Meson Area

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Revision History

Author	Description of Change	Revision No. & Date
Wayne Schmitt Thomas R. Kobilarcik	• Updated MCenter beamline area description • Updated operating intensity limits, where applicable	Revision 1 January 18, 2019
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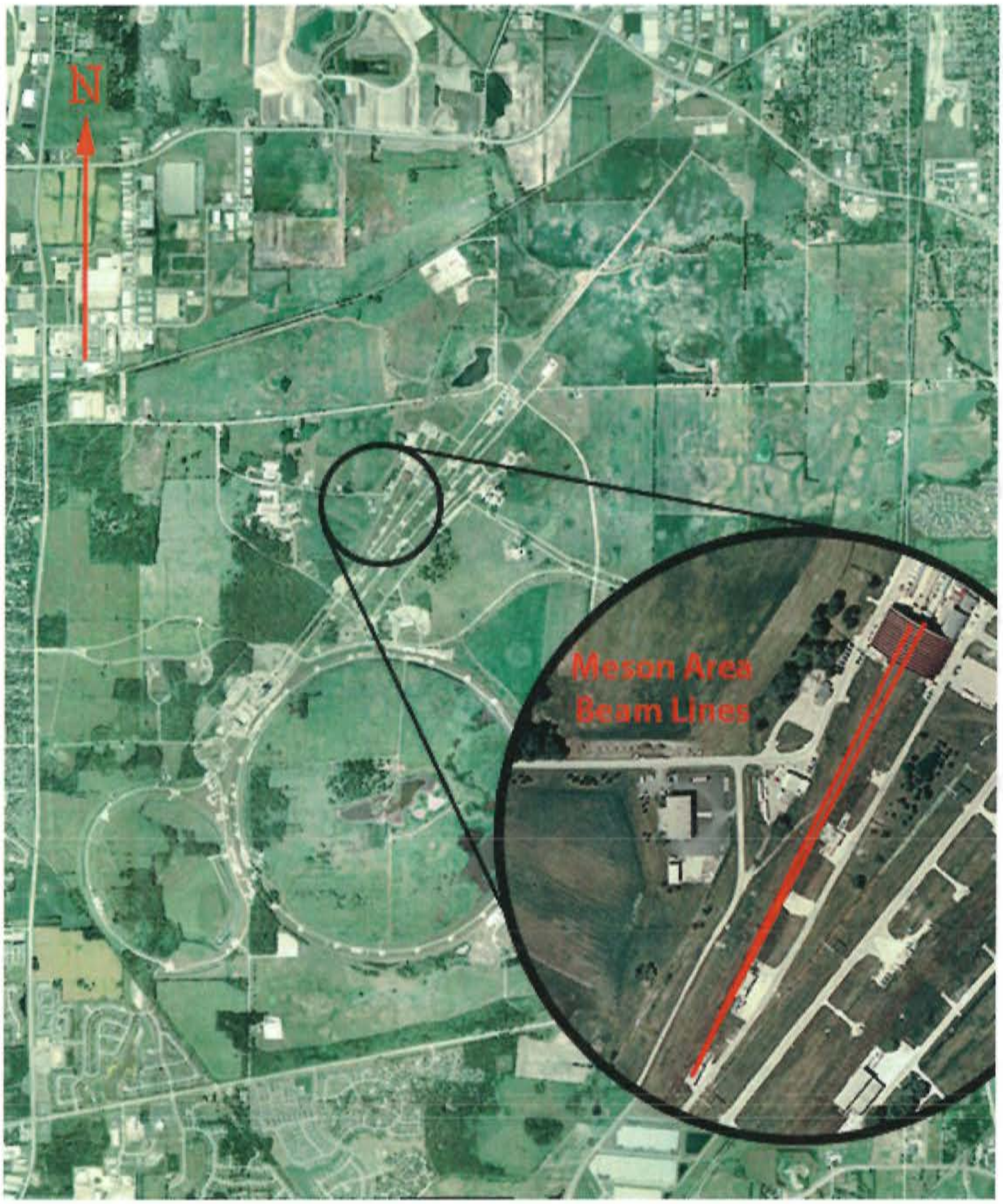
II - 15.1 Meson Area Location on Fermi National Accelerator (Fermilab) Site

The following aerial photograph shows the location of the Meson area beam lines in relation to the Fermilab site.



