MESON AREA

SECTION III CHAPTER 13 OF THE FERMILAB SAD

Revision 2 August 7, 2023

This Chapter of the Fermilab Safety Assessment Document (SAD) contains a summary of the results of the Safety Analysis for the Meson Area of the Fermi 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 III, Chapter 13 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), Meson Area, was prepared and reviewed by the staff of the Accelerator Directorate, Beams Division, External Beam Delivery 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.

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Revision History

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

Author	Rev. No.	Date	Description of Change
Michael K. Olander	2	August 7, 2023	• Updated to align with new SAD Layout • Incorporated Risk Matrix & hazard discussion
Wayne Schmitt Thomas R. Kobilarcik	1	January 18, 2019	• Updated MCenter beamline area description • Updated operating intensity limits, where applicable
John E. Anderson Jr. Craig Moore	0	April 29, 2014	Initial release of the Meson Area Chapter for the Fermi National Accelerator Laboratory Safety Assessment Document (SAD).

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Acronyms and Abbreviations

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

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

HLCF	High Level Calibration Facility
HPR	Highly Protected Risk
Hr	Hour
HRA	High Radiation Area
HSSD	High Sensitivity Air Sampling Detection
HVAC	Heating, Ventilation, and Air Conditioning
HWSF	Hazardous Waste Storage Facility
Hz	Hertz
IB	Industrial Building
IBC	International Building Code
ICW	Industrial Cooling Water
IEPA	Illinois Environmental Protection Agency
IEEE	Institute of Electrical and Electronics Engineers
INFN	Istituto Nazionale di Fisica Nucleare
IMPACT	Integrated Management Planning and Control Tool
IPCB	Illinois Pollution Control Board
IQA	Integrated Quality Assurance
ISD	Infrastructure Services Division
ISM	Integrated Safety Management
ITNA	Individual Training Needs Assessment
KeV	kilo-electron volt
kg	kilo-grams
kW	kilo-watt
LBNF	Long Baseline Neutrino Facility
LCW	Low Conductivity Water
LHC	Harge Hadron Collider
LLCF	Low Level Calibration Facility
LLWCP	Low Level Waste Certification Program
LLWHF	Low Level Waste Handling Facility
LOTO	Lockout/Tagout
LPM	Laser Profile Monitor
LSND	Liquid Scintillator Neutrino Detector
LSO	Laser Safety Officer
m	meter
mA	milli-amp
MABAS	Mutual Aid Box Alarm System
MARS	Monte Carlo Shielding Computer Code
MC	Meson Center
MC&A	Materials Control and Accountability

MCR	Main Control Room
MEBT	Medium Energy Beam Transport
MEI	Maximally Exposed Individual
MeV	Mega-electron volt
MI	Main Injector
MINOS	Main Injector Neutrino Oscillation Search
MMR	Material Move Request
MOI	Maximally-Exposed Offsite Individual *(Note: due to the Fermilab Batavia Site being open to the public, the location of the MOI is taken to be the location closest to the accelerator that is accessible to members of the public.)*
MP	Meson Polarized
mrad	milli-radian
mrem	milli-rem
mrem/hr	milli-rem per hour
MT	Meson Test
MTA	400 MeV Test Area
MTF	Magnet Test Facility
^{22}Na	Sodium-22
NC	Neutrino Center
NE	Neutrino East
NEC	National Electrical Code
NEPA	National Environmental Policy Act
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NM	Neutrino Muon
NMR	Nuclear Material Representative
NOvA	Neutrino Off-axis Electron Neutrino (ve) Appearance
NPH	Natural Phenomena Hazard
NRTL	Nationally Recognized Testing Laboratory
NIF	Neutron Irradiation Facility
NTSB	Neutrino Target Service Building, see also TSB
NuMI	Neutrinos at the Main Injector
NW	Neutrino West
ODH	Oxygen Deficiency Hazard
ORC	Operational Readiness Clearance
OSHA	Occupational Safety and Health Administration
pCi	pico-Curie
pCi/mL	pico-Curie per milliliter
PE	Professional Engineer

PIN	Personal Identification Number
PIP	Proton Improvement Plan
PIP-II	Proton Improvement Plan - II
PHAR	Preliminary Hazards Analysis Report
PPD	Particle Physics Directorate
PPE	Personnel Protective Equipment
QA	Quality Assurance
QAM	Quality Assurance Manual
RA	Radiation Area
RAF	Radionuclide Analysis Facility
RAW	Radioactive Water
RCT	Radiological Control Technician
RF	Radio-Frequency
RFQ	Radio-Frequency Quadrupole
RIL	RFQ Injector Line
RMA	Radioactive Material Area
RMS	Root Mean Square
RPCF	Radiation Physics Calibration Facility
RPE	Radiation Physics Engineering Department
RPO	Radiation Physics Operations Department
RRM	Repetition Rate Monitor
RSI	Reviewed Safety Issue
RSIS	Radiation Safety Interlock System
RSO	Radiation Safety Officer
RWP	Radiological Work Permit
SA	Shielding Assessment
SAA	Satellite Accumulation Areas
SAD	Safety Assessment Document
SCF	Standard Cubic Feet
SCFH	Standard Cubic Feet per Hour
SEWS	Site-Wide Emergency Warning System
SNS	Spallation Neutron Source
SR	Survey Riser
SRF	Superconducting Radio-Frequency
SRSO	Senior Radiation Safety Officer
SSB	Switchyard Service Building
SSP	Site Security Plan
SWIC	Segmented Wire Ionization Chambers
TLM	Total Loss Monitor

TLVs	Threshold Limit Values
TPC	Time Projection Chamber
TPES	Target Pile Evaporator Stack
TPL	Tagged Photon Lab
TSB	Target Service Building, see also NTSB
TSCA	Toxic Substances Control Act
TSW	Technical Scope of Work
T&I	Test and Instrumentation
UPB	Utility Plant Building
UPS	Uninterruptible Power Supply
USI	Unreviewed Safety Issue
VCTF	Vertical Cavity Test Facility
VHRA	Very High Radiation Area
VMS	Village Machine Shop
VMTF	Vertical Magnet Test Facility
VTS	Vertical Test Stand
WSHP	Worker Safety and Health Program
µs	micro-second

III-13. Meson Area

III-13.1. Introduction

This Section III, Chapter 13 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the Meson Area.

