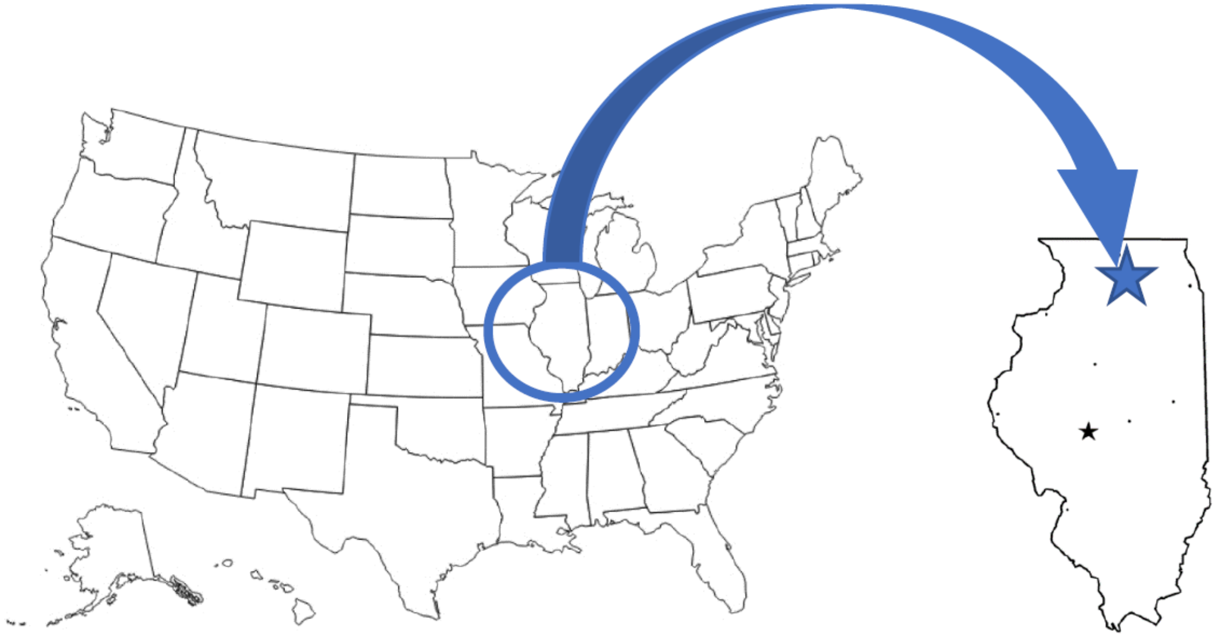

Figure 2. Regional view showing the location of the Fermilab site in Batavia, IL.

The NOvA Near Detector is located in the MINOS Underground Area, accessed via the MINOS Service Building, in the Neutrino Campus, northwest of the Fermilab Main Accelerator on the Fermilab site. It is in the NuMI (Neutrinos at the Main Injector) Beamline.

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

IV-5.1.5 Management Organization

NOvA Near Detector is managed by the NOvA collaboration and Neutrino Division within the Particle Physics Directorate (PPD) of Fermilab. It receives area facility management from the Infrastructure Services Division and safety support from the ES&H Division.

IV-5.1.6 Operating Modes

The NOvA Near Detector operates as a neutrino detector which is geographically separated from Accelerator Directorate-managed accelerators. The PPD is responsible for the operations of the NOvA detector.

IV-5.1.7 Inventory of Hazards

The following table lists all of the identified hazards found in the NOvA Near Detector enclosure and support buildings. Section IV-5.9 *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-5.2 *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 NOvA Near Detector.

All other hazards present in the NOvA Near 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 NOvA Near 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-5.2. Safety Assessment

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

IV-5.2.1 Radiological Hazards

The NOvA Near Detector receives only neutrino beam and presents no radiological hazards.