II - 15.2 Inventory of Hazards

The following table lists the identified hazards found in the Meson area enclosures and support buildings. All hazards with an asterisk (*) have been addressed in Chapters 1-10 of the Fermilab SAD and are not addressed in this section of the SAD.

Radiation Ionizing radiation Residual activation Groundwater activation Surface water activation Particle interactions in soil Radioactive waste	**Kinetic Energy** Power tools * Pumps and motors *
Toxic Materials Lead shielding * Beryllium components *	**Potential Energy** Crane operations * Compressed gases * Vacuum / pressure vessels * Vacuum Pumps *
Flammable & Combustible Materials Cables *	**Magnetic Fields** Fringe fields *
Electrical Energy Stored energy exposure * High voltage exposure * Low voltage, high current exposure *	**Gaseous Hazards** Confined spaces * Oxygen Deficiency Hazards (ODH) *
Thermal Energy Cryogenic Liquids *	**Access / Egress** Life Safety Egress *

II - 15.3 Introduction

This Section II, Chapter 15 of the Fermilab SAD, covers the Meson area. The chapter has been prepared by the staff of the Fermilab Accelerator Division (AD) External Beamlines Department and Fermilab Environment, Safety, Health and Quality Section (ESH&Q) Radiation Physics Science Department.

II - 15.3.1 *Purpose of the Meson Area*

The purpose of the Meson area is to deliver two incoming primary proton beams to separate targets and convey secondary particles produced from the target collisions to two independent experimental areas Meson Test (MTest) and Meson Center (MCenter).

The upstream Meson area receives 120 giga-electron volt (GeV) beam from the Main Injector, which is split in the Switchyard and delivered to the Meson experimental facilities. In 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. MTest has the additional capability of transporting 120 GeV primary beam to its test beam facility, although at a greatly reduced rate.

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 MTest facility is capable of providing on the order of 4.2E7 particles per hour. Three modes of operation are available: 120 GeV beam ("Diffracted Proton Mode"), 60 to 32 GeV secondary particles ("High Energy Mode" -- protons, pions, muons, kaons, and electrons), and 32 to 1 GeV secondary particles ("Low Energy Mode"). Oppositely charged particles are not available simultaneously; there is no provision for neutral particles. Individual species cannot be selected -- the experimenter is responsible for particle type identification.

The MCenter facility is capable of providing experimenters a secondary beam with positively or negatively charged particles (but not both simultaneously) in the energy range of 80 to 8 GeV. Currently, there is no provision for neutral particles. The particles provided are electrons, muons, pions, kaons, and protons (along with their anti-particles when the polarity of the electromagnetic transport system is reversed). As with MTest, individual species cannot be selected -- the experimenter is responsible for particle type identification. Rates up to 3E6 particles per minute are possible.

II - 15.3.2 *Description of the Meson Area*

The Meson area beam lines 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. The Meson area beam lines comprise the following:

- Meson beam line enclosures M01, M02, M03, M04, M05, MT6 Section 1, MT6 Section 2, MC6, MC7 Section 1, MC7 Section 2, and MB7.
- Service Buildings MS1, MS2, MS3, MS4, and Meson Detector Building (MDB).

Associated infrastructure, such as power supplies, is housed in the MS1, MS2, MS3, and MS4 service buildings. The MT6 Sections 1 and 2 enclosures, and the MC6 enclosure, are housed in the Meson Detector Building. The Meson Detector building houses additional experimental facilities not addressed in this assessment.

The Meson enclosures and associated beam lines are depicted in Figure 1. This experimental area formerly comprised several other beam lines, Meson West, Polarized, and East, that no longer exist.