III-13.1.1 Purpose/Function

The purpose of the Meson area is to deliver primary proton beam to separate targets and convey secondary particles produced from the target collisions to two independent experimental areas, Meson Test (MTest) and Meson Center (MCenter), for use in test beam research and development.

III-13.1.2 Current Status

The Meson Test (MTest) segment of the Meson Area is currently: Operational

The Meson Center (MCenter) segment of the Meson Area is currently: Operational

The Meson East (MEast) segment of the Meson Area is currently: Non-operational

The Meson Polarized (MPolarized) segment of the Meson Area is currently: Non-operational

The Meson Bottom (MBottom) segment of the Meson Area is currently: Non-operational

III-13.1.3 Description

The Meson Area beamlines start at the upstream end of the M01 enclosure and continue to the downstream end of MT6 Section 2 for the MTest beamline and the downstream end of MC7 Section 2 for the MCenter beamline. Associated beamline infrastructure is located at the service buildings.

The Meson area beamlines comprise the following enclosures:

- M01
- M02
- M03
- M05
- M05
- MC6
- MT6 Section 1 (MT6-1)
- MT6 Section 2 (MT6-2)
- MC7 Section 1 (MC7-1)
- MC7 Section 2 (MC7-2)
- MB7

The Meson Area beamlines comprise of the following service buildings:

- MS1
- MS2
- MS3
- MS4
- MS5

The Meson Area may refer to the following beamlines:

- Meson East (MEast)
- Meson Polarized (MPolarized)
- Meson Center (MCenter)
- Meson West (MWest)
- Meson Test (MTest)

The Meson Area beamlines includes the following areas:

- The Meson Target Train located between the M01 Enclosure and M02 Enclosure

The MT6 Sections 1 and 2 enclosures, and the MC6 enclosure, are housed in the Meson Detector Building. The Meson Detector Building also houses additional experimental facilities not addressed in this assessment.

III-13.1.4 Location

The Meson Area is located on the Fermilab site in Batavia, IL.

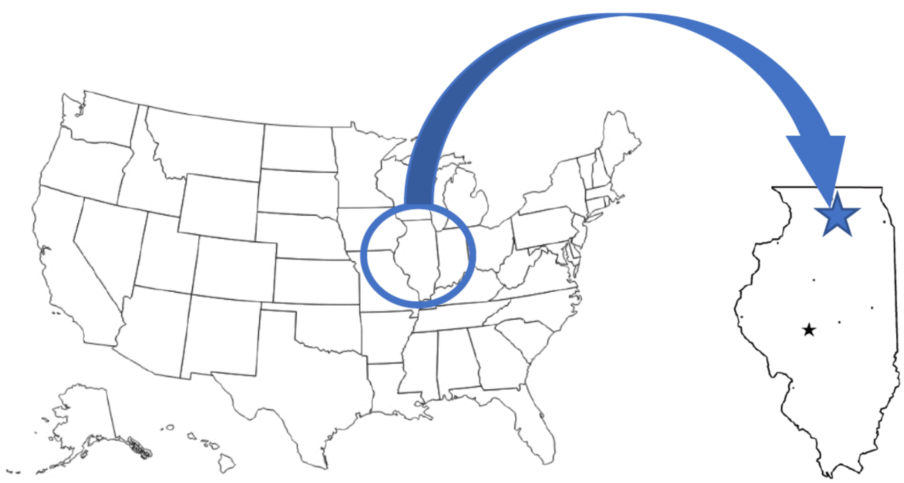

Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.

The Meson Area is located to the north of Wilson Hall on the Fermilab site.

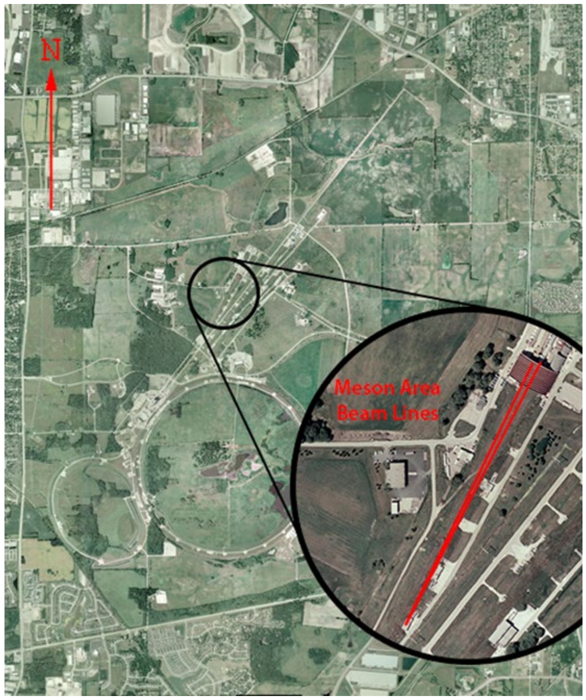

Figure 2. Aerial view of the Fermilab site, indicating the location of the Meson Area.