IV-5.2.1.1 Prompt Ionizing Radiation

N/A

IV-5.2.1.2 Residual Activation

N/A

IV-5.2.1.3 Groundwater Activation

N/A

IV-5.2.1.4 Surface Water Activation

N/A

IV-5.2.1.5 Radioactive Water (RAW) Systems

N/A

IV-5.2.1.6 Air Activation

N/A

IV-5.2.1.7 Closed Loop Air Cooling

N/A

IV-5.2.1.8 Soil Interactions

N/A

IV-5.2.1.9 Radioactive Waste

N/A

IV-5.2.1.10 Contamination

N/A

IV-5.2.1.11 Beryllium-7

N/A

IV-5.2.1.12 Radioactive Sources

During commissioning of the NOvA Near Detector, it was sometimes necessary to calibrate the response of the detector with sealed radioactive sources. The usage of these sources is governed by Chapter 4 *Radioactive Materials* of the Fermilab Radiological Control Manual (FRCM) [1]. All radioactive source usage adhered to the sealed radioactive source controls section contained within the chapter.

Radioactive sources are no longer used or anticipated for the current operation or future decommissioning of the NOvA Near Detector, so this hazard is designated not applicable.

IV-5.2.1.13 Nuclear Material

N/A

IV-5.2.1.14 Radiation Generating Devices (RGDs)

N/A

IV-5.2.1.15 Non-Ionizing Radiation Hazards

N/A

IV-5.2.2 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.

IV-5.2.2.1 Lead

N/A

IV-5.2.2.2 Beryllium

N/A

IV-5.2.2.3 Fluorinert & Its Byproducts

N/A

IV-5.2.2.4 Liquid Scintillator Oil

The NOvA Near Detector contains approximately 41,200 gallons of liquid scintillator oil. A pliable PVC membrane secondary containment is installed around the entire detector. The NOvA Near Detector secondary containment has been reviewed and certified in the Fermilab Spill Prevention, Control and Countermeasure (SPCC) Plan, July 15, 2013 [2]. The scintillator distribution system design has minimal joints and connections to limit the potential for spills. The Fermilab SPCC plan dictates that the secondary containment be included on the monthly inspection schedule. The SPCC is periodically revised in accordance with regulatory standards. The secondary containment of the NOvA Near Detector will be included in the SPCC on a continuing basis.

NOvA's liquid scintillator oil contains 5.35% pseudocumene. The pseudocumene is an eyes, skin and respiratory irritant, central nervous system depressant, and is toxic to marine life. A job-specific hazard analysis and procedure govern filling the detector and prescribe Personal Protective Equipment (PPE) to prevent worker contact with the liquid scintillator. The PVC modules, once filled, completely contain the pseudocumene, resulting in no further exposure. Emergency spill equipment, an eye wash and PPE are stationed near the detector in the event of a release. The entire detector is inside of a secondary containment membrane that has the capacity to contain 100% of the liquid scintillator oil and prevent a release to the environment. For facility and co-located workers, the baseline risk is III and the mitigated risk is IV. For MOI, the baseline risk is IV and the mitigated risk is IV.

IV-5.2.2.5 Ammonia

N/A

IV-5.2.2.6 Nanoparticle Exposures

N/A

IV-5.2.3 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-5.2.3.1 Combustible Materials

The Near Detector cavern underwent a fire hazard and life safety analysis [3] using the International Building Code and NFPA 520 provisions as appropriate. Hughes Associates, Inc. completed this evaluation during March 2010. The liquid scintillator, as delivered to Fermilab, is a Class III B combustible liquid according to the flash point indicated by the MSDS. The liquid scintillator presents a potential fire hazard during detector filling. The cellular structure of the detector significantly mitigates this hazard by containing the liquid scintillator within fire retardant cellular PVC extrusions. A burn test performed on the rigid PVC extrusions and contained in the *NOvA Rigid PVC Flammability Testing and other Fire related* issues [4] concluded that this design and the liquid scintillator's high flash point of >202°F reduce the opportunity for ignition. Hazard mitigation includes restricting open flames or other sources of ignition present in any areas containing liquid scintillator via FESHM [5] Chapter 6020.2 *Welding, Burning, and Brazing*, an automatic water mist fire suppression system, a VESDA smoke detection, and Fermilab Fire and Utilities Monitoring System (FIRUS).

The large quantity of wavelength shifting fiber is a combustible but does not constitute a fire hazard because it is completely enclosed inside the individual PVC cells.