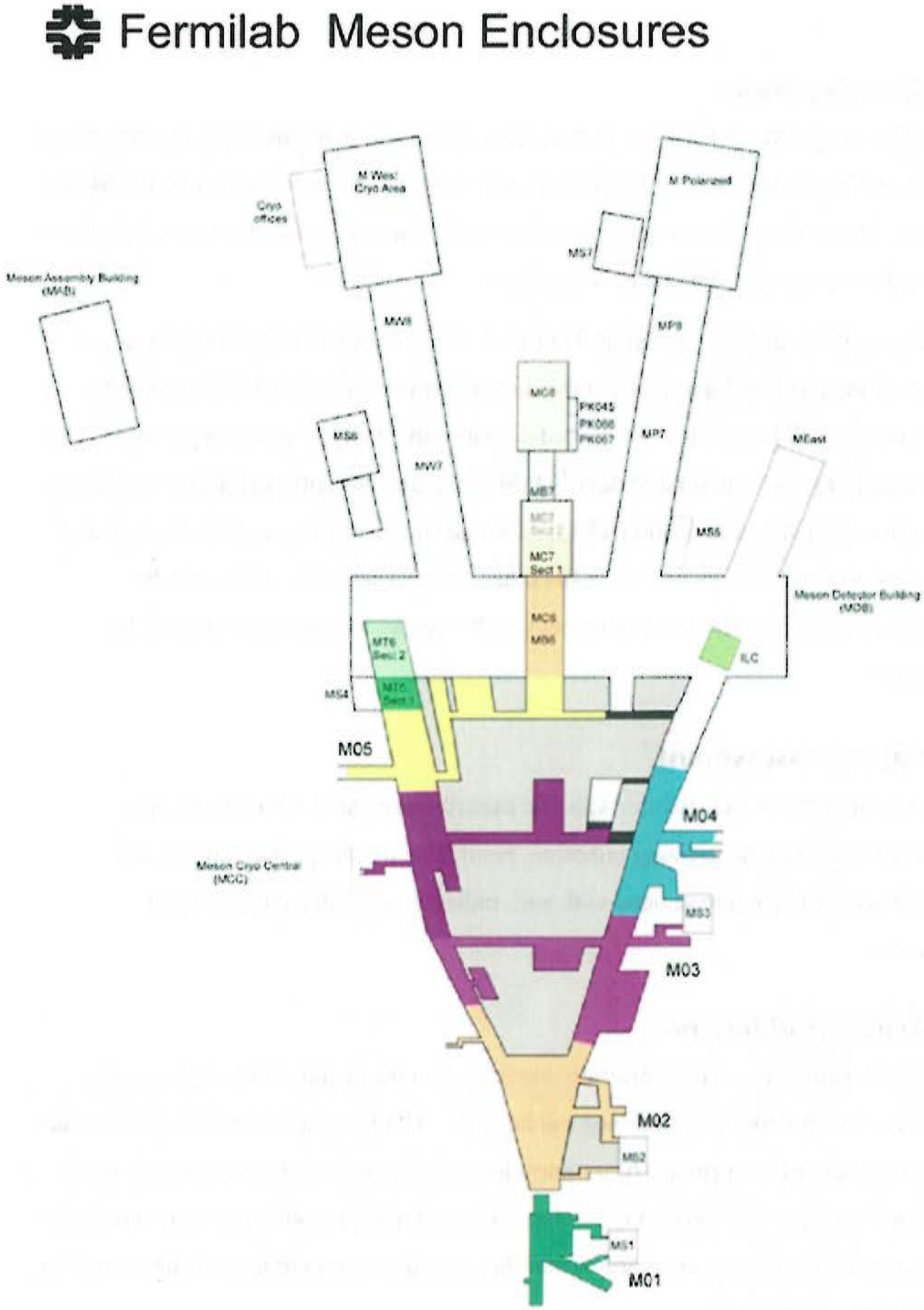


Figure 1: Meson enclosures and associated beam lines. Colors are used to denote beam enclosure boundaries.

II - 15.3.3 *Operating Modes*

The Meson area receives a 120 GeV proton slow spill beam from the Main Injector that is split in the Switchyard into two beams and delivered over a several-second duration to the Meson experimental areas. These Meson beam lines currently service two experimental areas, MTest and MCenter, for use in test beam research and development.