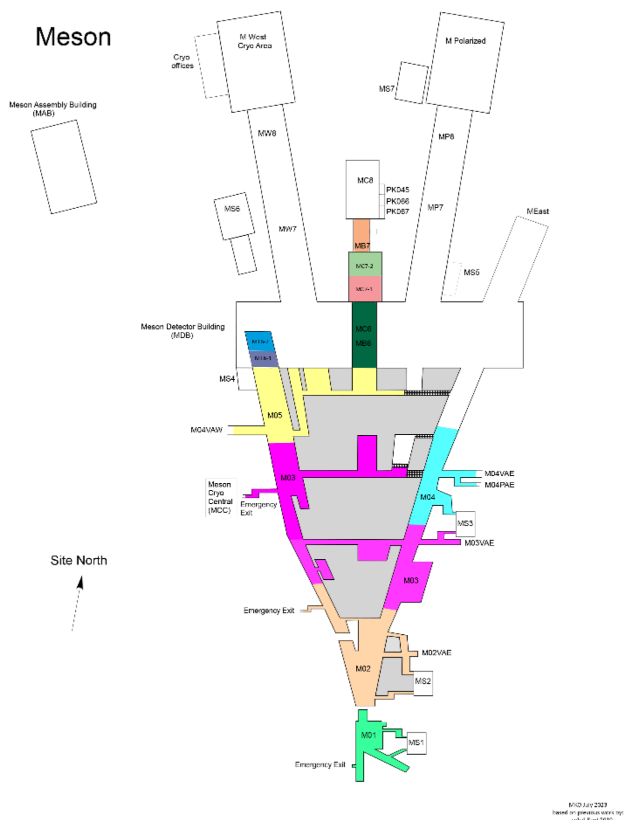

Figure 3: Meson Enclosures & Service Buildings

III-13.1.5 Management Organization

The Meson Area is Managed by Accelerator Directorate, Beams Division, External Beam Delivery Department. The experimental areas, Fermilab Test Beam Facility (FTBF) is managed by Particle Physics Directorate, Engineering Division, Detector Development & Testing Department, Test Beam Facilities Group.

III-13.1.6 Operating Modes

The upstream Meson Area, the M01 enclosure, receives 120 giga-electron volt (GeV) beam from the Switchyard Fixed Target beamlines and delivers to the Meson experimental facilities. For each facility, 120 GeV protons strike a target. The secondary particles produced from these targets are transported via a system of electromagnets to the test beam facilities. The production targets and transport systems are separate and independent of each other. Changes in the running conditions at one of the experimental areas do not affect operations in the other experimental area. Beam can be provided to any one experiment or both experiments simultaneously without special beam line configuration changes.

The Meson Target Train is located between enclosures M01 and M02. For operational purposes, such as tuning or temporarily inhibiting beam, primary beam for MTest or MCenter may be temporarily disabled and absorbed on the target train.

The upstream Meson Area and MTest Accelerator Safety Envelope (ASE) beam intensity limit is 1.03x1016 protons per hour. The MCenter ASE beam intensity limit is 9.60x1016 protons per hour.

The MTest facility modes of operation are described in detailed shielding assessments. The modes of operation are based on the shielding assessments, which consider beamline configuration of targets, collimators, and magnet power supply settings. The modes of operation of the MTest facility are:

- Diffracted Proton Mode
- High Energy Pion Mode
- Low Energy Pion Mode

There is no provision for neutral particles. Individual species cannot be selected – the experiment is responsible for particle type identification.

The MCenter facility modes of operation are described in detailed shielding assessments. The modes of operation are based on the shielding assessments, which consider beamline configuration of targets, collimators, and magnet power supply settings. The modes of operation for the MCenter facility are:

- Pion Mode

There is no provision for neutral particles. Individual species cannot be selected – the experiment is responsible for particle type identification.

The Meson Area houses several non-operational beamlines, which are not capable of delivering beam. These areas are Meson East (MEast), Meson Polarized (MPolarized), Meson Bottom (MBottom), and Meson West (MWest).

III-13.1.7 Inventory of Hazards

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

Prompt ionizing, Oxygen Deficiency Hazards due to cryogenic systems within accelerator enclosures, and fluorinert byproducts due to use of fluorinert that is subject to particle beam have been identified as accelerator specific hazards, and as such their controls are identified as Credited Controls. The analysis of these hazards and their Credited Controls will be discussed within this SAD Chapter, and their Credited Controls summarized in the Accelerator Safety Envelope for the Meson Area. Accelerator specific controls are identified as **purple/bold** throughout this Chapter.

All other hazards present in the Meson 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 Standard Industrial Hazards (SIH), and their analysis will be summarized in this SAD Chapter.

Table 1. Hazard Inventory for the Meson Area.

