Main Injector Neutrino Oscillation Search (MINOS) Experimental Hall

Section III – Chapter 6

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Revision History

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Angela Aparicio	Initial release of the MINOS Experimental Hall chapter of the Fermilab Safety Assessment Document.	Revision 0 October 20, 2020

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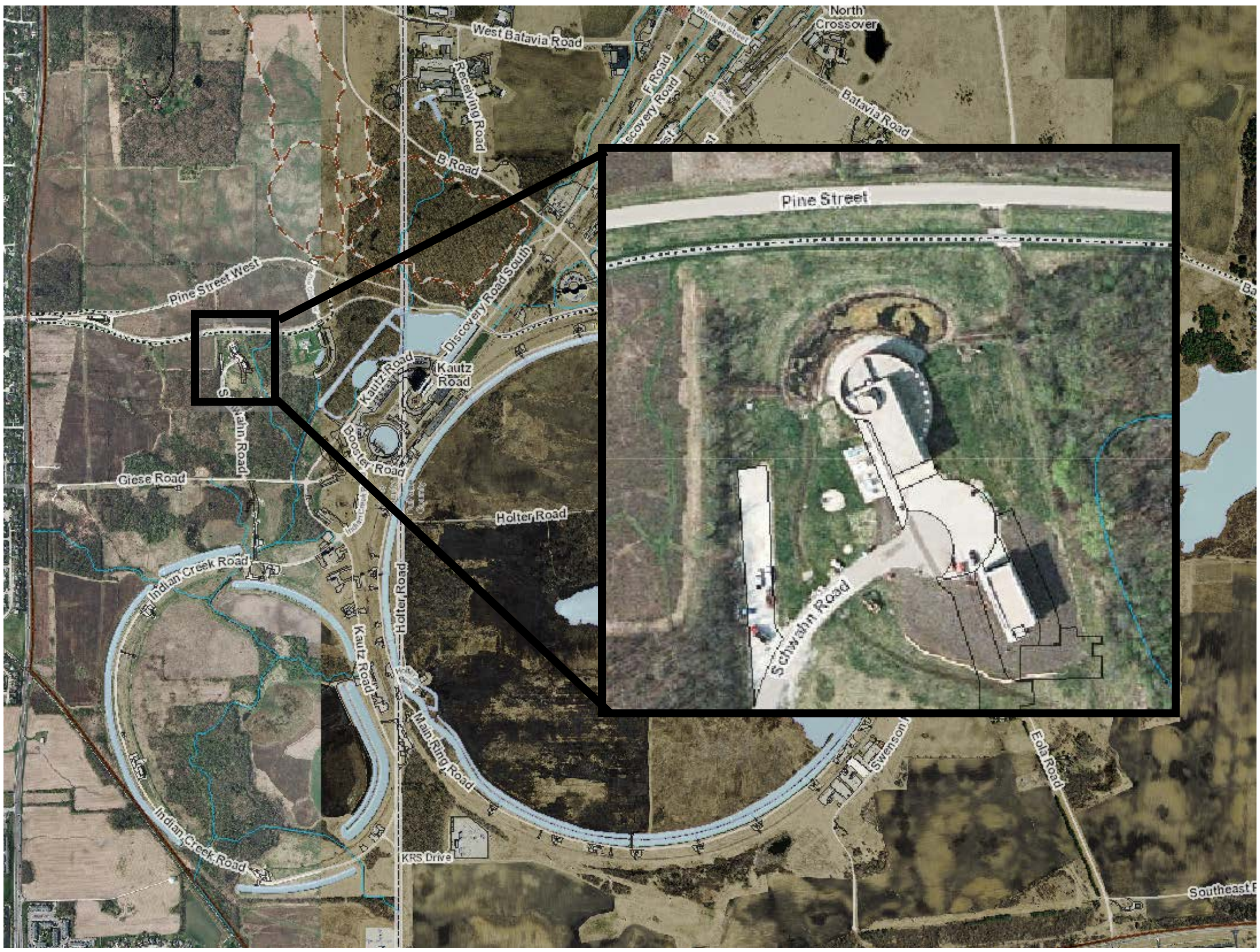
III - 6.1 MINOS Location on Fermi National Accelerator Site

The MINOS Experimental Hall location is shown in the following photograph.



III - 6.2 Inventory of Hazards

The following table lists the identified hazards found in the MINOS Experimental Hall. All hazards with an * have been discussed in Chapters 1-10 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) and are covered no further in this section.