Meson Primary (M01 and Meson Target Train) can safely transport 1.68×10^{14} protons per hour, well in excess of the combined intensities of the downstream beamlines. MTest can safely transport 1.2×10^{13} particles per hour. MCenter can safely transport 1.02×10^{12} particles per hour. The upper limits on intensity are the outcome of detailed shielding assessments performed to address radiological concerns summarized in section 15.4.1. 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.

II - 15.4 Safety Assessment

This section analyzes the accelerator-specific hazards associated with Meson area operations. These hazards include ionizing radiation, residual activation, groundwater and surface water activation, particle interactions with soil, radioactive waste, and toxic and combustible materials.

II - 15.4.1 *Radiological Hazards*

Radiological hazards have been carefully considered in the design of the Meson area beam lines. There are two predominant radiological hazards. The first type of radiological hazard results from the interaction of the primary beam particles in the materials surrounding the beam pipes and beam line elements. The second type of radiological hazard results from the interaction of the primary beam with the Meson area targets and the subsequent interactions of the secondary beams with surrounding materials.

There are three categories of beam-induced radiation hazards:

- Prompt radiation inside and surrounding the enclosures that is present during beam transport. Prompt radiation may propagate offsite. The radiation includes neutrons, muons, and other energetic particles.

- Residual radiation due to activation of beam line components. Residual radiation can give rise to radiation exposures to personnel during accesses to the beam enclosures for repair, maintenance and inspection activities.
- Environmental radioactivity associated with activation of air, groundwater and soil due to the operation of the beam transport system.

Detailed shielding assessments [1, 2, 3] and post-assessment documents address these concerns. The assessments provide a detailed analysis of this area, demonstrating the required overburden, use of signs, fences, and active interlocks to comply with the Fermilab Radiological Control Manual (FRCM).[4] The shielding assessments for the Meson area include beam line enclosures M01, M02, M03, M04, M05, MT6-1, MT6-2, MC6, MC7-1, and MC7-2; Service Buildings MS1, MS2, MS3, MS4, and Meson Detector Building.

The shielding assessments consider groundwater and surface water activation; air activation; particle interactions in soil; radiation shielding requirements; labyrinth and penetration considerations; residual dose rates; and active and passive shielding controls and monitoring.

II - 15.4.1.1 Prompt Ionizing Radiation

Prompt ionizing radiation is the principle radiological hazard that arises when beam is transported through the Meson area beam lines. In order 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 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 beam lines (M01-M02) shall not exceed 1.68x10^{14} 120 GeV protons/hr.*
- *The average beam intensity in the MTest beam line shall not exceed 1.20x10^{13} 120 GeV protons/hr.*
- *The average beam intensity in the MCenter beam line shall not exceed 1.02x10^{12} 120 GeV protons/hr.*
- *The radiation safety interlock system must be certified as working.*
- *Radiation detectors around the Meson beam lines are installed and interlocked to the radiation safety interlock system.*

II - 15.4.1.2 Residual Activation

The Meson Target Train, MTest M03 pinhole collimator, MT3 low energy pion target, MC6 target, and MC6 momentum collimator may be highly activated even when the Meson beam lines are not in operation or in a standby status. 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).

II - 15.4.1.3 Groundwater and Surface Water Activation

Radioactivity is induced by the interaction of the high-energy particles with the soils that surrounds the beam line at the Meson Target Train, MTest M03 pinhole collimator, MT3 low energy pion target, and MC6 target. Methodologies have been designed to provide conservative estimates of groundwater and surface water activation. The ground and surface water methodologies calculate the estimated annual concentration and then calculate the concentration buildup for continuous operations over an extended period.

The release estimate for surface and groundwater after 10 years of operation to the Meson Target Train in M01 at an integrated intensity of 7.94×10^{17} protons per year will produce combined ^{3}H (tritium) and ^{22}Na (sodium-22) concentrations that are 22% 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 M03 Pinhole Collimator at an integrated intensity of 1.74×10^{17} protons per year will produce combined ^{3}H and ^{22}Na concentrations that are 32% 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 MT3 Low Energy Pion Mode target at an integrated intensity of 1.2×10^{17} protons per year will produce combined ^{3}H and ^{22}Na 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 5.26×10^{16} protons per year will produce combined ^{3}H and ^{22}Na concentrations that are 0.6% of the surface water limits and a negligible fraction of the groundwater limits respectively.[3] The annual concentration estimates for ^{3}H and ^{22}Na in surface water and groundwater from these absorbers are given in Table 1.