	Radiological		**Toxic Materials**
☒	Prompt Ionizing Radiation	☒	Lead Shielding
☒	Residual Activation	☒	Beryllium
☒	Groundwater Activation	☐	Fluorinert & Its Byproducts
☒	Surface Water Activation	☐	Liquid Scintillator Oil
☒	Radioactive Water (RAW) Systems	☐	Pseudocumene
☒	Air Activation	☐	Ammonia
☐	Closed Loop Air Cooling	☐	Nanoparticle Exposures
☒	Soil Interactions		**Flammables and Combustibles**
☒	Radioactive Waste	☒	Combustible Materials (e.g., cables, wood cribbing, etc.)
☒	Contamination	☐	Flammable Materials (e.g., flammable gas, cleaning materials, etc.)
☒	Beryllium-7		**Electrical Energy**
☒	Radioactive Sources	☒	Stored Energy Exposure
☐	Nuclear Material	☒	High Voltage Exposure
☐	Radiation Generating Devices (RGDs)	☒	Low Voltage, High Current Exposure
☐	Non-Ionizing Radiation Hazards		**Kinetic Energy**
	Thermal Energy	☒	Power Tools
☐	Magnet Bakeouts	☒	Pumps and Motors
☒	Hot Work	☒	Motion Tables
☒	Cryogenics	☐	Mobile Shielding
	Potential Energy		**Magnetic Fields**
☒	Crane Operations	☒	Fringe Fields
☒	Compressed Gasses		**Other Hazards**
☒	Vacuum/Pressure Vessels/Piping	☒	Confined Spaces
☒	Vacuum Pumps	☒	Noise
☐	Material Handling	☐	Silica
	Access & Egress	☒	Ergonomics
☒	Life Safety Egress	☐	Asbestos

III-13.2. Safety Assessment

All hazards for the Meson Area are summarized in this section, with additional details of the analyses for accelerator specific hazards.

III-13.2.1 Radiological Hazards

The Meson Area presents radiological hazards in the form of Prompt Ionizing Radiation, Residual Activation, Groundwater Activation, Surface Water Activation, Radioactive Water (RAW) Systems, Air Activation, Soil Interactions, Radioactive Waste, Contamination, Beryllium-7, and Radioactive Sources. A detailed shielding assessment[2] addresses these hazards and provide a detailed analysis of the facility demonstrating the required shielding, controls and interlocks to comply with the Fermilab Radiological Control Manual (FRCM)[1].

The shielding assessments for the Meson Area assess the areas described in Section III Chapter 13.1.3. Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from the Radiological Hazards within the Meson Area are at an acceptable level.

III-13.2.1.1 Prompt Ionizing Radiation

Prompt ionizing radiation is the principle radiological hazard that arises when beam is transported through the Meson area beam lines. To protect workers and the general public, the enclosures and beam pipes are surrounded either by sufficient amounts of shielding (soil, concrete, or iron), and/or networks of interlocked detectors to keep any prompt radiation exposure within acceptable levels.

The Fermilab Shielding Assessment Review Panel (SARP) reviewed the detailed shielding assessments to address ionizing radiation concerns. The assessments provide a detailed analysis of the beam lines; assess both passive and active shielding; assess required overburden or soil shielding; and review the use of signs, fences, and active interlocks to maintain any prompt radiation within acceptable levels.

Shielding assessments for the Meson area beam lines have included analyses of beam transport, targeting, and absorption areas. The shielding assessments require that:

- *All penetrations must be filled with shielding as specified.*
- *All movable shielding blocks must be installed as specified.*
- *Radiological fences must be installed as specified.*
- *The average beam intensity in the Meson Primary beamlines (M01-M02) shall not exceed 1.68×10^{14} 120 GeV protons per hour.*
- *The average beam intensity in the MTest beamline shall not exceed 1.20×10^{13} 120 GeV protons per hour.*
- *The average beam intensity in the MCenter beamline shall not exceed 1.02×10^{12} 120 GeV protons per hour.*
- *The Radiation Safety Interlock System (RSIS) must be certified as working.*
- *Radiation detectors around the Meson Area beamlines are installed and interlocked to the Radiation Safety Interlock System (RSIS).*

Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from the Prompt Ionizing Radiation within the Meson Area is at an acceptable level.

III-13.2.1.2 Residual Activation

The Meson Target Train, MTest M03 Pinhole Collimator, MTest M03 Low Energy Pion Target, MCenter MC6 Target, and MCenter MC6 Momentum Collimator may be highly activated even when the Meson beamlines are in a non-operational or standby condition. Access to these components will be tightly controlled with the control dependent on the level of residual radiation. The control measures include training and training verification, centralized access authorization, and key entry. Controls required for different levels of residual radiation are specified in the FRCM and are detailed in the Radiological Work Permit (RWP) for the work to be performed.

In most situations, general RWPs for accesses will suffice. A job-specific RWP and/or an ALARA ("as-low-as-reasonably-achievable") plan will be required for work on any highly activated equipment with a potential individual exposure greater than 200 millirem (mrem) or potential exposure for all persons on the job greater than 1000 mrem. These tasks will be supervised by members of the Radiological Control Organization under the direction of the assigned Radiation Safety Officer (RSO).

Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from Residual Activation within the Meson Area is at an acceptable level.

III-13.2.1.3 Groundwater Activation

Table 2: Meson Area Surface Water & Groundwater ^{3}H & ^{22}Na Release Concentrations

Description	Annual Concentration Limits In picocuries per milliliter (pCi/ml)		Annual Concentration Estimate In picocuries per milliliter (pCi/ml)	
	^{3}H	^{22}Na	^{3}H	^{22}Na
Target Train Surface Water	1900	10	2.4×10^{1}	2.1×10^{0}
Target Train Groundwater	20	0.4	2.2×10^{-7}	1.0x10-8
M03 Pinhole Collimator Surface Water	1900	10	3.4×10^{1}	3.0×10^{0}
M03 Pinhole Collimator Groundwater	20	0.4	3.2×10^{-7}	1.5×10^{-8}
MT3 Low Energy Pion Target Surface Water	1900	10	1.7×10^{1}	1.5×10^{0}
MT3 Low Energy Pion Target Groundwater	20	0.4	1.6×10^{-7}	7.0×10^{-9}
MCenter Target Pile Surface Water	1900	10	6.5×10^{-1}	5.8×10^{-2}
MCenter Target Pile Groundwater	20	0.4	1.3×10^{-8}	2.6×10^{-13}

^{3}H Regulatory Limit from 40CFR141 *Federal Drinking Water Standards*.
^{22}Na Regulatory Limits from the Department of Energy STD-1196-2011 *Derived Concentration Standards.*

The release estimate for surface and groundwater after 10 years of operation to the Meson Target Train in M01 at an integrated intensity of 7.94x1017 protons per year will produce combined 3H (tritium) and 22Na (sodium-22) concentrations that are 22% of the surface water limits and a negligible fraction of the groundwater limits respectively.