Radiation Lasers Neutron generator Sealed source usage Other radiological hazards	**Kinetic Energy** Power tools* Pumps and motors*
Toxic Materials Lead shielding* Pseudocumene*	**Potential Energy** Crane operations* High pressure*
Flammable & Combustible Materials Cables* Flammable gas Liquid scintillator oil* PVC extrusions*	**Magnetic Fields** N/A
Electrical Energy High voltage*	**Gaseous Hazards** Cryogenic liquids Oxygen deficiency
Thermal Energy Cryogenic liquids*	**Access / Egress** Life safety egress

III - 6.3 Introduction

This Section III, Chapter 6 of the Fermilab SAD covers the MINOS Experimental Hall and respective service building. All areas upstream of the MINOS Experimental Hall are included in Section II, Chapter 9, Neutrinos at the Main Injector (NuMI) Beam Line, of the Fermilab SAD. The MINOS Experimental Hall is not an accelerator; nevertheless, MINOS Experimental Hall detectors have specific hazards that warrant consideration in this Section.

III - 6.3.1 Purpose of the MINOS Experimental Hall

The purpose of the MINOS Experimental Hall is to provide a space within the neutrino beam that can be utilized to observe neutrino behavior at a "near" site and coordinated with a detector at a "far" site (e.g. Ash River, MN). Experiments in the MINOS Experimental Hall currently include NOvA and SENSEI. Future experiments include, but are not limited to, ArgonCube, NEXUS, and MAGIS-100. Future experiments are reviewed as part of the Technical Scope of Work (TSW) process with the hazards identified in this SAD Chapter and approved for operations following FESHM Chapter 2005, *Operational Readiness Clearance (ORC)*.

III - 6.3.2 Description of the NOvA Near Detector

The NOvA Experiment has been designed to study neutrino oscillations. The Near Detector consists of eight extruded plastic scintillator blocks filled with liquid scintillator (95%

mineral oil, 5% psuedocumene), and one muon catcher with heavy steel plates sandwiched with scintillator layers. The plastic scintillator tubes that comprise the blocks are fitted with fiber optics. See SAD Section III, Chapter 5, NuMI Off-axis Electron Neutrino (ve) Appearance (NOvA) Experiment Near Detector, for further details.

III - 6.3.3 Description of SENSEI

The Sub-Electron Noise Skipper Experimental Instrument (SENSEI) is a prototype dark matter detector located in a small clean tent in the MINOS underground tunnel. It is located in the underground area to reduce exposure to cosmic rays. The SENSEI system utilizes skipper charge-coupled devices (CCDs) inside a small vacuum vessel.

III - 6.3.4 Description of NEXUS

The Northwestern Experimental Underground Site at Fermilab (NEXUS @ FNAL) is a dark matter detector testing facility in support of SuperCDMS. A dilution refrigerator is used for detector characterization and prototyping. A neutron generator, with associated shielding materials, is used for calibration. It is located in the underground area to reduce exposure to cosmic rays.

III - 6.3.5 Description of MAGIS-100

The 100-meter Matter-wave Atomic Gradiometer Interferometric Sensor (MAGIS-100) is a project associated with the Quantum Science Program. The MAGIS-100 Experiment will be installed in the MINOS shaft. The experiment will consist of a cold atom source, atom cloud shuttle, launch system, vacuum pipe, laser system and atom detection system.

III - 6.3.6 Description of ArgonCube 2x2 Demonstrator

The ArgonCube 2x2 Demonstrator has a low-pressure cryostat vessel with four DUNE Near Detector prototype LAr modules inside. There are 36 reconfigured scintillator planes from the Main Injector Neutrino ExpeRiment v-A (MINERvA) detector to be placed at the front and behind the LAr vessel.

III - 6.3.7 Operating Modes

The MINOS underground neutrino experiments operate as neutrino detectors utilizing the neutrino beam from the NuMI Beam Line. The Neutrino Division (ND) is responsible for the operation of the neutrino detectors. The operational neutrino experiments assign shifters to monitor the experiment systems, either in the Remote Operations Center (ROC-West) or remotely. Cryogenic engineers on shift respond to Fermilab Fire Incident Reporting and Utility System (FIRUS) trouble or emergency alarms related to the cryogenic system(s).

The dark matter detectors operate independently of the NuMI Beam Line. The Particle Physics Division (PPD) is responsible for the oversight and operations of these detectors.