The installation of electronics, power supplies, and all other electrical components of the experiments performed in the Near Detector cavern are in accordance with the Particle Physics Division (PPD, later Directorate) Electrical Department guidelines and FESHM to ensure that they do not constitute a fire or shock hazard. All installations have been reviewed according to the ORC process. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.3.2 Flammable Materials

Filling the cells with liquid scintillator oil presents a fire hazard due to static accumulation and discharge on the plumbing. This hazard is mitigated using plumbing that is conductive, grounded and bonded. Also, an anti-static additive is added to the scintillator in concentrations that increase conductivity to reduce the steady state electric current flow in the main distribution lines by a factor of ~100, reducing the charge delivered to the module by this factor. An additional risk from scintillator-initiated fire would stem from improper storage and disposal of oil-soaked rags. Spills are dealt with promptly, and fire-proof disposal receptacles are provided where needed. Appropriate interlocks and controls on the scintillator filling machines reduce the probability of spills during scintillator liquid transfer. If removal of the scintillator is required, similar provisions will mitigate these hazards.

The installation of electronics, power supplies, and all other electrical components of the experiments performed in the Near Detector cavern are in accordance with the PPD Electrical Department guidelines and FESHM to ensure that they do not constitute a fire or shock hazard. All installations have been reviewed according to the ORC process. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.4 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. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use.

IV-5.2.4.1 Stored Energy Exposure

N/A

IV-5.2.4.2 High Voltage Exposure

The NOvA Near Detector has a high voltage power supply located in the electronics racks on the mezzanine level in the NOvA Cavern next to the Near Detector. This supplies 450 V to all 631 avalanche photodiodes (APDs) used in the detector, via some custom electronics and power distribution devices. All custom electronics and power distribution devices were cleared for use via Fermilab's Operational Readiness Clearance program. Any work involving high voltage exposure is conducted following hazard analysis and work planning and controls guidelines.

This hazard has been evaluated within the common risk matrix table included in SAD Section I Chapter 04 *Safety Analysis*. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.4.3 Low Voltage, High Current Exposure

N/A

IV-5.2.5 Thermal Energy

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

IV-5.2.5.1 Bakeouts

N/A

IV-5.2.5.2 Hot Work

There are no plans to conduct hot work in this facility at the moment. However, such activities may take place during decommissioning of the NOvA Near 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 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-5.2.5.3 Cryogenics

N/A

IV-5.2.6 Kinetic Energy

The service buildings that support accelerator and 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-5.2.6.1 Power Tools

Power tools are not typically used in the facility. However, there is a possibility of use during maintenance or during decommissioning of the NOvA Near Detector. 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 NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.6.2 Pumps and Motors

The NOvA Near Detector water cooling system has two water pumps and a heat exchanger. The dry gas system uses two air compressors and two air driers. In both systems, one pump/compressor/drier is used at a time with the second as a ready spare.

This hazard has been evaluated within the common risk matrix table included in SAD Section I Chapter 04 *Safety Analysis*. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R III.

IV-5.2.6.3 Motion Tables

N/A

IV-5.2.6.4 Mobile Shielding

N/A

IV-5.2.7 Potential Energy

Potential energy hazards which are applicable to the NOvA Near Detector are discussed in this section.

IV-5.2.7.1 Crane Operations

N/A

IV-5.2.7.2 Compressed Gasses

The NOvA Near Detector uses eight standard compressed gas bottles of ultra-high purity nitrogen which function as a backup system to the detector's dry gas system. To maintain a design pressure of 2200 psi, four bottles are used at a time, with spares in place. These are located on the north side of the NOvA cavern, downstream in the beam direction from the detector itself. While they stay connected, the bottles are typically only actively in use during power outages to the dry gas system. As that system is on emergency power this is not common.

This hazard has been evaluated within the common risk matrix table included in SAD Section I Chapter 04 *Safety Analysis*. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.7.3 Vacuum/Pressure Vessels/Piping

There are three pressure vessels at the NOvA Near Detector: the dry gas buffer tank, the dry gas reservoir, and the water system heat exchanger. There are ASME pressure vessel notes for all three in accordance with FESHM Chapter 5031.