The release estimate for surface and groundwater after 10 years of operation to the M03 Pinhole Collimator at an integrated intensity of 1.74x1017 protons per year will produce combined 3H and 22Na concentrations that are 32% of the surface water limits and a negligible fraction of the groundwater limits respectively.

The release estimate for surface and groundwater after 10 years of operation to the MT3 Low Energy Pion Mode target at an integrated intensity of 1.2x1017 protons per year will produce combined 3H and 22Na concentrations that are 65% of the surface water limits and a negligible fraction of the groundwater limits respectively.1

The release estimate for surface and groundwater after 10 years of operation to the MCenter Target Pile in MC6 at an integrated intensity of 5.26x1016 protons per year will produce combined 3H and 22Na concentrations that are 0.6% of the surface water limits and a negligible fraction of the groundwater limits respectively.[Error! Bookmark not defined.] The annual concentration estimates for 3H and 22Na in surface water and groundwater from these absorbers are given in Table 2.

The 3H and 22Na surface and groundwater concentration estimates are all within the FRCM limits. Groundwater and Surface Water is sampled as part of the Fermilab Environment, Safety, Health, and Quality Section Environmental Monitoring Program.

Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from Groundwater and Surface Water within the Meson Area is at an acceptable level.

III-13.2.1.4 Surface Water Activation

Surface water activation in the Meson Area is characterized in Section III Chapter 13.2.1.3.

III-13.2.1.5 Radioactive Water (RAW) Systems

The Meson Area uses a Radioactive Water (RAW) System in the M01 enclosure. This system is used to cool the Meson Target Train. The system is a closed-loop system. Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from Radioactive Water (RAW) System within the Meson Area is at an acceptable level.

III-13.2.1.6 Air Activation

Air activation measurements were taken during the 1999 Fixed Target run and documented in the shielding assessment [2]. 0 Ci of measured air release was observed under similar beam operating conditions to the present day. [2] Therefore, the consequence of air activation in the Meson Area is negligible. Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazard from Air Activation within the Meson Area is at an acceptable level.

III-13.2.1.7 Closed Loop Air Cooling

This hazard is not applicable to the Meson Area.

III-13.2.1.8 Soil Interactions

A forward cone, with angles on the order of 5 milliradians (mrad) of energetic penetrating muons is created whenever a 120 GeV proton beam is absorbed in the Meson Area beam absorbers. There is no significant flux of pions and kaons produced at energies above 100 GeV and hence no significant flux of muons produced at energies above 80 GeV. The 80 GeV muons have a specific ionization energy loss of 4 mega-electron volt per centimeter (MeV/cm) and can only penetrate up to 200 meters of earth equivalent shielding.

The Meson Target Train and M03 Pinhole Collimator are followed by steel and earth shielding. There is shielding well over 200 m earth equivalent in thickness in the forward direction for production angles of less than 5 mrad. This amount of shielding is sufficient to stop the muon plumes that arise from penetrating beyond M05. For MCenter operations, the MC6 Target Pile has the potential to produce muon dose rates downstream of the target. MARS Monte Carlo code simulations of the target pile indicate muon dose rates in all potentially occupied areas are less than 0.05 mrem/hr.

The soil surrounding the Meson Area will be sampled during decommissioning to document activation levels as required by the Fermilab Environment, Safety, and Health (ES&H) Manual (FESHM).

Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazard from Soil Interactions within the Meson Area is at an acceptable level.

III-13.2.1.9 Radioactive Waste

Radioactive waste produced in the course of Meson Area operations will be managed within the established Radiological Protection Program (RPP) and as prescribed in the Fermilab Radiological Control Manual (FRCM). Radioactive waste is a standard radiological hazard that is managed within the established Radiological Protection Program (RPP) and as prescribed in the Fermilab Radiological Control Manual (FRCM). Waste minimization is an objective of the equipment design and operational procedures. Although production of radioactive material is not an operational function of the Meson Area, beam loss and, in the case of some beam diagnostics devices, intentional interception of the beam will result in activation of beam line elements. Reuse of activated items will be carried out when feasible. Activated items that cannot be reused will be disposed of as radioactive waste in accordance with the FRCM requirements.

Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazard from Radioactive Waste within the Meson Area is at an acceptable level.

III-13.2.1.10 Contamination

Contamination of components caused by beam interaction may exist in the Meson Area. Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from Contamination within the Meson Area is at an acceptable level.

III-13.2.1.11 Beryllium-7

^{7}Be is not hazardous in this pattern of use by the facility. Based on hazard analysis, and implementation of indicated preventative and mitigated controls, the risk of hazards from ^{7}Be within the Meson Area is at an acceptable level.

III-13.2.1.12 Radioactive Sources

Radioactive Sources may be used in shutdown and maintenance activities. These sources, when used in the Meson Area, are handled in accordance with FRCM. Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from Radioactive Sources within the Meson Area is at an acceptable level.