III - 6.4 Safety Assessment

This section identifies the specific hazards of the MINOS underground experiments and discusses how the hazards are managed. These hazards include lasers, neutron generator, sealed radioactive sources, flammable gases, cryogenic liquids, oxygen deficiency, and enclosure access-egress.

III - 6.4.1 Radiological Hazards

III - 6.4.1.1 Lasers

Lasers may be utilized for experiments located in the shaft or underground, including MAGIS-100. Class 3B and Class 4 lasers can cause eye or skin injuries if a worker is exposed to the beam. To prevent injuries, the laser is encapsulated in a light-tight interlocked enclosure, and safety signage is posted on the enclosure. Any individual who operates/services the laser will have undergone laser safety training and a laser eye exam.

Any laser installation must be reviewed and approved by the Fermilab Laser Safety Officer, thereby meeting all requirements found in the Fermilab Environment, Safety and Health Manual (FESHM)[1] Chapter 4260, *Lasers*.

III - 6.4.1.2 Neutron Generator

The NEXUS site will be utilizing a D-D neutron generator for calibration of the detectors tested in the underground facility. Neutron generators require registration at Fermilab, and their use must be approved in accordance with the Fermilab Radiological Control Manual (FRCM)[2] Article 362, *Radiation Generating Devices and Radiography Sources*. Final operational approval is made through an Operational Readiness Clearance (ORC) review. The Environment, Safety and Health (ES&H) Section Radiation Physics Departments will ensure adequate shielding and interlocks are provided, if necessary, to protect workers and visitors. Operating procedures must be developed and approved.

III - 6.4.1.3 Sealed Radioactive Sources

Calibrating the response of the detectors with sealed radioactive sources may be necessary during the course of commissioning and operating. These sources present potential radiation exposures to the worker if handled improperly, so all radioactive source usage will adhere to the provisions in the sealed radioactive source controls section contained within FRCM Chapter 4.

III - 6.4.1.4 Other Radiological Hazards

The MINOS underground installations do not pose any other radiological hazards.

III - 6.4.2 Flammable Gases

The NEXUS facility will use deuterium gas in their neutron generator. The quantity will be limited to the amount necessary to operate the generator. All use of flammable gases in the underground will be in conformance with FESHM 6020.3, *Storage and Use of Flammable Gases*, and will be reviewed and approved by the Fermilab Fire Hazard Subcommittee prior to operation.

III - 6.4.3 Gaseous Hazards

III - 6.4.3.1 Cryogenics

There are experiments that may be installed in the MINOS Experimental Hall that will utilize cryogenic liquids. The experimental hall is equipped with an ODH monitoring system to alert personnel working in the area when there is a potential oxygen-deficient atmosphere. An oxygen-deficient atmosphere could result from cryogenic system failure/rupture of the vessel or piping, insulation failure, mechanical damage/failure, deficient maintenance, or improper procedures. The cryogenic system will be designed and installed to comply with applicable American Society of Manufacturing Engineers (ASME) and American National Standards Institute (ANSI) standards, per FESHM 5000 Chapters *Mechanical, Cryogenic and Structural Safety*.

Personnel who access the space will be trained through the *NuMI/MINOS Underground Safety Training* course regarding the potential hazards associated with the cryogenics operations, protective measures in place, and any emergency actions that would need to be taken. Visitors to the underground area are given a safety briefing that covers potential hazards that may be experienced while underground and mitigation measures.

III - 6.4.3.2 Oxygen Deficiency Hazard (ODH)

The use of cryogenic liquids potentially can produce an oxygen-deficient atmosphere, which can result in death or injury from asphyxiation or from contact with the extremely cold fluids/gases. The failure of cryogenic systems can release gas and initiate an ODH event. FESHM Chapter 5032, *Cryogenic System Review* provides guidelines for designing and operating cryogenic vessels and systems to mitigate ODH hazards.

The underground experimental hall will be analyzed and classified according to the requirements of FESHM Chapter 4240, *Oxygen Deficiency Hazards (ODH)*. Once the ODH hazard level classification has been determined, hazard controls will be implemented. These may include ODH warning signals, oxygen sensors (interlocked to the FIRUS for remote alarm monitoring), ventilation fans and other measures as determined by the ODH analysis. The cryogenics control system will be designed to monitor and report any alarms to the experiment shifter in the ROC-West or connected remotely, and the cryogenics engineer on shift.

The underground emergency passageway is supplied with a ventilation system that operates independently of the experimental hall ventilation. This ventilation system is on the emergency back-up generator so ventilation will still be supplied during power outages.