This hazard has been evaluated within the common risk matrix table included in SAD Section I Chapter 04 *Safety Analysis*. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.7.4 Vacuum Pumps

N/A

IV-5.2.7.5 Material Handling

Material handling may be conducted in this facility. This hazard has been evaluated within the common risk matrix table included in SAD Section I Chapter 04 *Safety Analysis*. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.8 Magnetic Fields

N/A

IV-5.2.8.1 Fringe Fields

N/A

IV-5.2.9 Other Hazards

Other hazards which are applicable to the NOvA Near Detector are discussed in this section.

IV-5.2.9.1 Confined Spaces

N/A

IV-5.2.9.2 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 NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R III and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.9.3 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 NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.9.4 Ergonomics

All work at the NOvA Near 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 NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.9.5 Asbestos

N/A

IV-5.2.9.6 Working at Heights

The main body of the NOvA Near Detector is 4.2 meters tall, with a shorter "muon catcher" section that is 2.8 meters tall. Occasionally work is done at heights. This requires fall protection training and hazard protection in accordance with Fermilab's training and work planning and controls program. There is a movable access platform (MAP) which is used to access and work on the top of the main body of the detector. There is a ladder attached to the side of the detector which allows access to the top of the muon catcher. Additionally, there are two retractable fall protection lifelines that can be attached either to the MAP or to an anchor point above the muon catcher.

This hazard has been evaluated within the common risk matrix table included in SAD Section I Chapter 04 *Safety Analysis*. Work at the NOvA Near Detector involving this hazard implements the controls specified in the common risk matrix table. No unique controls are in use. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R III.

IV-5.2.10 Access & Egress

Primary egress for workers (general access and emergency evacuation) is the personnel elevator located in the MINOS building. Secondary emergency egress is along the decay pipeline to MI-65 to a stairwell that leads to the surface; there is also an elevator at this location. The NOvA Near Detector cavern access/egress is governed by NuMI/MINOS underground training and coordination with the MINOS Area Coordinator. Access requires current training, at least one other trained individual, a hard hat, closed toe shoes, and a flashlight. Depending upon work in the underground area, the PPE required for entry may change as appropriate.

Specially trained crane operators transport all heavy equipment and materials underground via the house crane through the shaft. The MINOS shaft crane requires special on-the-job training due to its unusually long wire rope and swing potential. The MINOS Area Coordinator and the MINOS Work Permit/Tour system coordinate all underground work.

IV-5.2.10.1 Life Safety Egress

The NOvA Near Detector is located in the MINOS Underground Area, which is about 100 meters underground. Life safety egress is discussed further in the chapter on MINOS, SAD Chapter IV-06. Briefly and in summary, the main access and egress to the MINOS Underground is via elevator. The MINOS Underground also contains positively pressured emergency escape passageways for life safety egress as well as a secondary emergency escape route which exits through the NuMI Target Hall at the MI-65 Service Building. There is also an emergency diesel generator which supplies power for several functions including emergency exit lighting, elevator, ventilation, and crane power. There are multiple separate backup systems to the groundwater sump pump system, which continuously runs to prevent flooding.

Baseline qualitative risk assessment identified this hazard as "anticipated" for workers and co-located workers, the consequence of the hazard to workers and co-located workers has been identified as "high," resulting in a risk level of I (event of major concern). To reduce the likelihood of this hazard, preventive measures described above, and in the risk tables, reduce the likelihood of this hazard to workers and co-located workers to "extremely unlikely," and mitigative measures reduce the consequences of this hazard from "high" to "negligible." After employing these hazard controls, residual risk level of IV results for workers and co-located workers, meaning that the hazard is of minimal concern.

For members of the public, the qualitative risk assessment indicates that this hazard "beyond extremely unlikely" for members of the public, with a "negligible" risk, because access to this building is forbidden to the public. Since the public remains outside of the hazard area, it is protected by location. Thus, the risk to members of the public remains at a risk level IV and is not considered further.

IV-5.2.11 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.