III-13.2.1.13 Nuclear Material

This hazard is not applicable to the Meson Area.

III-13.2.1.14 Radiation Generating Devices (RGDs)

This hazard is not applicable to the Meson Area.

III-13.2.1.15 Non-Ionizing Radiation Hazards

This hazard is not applicable to the Meson Area.

III-13.2.2 Toxic Materials

The Meson Area presents toxic material hazards in the form of a list of checked off hazards shown in Table 1 of the Meson Area SAD. All toxic material hazards present in the Meson Area are in the form of Standard Industrial Hazards discussed in SAD Section I, Chapter 04.

III-13.2.2.1 Lead

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.2.2 Beryllium

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.2.3 Fluorinert & Its Byproducts

This hazard is not applicable to the Meson Area.

III-13.2.2.4 Liquid Scintillator Oil

This hazard is not applicable to the Meson Area.

III-13.2.2.5 Pseudocumene

This hazard is not applicable to the Meson Area.

III-13.2.2.6 Ammonia

This hazard is not applicable to the Meson Area.

III-13.2.2.7 Nanoparticle Exposures

This hazard is not applicable to the Meson Area.

III-13.2.3 Flammables and Combustibles

III-13.2.3.1 Combustible Materials

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.3.2 Flammable Materials

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.4 Electrical Energy

III-13.2.4.1 Stored Energy Exposure

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.4.2 High Voltage Exposure

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.4.3 Low Voltage, High Current Exposure

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.5 Thermal Energy

III-13.2.5.1 Bakeouts

This hazard is not applicable to the Meson Area.

III-13.2.5.2 Hot Work

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.5.3 Cryogenics

The Meson Area beamlines do not use cryogenics operationally, however test stands located in the Meson Detector Building (MDB), use cryogenic helium for various experiments. The liquification plant is located at the Meson Cryo Central building. The cryogenics then use existing piping through enclosures M03 and M04 to reach the test stands. Due to the active use of the cryogenic test stands in the Meson Detector Building, the Meson enclosures M02, M03, M04, and M05 are classified as ODH-1 areas. The Meson Area ODH analysis is on file with APS/TD Cryogenics. The hazards associated with cryogenics include ODH conditions and burns.

These hazards have been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving these hazards implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.6 Kinetic Energy

III-13.2.6.1 Power Tools

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.6.2 Pumps and Motors

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.6.3 Motion Tables

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.6.4 Mobile Shielding

This hazard is not applicable to the Meson Area.

III-13.2.7 Potential Energy

III-13.2.7.1 Crane Operations

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.7.2 Compressed Gasses

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.7.3 Vacuum/Pressure Vessels/Piping

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.7.4 Vacuum Pumps

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.7.5 Material Handling

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.8 Magnetic Fields

III-13.2.8.1 Fringe Fields

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.9 Other Hazards

III-13.2.9.1 Confined Spaces

The Meson Area has several areas considered Confined Spaces. In the M03 and MC6 enclosures, there are areas that exist below grade and have only one point of entry and egress. Access to these areas follow Confined Space policy from FESHM 4230. Based on hazard analysis and implementation of indicated preventative and mitigated controls, risk of hazards from Confined Spaces within the Meson Area is at an acceptable level.

All other confined spaces in the Meson Area, e.g., sump pits, have been evaluated within the Common Risk Matrix, included in SAD Section I, Chapter 04 Safety Analysis. Work involving Confined Spaces in the Meson Area implement the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.9.2 Noise

The upstream area of the M02 enclosure is marked as a noise hazard due when the MS2 LCW System is running. This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.9.3 Silica

This hazard is not applicable to the Meson Area.

III-13.2.9.4 Ergonomics

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.9.5 Asbestos

This hazard is not applicable to the Meson Area.

III-13.2.9.6 Working at Heights

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.10 Access & Egress

III-13.2.10.1 Life Safety Egress

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.11 Environmental

III-13.2.11.1 Hazard to Air

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.11.2 Hazard to Water

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.2.11.3 Hazard to Soil

This hazard has been evaluated within the Common Risk Matrix Table included in SAD Section I Chapter 04 Safety Analysis. Work in the Meson Area involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

III-13.3. Summary of Hazards to Members of the Public

Under normal operating conditions, the Meson Area beam lines are not hazardous to members of the public.

III-13.4. Summary of Credited Controls

III-13.4.1 Passive Credited Controls

Passive controls are accelerator elements that are part of the physical design of the facility that require no action to function properly. These passive controls are fixed elements of the beam line that take direct human intervention to remove. The Meson Area was designed with a concrete and earth covered radiation shield to protect personnel from radiological exposure during beam operations.

III-13.4.1.1 Shielding

The Meson Area beam lines shielding analyses indicate the mitigations necessary to comply with the FRCM requirements. Interlocked radiation detectors are installed along the MTest and MCenter beam lines as prescribed by the shielding assessments to mitigate this concern.

III-13.4.1.1.1 Permanent Shielding Including Labyrinths

The details of the Meson Area labyrinth assessments have been documented.[2][3][4] The shielding summary indicates that all labyrinths provide adequate shielding to conform to the requirements of the FRCM.

III-13.4.1.1.2 Movable Shielding

The Meson Area has moveable shielding placed in the tunnel vehicle access entrances at M01, M02, M03, and M04, at the M04 and M05 crossovers, and along the sides and in between the MC7 and MC8 enclosures. The MC6 and MT6 enclosures are assembled from large concrete movable shielding blocks. These movable shield blocks are either posted to prohibit moving of these blocks without ESH approval or are additionally chained and locked with a Radiation Safety lock and an applicable padlock, where deemed necessary.