III - 6.4.4 Access/Egress

The MINOS Experimental Hall is accessible via an elevator during normal operations. The elevator access is controlled by keys that are checked out from the Main Control Room. In order to obtain a key, personnel must have current General Employee Radiation Training (GERT) and NuMI/MINOS Underground Safety Training.

The secondary egress route is through the absorber access tunnel, up the decay pipe walkway, and into the NuMI Target Hall, where personnel are directed to the stairs or elevator in that location.

Primary and secondary egress routes are explained in the NuMI/MINOS Underground Safety Training and in the safety briefing for tourists.

III - 6.5 Defense in Depth Controls

III - 6.5.1 Administrative Controls

Administrative procedures have been put in place to ensure safe operations in the MINOS Underground. Operational readiness of any of the experiments located underground is governed by FESHM Chapter 2005, *Operational Readiness Clearance*. Subject matter experts review each aspect of an experiment prior to operations to ensure safe operations. The review includes procedure, hazard analysis and document reviews and walk-throughs of the experiment components. The Division Head of the area in which experimental components reside grants approval for operations.

III - 6.5.1.1 Detector Operations

Commissioning, normal operations, and emergency management of the experiments are all conducted under the purview of the Neutrino Division Office, Particle Physics Division Office, and Environment Safety & Heath Section.

III - 6.6 Credited Controls

As described in Chapters 1-10 of the Fermilab SAD, credited controls are the primary controls that assure that the level of risk to all workers, the public, and the environment is maintained at an acceptable level. The MINOS Experimental Hall is geographically separated from the accelerator components and thus does not require any passive, active or administrative controls that rise to the level of a Credited Control needing inclusion in the Accelerator Safety Envelope. The controls identified in Sections 6.4 and 6.5 exist to ensure safe operations during all conditions in the MINOS Experimental Hall and are not specific to accelerator operation.

III - 6.7 Decommissioning

Decommissioning of any of the experiments in the MINOS Experimental Hall will follow the requirements of FESHM Chapter 8070, *Decontamination and Decommissioning*.

III - 6.8 Summary & Conclusion

This chapter of the Fermilab SAD identifies and assesses specific hazards associated with experiments that may be present in the MINOS Experimental Hall. The chapter identifies and describes designs, controls, and procedures to mitigate those hazards. In addition to the specific safety considerations presented in this chapter, the MINOS Experimental Hall experiments are subject to the global and more general safety requirements, controls, and procedures outlined in Section 1 of this Fermilab SAD.

All experiments installed and operated in the hall will be constructed, commissioned, and operated within the specific and general considerations of this safety assessment. The preceding discussion of the hazards presented by the experiments and the controls established to mitigate those hazards demonstrate that the experiments can be operated in a manner that will produce minimal hazards to the health and safety of Fermilab workers, researchers, members of the public, as well as to the environment.

III - 6.9 Glossary, Acronyms

ANSI	American National Standards Institute
ASME	American Society of Manufacturing Engineers
CCD	Charge-Coupled Device
DUNE	Deep Underground Neutrino Experiment
ES&H	Environment, Safety and Health
FESHM	Fermilab Environment, Safety, and Health Manual
FIRUS	Fire Incident Reporting and Utility System
Fermilab	Fermi National Accelerator Laboratory
FRCM	Fermilab Radiological Control Manual
GERT	General Employee Radiation Training
LAr	Liquid Argon
MAGIS	Matter-wave Atomic Gradiometer Interferometric Sensor
MINERvA	Main Injector Neutrino ExpeRiment v-A
MINOS	Main Injector Neutrino Oscillation Search
ND	Neutrino Division
NEXUS	Northwestern Experimental Underground Site
NOvA	NuMI Off-axis Electron Neutrino Appearance
NuMI	Neutrinos at the Main Injector
ODH	Oxygen Deficiency Hazard
ORC	Operational Readiness Clearance
PPD	Particle Physics Division
ROC-West	Remote Operations Center West
SAD	Safety Assessment Document
SENSEI	Sub-Electron Noise Skipper Experimental Instrument
SuperCDMS	Super Cryogenic Dark Matter Search

III - 6.10 References

[1] Fermilab Environment, Safety and Health Manual (FESHM) - The current link is: https://eshq.fnal.gov/manuals/feshm/

[2] Fermilab Radiological Control Manual (FRCM) – The current link is: https://eshq.fnal.gov/manuals/frcm/