The NOvA project as a whole has been reviewed for environmental impacts according to NEPA and was issued a Finding of No Significant Impact by the Department of Energy [6].

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 NOvA Detector have been deemed to be "negligible." Additionally, 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-5.2.11.1 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 NOvA Near Detector. Baseline risk for this hazard was R IV and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.11.2 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 and applicable standards. There is no hazard to water resulting from the NOvA Near Detector.

The detector contains approximately 41,200 gallons of liquid scintillator oil. A pliable PVC membrane secondary containment is installed around the entire detector. In the event of a serious spill of liquid scintillator from the detector, this is designed to supply 100% secondary containment for the liquid scintillator. The potential release of the oil 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. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.2.11.3 Hazard to Soil

There is no radiation hazard to soil resulting from the NOvA Near Detector.

The detector contains approximately 41,200 gallons of liquid scintillator oil. A pliable PVC membrane secondary containment is installed around the entire detector. In the event of a serious spill of liquid scintillator from the detector, this is designed to supply 100% secondary containment for the liquid scintillator. Baseline risk for this hazard was R I and, after control measures were evaluated, the residual risk level was R IV.

IV-5.3. Summary of Hazards to Members of the Public

The NOvA Near Detector presents no specific hazards to members of the public.

IV-5.4. 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 NOvA Near Detector site is geographically separated from the accelerator components. The NOvA Near Detector does not have any accelerator components and thus does not require Credited Controls.

IV-5.5. Defense-in-Depth Controls

IV-5.5.1 Administrative Controls

Administrative controls and procedures have been put in place to ensure safe operations at the NOvA Near Detector site. Operational readiness of the experiment is governed by *PPD ESH 006 ES&H Review of Experiments*. 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 that experimental components reside grant approval for operations.

IV-5.5.1.1 Operation Authorization Document

Commissioning, normal operations, and emergency management of the NOvA Near Detector site are all conducted under the auspices of the Neutrino Division, Particle Physics Directorate Headquarters, and the ES&H Division.

IV-5.6. Decommissioning

NOvA is planned to continue normal operations until the long beam shutdown for LBNF/DUNE, projected for 2027. Decommissioning of the NOvA Near Detector would be after this time.

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

IV-5.7. Summary and Conclusion

This chapter of the Fermilab Safety Assessment identifies and assesses specific hazards associated with commissioning and operation of the NOvA Near Detector. The chapter identifies and describes designs, controls, and procedures to mitigate NOvA Near Detector specific hazards. Further, in addition to the specific safety considerations presented in this chapter, the NOvA experiment is subject to the global and more general safety requirements, controls, and procedures outlined in Section 1 of this Fermilab Safety Assessment Document.

The NOvA experiment has been constructed, commissioned, and operated within the specific and general considerations of this safety assessment. The preceding discussion of the hazards presented by the NOvA experiment operations and the Credited Controls established to mitigate those hazards demonstrate that the experiment 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-5.8. References

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

[2] Spill Prevention Control and Countermeasures Plan, Fermi Research Alliance, LLC, Fermi National Accelerator Laboratory, Revision 4, July 2013

[3] Lab Safety/Fire Protection Analysis for Fermilab NOvA Near Detector Cavern, Hughes Associates, Inc., March 5, 2010

[4] NOvA Rigid PVC Flammability Testing and other Fire Related Issues, NOvA Document Data Base, document #358, James Priest, February 2005

[5] Fermilab Environment, Safety, and Health Manual. – The current link is: http://esh.fnal.gov/xms/ESHQ-Manuals/FESHM

[6] Construction and Operation of Neutrinos at the Main Injector (NuMI) Off-axis Electron Neutrino (ν_e) Appearance Experiment (NOvA) at the Fermi National Accelerator Laboratory, Batavia, Illinois, and St. Louis County, Minnesota (DOE-EA-1570) – U.S. Department of Energy Finding of No Significant Impact, Peter Siebach, June 2008

[7] Fermilab Engineering Manual. The current web link is: https://directorate-docdb.fnal.gov/cgi-bin/sso/ShowDocument?docid=34

IV-5.9. 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, co-located workers, and maximally-exposed offsite individuals (MOI).