III-13.4.1.1.3 Penetration Shielding

The details of the Meson Area penetration assessments have been documented. [2][3][4] The shielding summary indicates that all penetrations provide adequate shielding to conform to the requirements of the FRCM.

III-13.4.1.2 Fencing

III-13.4.1.2.1 Radiation Area Fencing

The Meson Area has posted and locked radiological fences to prohibit access to outside berm areas. These include the fences at the M01 enclosure including Gates M01PAE and M01PAW, at the M03 enclosure including Gates M03PAE1, M03PAE2 and M03VAE, at the M04 enclosure including gates M04PAE, M04PAW, M04VAE, and M04VAW, and at the MC6-MC8 enclosures that provides a barrier to limit personnel access near the MCenter beamlines.

III-13.4.1.2.2 Controlled Area Fencing

There is no Controlled Area Fencing required in the Meson Area.

III-13.4.2 Active Engineered Credited Controls

Active engineered controls are systems designed to reduce the risks from accelerator operations to acceptable levels. These automatic systems limit operations, shut down operations, or provide warning alarms when operating parameters are exceeded. The active controls in place for the Meson Area include beam loss controls and a Radiation Safety Interlock System (RSIS).

III-13.4.2.1 Radiation Safety Interlock System

The Meson Area beamlines employ three Radiation Safety Interlock Systems (RSIS). The characteristics of the systems are described in Section I of the Fermilab SAD. The first system allows beam into the Meson Target Train enclosures; the other two systems allow beam into the two experimental areas MTest and MCenter.

The Meson Primary RSIS inhibits beam transport to the F Line Manholes and enclosures M01-M05 by controlling redundant critical devices, MLAM1 and V204, which are a string of Lambertson magnets and dipole bend string respectively, located in the Switchyard Enclosure C. MLAM1 bends the beam to the west by 8.0 mrad. With MLAM1 off, the beam goes straight ahead to the Switchyard absorber. V204 bends the beam up by 11.9 mrad into the Meson beamline. Beam cannot traverse beyond the first magnet in the V204 string when off. In the event of a critical device failure, the system has a failure mode function that will reach back and disable the upstream Switchyard RSIS, preventing beam from entering the Switchyard. The Meson Primary RSIS inhibits beam when personnel access the F1, F2, or F3-Manholes, M01, M02, M03, M04, or M05 enclosures. Access is not allowed to these areas unless the critical devices are disabled.

The MTest RSIS inhibits beam transport to the MTest experimental areas MT6 Section 1 and MT6 Section 2 by controlling redundant critical devices, MW1W and MT3BS, which are a string of Lambertson magnets and a beam stop, located in the Meson M01 and M03 enclosures respectively. MW1W bends the beam to the west by 3.7 mrad into the MTest beamline. With MW1W off, the beam travels straight and is absorbed in the Meson Target Train collimators. With MT3BS closed, the beam is absorbed in the beam stop. In the event of a critical device failure, the system has a failure mode function that will reach back and disable the upstream Meson Primary RSIS preventing beam from entering the MTest beamline. The

MTest RSIS inhibits beam when personnel access the MT6 Sections 1 and 2 enclosures. Access is not allowed to these areas unless the critical devices are disabled.

The MCenter RSIS inhibits beam transport to the MCenter experimental areas MC6, MC7 Section 1, MC7 Section 2, and MB7 by controlling redundant critical devices. These devices are MC1D and MC2BS, which are a dipole magnet and a beam stop located in the Meson M01 and M02 enclosures, respectively. MC1D bends the beam down by 1.5 mrad into the MCenter beamline. With MC1D off, the beam travels straight and is absorbed in the Meson Target Train collimators. With MC2BS closed, the beam is absorbed in the beam stop. In the event of a critical device failure, the system has a failure mode function that will reach back and disable the upstream Meson Primary RSIS preventing beam from entering the MCenter beamline. The MCenter RSIS inhibits beam when personnel access the MC6, MC7 Sections 1 and 2, or MB7 enclosures. Access is not allowed to these areas unless the critical devices are disabled.

Radiation detectors are placed around the MTest and MCenter experimental areas. The alarm levels of radiation detectors are interlocked to either the MTest or MCenter RSIS to ensure compliance with FRCM requirements. Such detectors are capable and set to disable beam within one second of exceeding a predetermined level.

Trained and qualified personnel from the AD Operations Department are required to search and secure the enclosures before permits from the RSIS can be reestablished following any personnel access to the area except under strictly specified controlled access conditions. The RSIS including requirements for hardware and system testing, inventory of interlock keys, search and secure procedures for the beam line, controlled access procedures, personnel training requirements, and procedures for maintaining interlock systems is maintained in conformance with the requirements stated in the FRCM.

III-13.4.2.2 ODH Safety System

The Meson Area has four enclosures that are identified as Oxygen Deficient Hazard areas, M02, M03, M04, and M05. These enclosures are classified as ODH-1 areas.

The Meson Area does not use cryogenics for beamline operation. Cryogenics are supplied by the Meson Cryo Central building, which is used for superconducting RF cavity research and development. This test area is located on the East side of the Meson Detector Building. The cryogenics use existing infrastructure to transport between the test area and Meson Cryo Central.

III-13.4.3 Administrative Credited Controls

All Meson area operations with the potential to affect the safety of employees, researchers, or the public or to adversely affect the environment are performed using approved laboratory, directorate, division, or department procedures. These procedures are the administrative controls that encompass the human interactions that define safe accelerator operations.

III-13.4.3.1 Operation Authorization Document

In accordance with Accelerator Directorate (AD) Administrative Procedure on *Beam Permits, Running Conditions, and Startup* (ADAP-11-0001), beam will not be transported to the Meson Target Train, MTest, or MCenter areas without an approved Beam Permit and Running Condition for the operating area. The

Beam Permit specifies the Accelerator Safety Envelope (ASE) and Operating beam intensity limits and is approved by the Head of Accelerator Directorate (AD) in consultation with the ESH&Q Section, BD Operations Department Head, and BD External Beam Delivery Department Head. The Running Conditions list the operating modes, ASE, and Operating beam intensity limits for the Meson Target Train, MTest or MCenter areas. Running Conditions are issued by the ESH&Q Section, and are signed by the AD Operations Department Head, assigned RSO, AD Systems Department Head, and Head of Accelerator Directorate.

- To run beam in the Meson Target Train areas, the F-Manholes, and enclosures M01 through M05 must be secure.
- To run beam in the MTest areas, the MT6 Section 1 and MT6 Section 2 enclosures must be secure.
- To run beam in the MCenter areas, the MC6, MC7 Section 1, MC7 Section 2, and MB7 enclosures must be secure.

III-13.4.3.2 Staffing

Commissioning, normal operations, and emergency management of the Meson Area are all conducted under the auspices of the Accelerator Directorate, the ES&H Directorate, and the AD Beams Division Operations Department in accordance with the Fermilab SAD.

III-13.4.3.3 Accelerator Operating Parameters

The Meson area beamlines have been assessed from the standpoint of beam operating and safety envelope parameters. The Meson Primary Accelerator Safety Envelope beam intensity limit is 1.03×10^{16} 120 GeV protons per hour. The MTest beamline Accelerator Safety Envelope beam intensity limit is 1.03×10^{16} 120 GeV protons per hour. The MCenter beamline Accelerator Safety Envelope beam intensity limit is 9.60×10^{16} 120 GeV protons per hour. In practice, operational beam intensity limits are set much lower than the ASE beam intensity limits.

Accelerator operational approvals shall be obtained by following the AD Procedure ADAP-11-0001, administered by the ESH Section and Head of Accelerator Directorate. Beam Permit and Running Condition documents shall identify the beam power and operating parameters allowed within the current Accelerator Safety Envelope. The Beam Permit specifies the ASE and Operating beam power limits as approved by the Head of Accelerator Directorate in consultation with the ESH&Q Section, assigned RSO, BD Operations Department Head, and BD External Beam Delivery Department Head. The Running Conditions for the Meson areas describe the operating configuration as reviewed by the assigned RSO, BD Operations Department Head, BD Systems Department Head, and as approved by the Head of Accelerator Directorate.

III-13.5. Defense-in-Depth Controls

Under normal operating conditions, the Meson Area is not hazardous to members of the public. Defense in depth exists in the form of active and passive controls sufficient to contain hazards even during unforeseen events.

III-13.6. Machine Protection Controls

Beam Loss Monitors routinely determine when beam is being lost at unacceptable regions and/or rates. Beam Position Monitors and Segmented Wire Ionization Chambers determine the trajectories of the beam so that the Main Control Room may control losses. The Beam Budget Monitor continually monitors the integrated beam delivered to the Meson Areas on an hourly basis.

III-13.7. Decommissioning

This hazard is not applicable to the Meson Area.

III-13.8. Summary and Conclusion

Specific hazards associated with the operation of the Meson Area enclosures are identified and assessed in this chapter of the Fermilab SAD. The designs, controls, and procedures to mitigate Meson Area specific hazards are identified and described. The Meson Area is subject to the safety requirements, controls and procedures outlined in Section I of the Fermilab SAD.

The preceding discussion of the hazards presented by Meson Area operations and the credited controls established to mitigate those hazards demonstrate that the area 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-13.9. References

[1] *Fermilab Radiological Control Manual*

[2] *2003 Shielding Assessment for the Switchyard 120 Project*

[3] *Addendum to the SY 120 Shielding Assessment to Add the MCenter Branch to the Beam Line (2004)*

[4] *"Post Assessment Document" to the 2003 SY120 Shielding Assessment to Enable a Low Energy Pion Mode of Operation in the MTest Beamline (2007)*

[5] *Addendum to the SY 120 Shielding Assessment for Continued Operation of the Meson Center Beam Line (2013)*

III-13.10. Appendix – Risk Matrices

Risk Assessment methodology was developed based on the methodology described in DOE-HDBK-1163-2020. Hazards and their potential events are evaluated for likelihood and potential consequence assuming no controls in place, which results in a baseline risk. A baseline risk (i.e., an unmitigated risk) value of III and IV does not require further controls based on the Handbook. Events with a baseline risk value of I or II do require prevention and/or mitigation measures to be established in order to reduce the risk value to an acceptable level of III or IV. Generally, preventive controls are applied prior to a loss event, reflecting a likelihood reduction, and mitigative controls are applied after a loss event, reflecting a consequence reduction. For each control put in place, likelihood or consequence can have a single “bin drop”, resulting in a new residual risk (i.e., a mitigated risk). This risk assessment process is repeated for each hazard for Facility Workers (FW), Co-Located Workers (CLW), and Maximally-Exposed Offsite Individual (MOI). At the conclusion of the risk assessments, controls that are in place for the identified accelerator specific hazards are identified as Credited Controls and further summarized in Section I-1.4 of this Chapter as well as SAD Chapter VII-A.1 *Accelerator Safety Envelope – Fermi Main Accelerator*.