Table 1: Meson Area Surface Water and Groundwater ^{3}H and ^{22}Na Release Concentrations

Description	Annual Concentration Limits ((pico Curie (pCi)/milliliter (ml))		Annual Concentration Estimate (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}	1.0×10^{-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 ^{3}H and ^{22}Na 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.

II - 15.4.1.4 Particle Interactions in Soil

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 (MeV)/centimeter and can only penetrate up to 200 meters of earth equivalent shielding.[1]

The M01 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.[1] 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.[3]

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).[5]

II - 15.4.1.5 Radioactive Waste

Meson area radioactive waste hazards and waste disposal will be managed within the program established for the Fermilab accelerator complex and as prescribed in the 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. Activated items will be reused when feasible. Activated items that cannot be reused will be disposed of as radioactive waste according to the FRCM requirements.

II - 15.5 Credited Controls

II - 15.5.1 *Passive 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.

II - 15.5.1.1 Permanent Shielding

The Meson Area beam lines shielding analyses indicate the mitigations necessary to comply with the FRCM requirements for operations up to 1.2×10^{13} protons/hr[1] to the MTest target and up to 1.02×10^{12} protons/hr[3] to the MCenter target. Interlocked radiation detectors are installed along the MTest and MCenter beam lines as prescribed by the shielding assessments to mitigate this concern.

II - 15.5.1.2 Labyrinth and Penetration Shielding

The details of the Meson Area labyrinth and penetration assessments have been documented.[1, 2, 3] The shielding summary indicates that all labyrinth and penetrations provide adequate shielding to conform to the requirements of the FRCM.

II - 15.5.1.3 Movable Shielding

The Meson Area has moveable shielding placed in the F1 enclosure drop hatch, 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. Except for the F1 Enclosure drop hatch, these movable shield blocks are either posted to prohibit moving of these blocks without Radiation Safety approval or are additionally chained and locked with a Radiation Safety lock and an applicable enclosure-cored padlock where deemed necessary. The movable shielding in the F1 enclosure drop hatch is controlled by the assigned RSO in accordance with AD Procedure ADSP-10-0102 *Non-Interlocked Beam Enclosure Equipment Access Hatch Administrative Control Lockout.*

II - 15.5.1.4 Radiation Fences

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.

II - 15.5.2 *Active 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 Switchyard area include Switchyard beam loss controls and a radiation safety interlock system.

II - 15.5.2.1 Meson Area Beam Loss Controls

Several types of Beam Loss Monitors routinely determine when beam is being lost in unacceptable regions. 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 Area beam lines on an hourly basis.

The radiation detectors limit the radiation flux from normal operations and one-pulse accidents to less than the limit appropriate to each Meson area. The detectors are set so that a beam loss producing a radiation flux that exceeds the allowable limit will turn off the critical devices. The critical devices inhibit beam to the affected area providing radiation protection for personnel.

The spill rate to the Meson Area is controlled by a Repetition Rate Monitor (RRM). This device currently inhibits beam extraction to the Switchyard enclosures if the extraction power supply is energized for more than four seconds in any forty-five second period. Thus, beam cannot be transported to any of the Meson beamlines or experimental areas at a frequency greater than this. The spill rate interval monitored by the RRM may be changed from the initial set point at the discretion of the assigned RSO in conformance with the FRCM.

The use of fences, gates, and locks, in addition to the aforementioned controls, provide necessary and sufficient protection for those working in the Meson areas. The design, installation, use and maintenance of all signs and posting of areas where radiation may be present, search and secure procedures, controlled access procedures, and personnel training systems are in conformance with the requirements of the FRCM.

II - 15.5.2.2 Radiation Safety Interlock System

The Meson Area beam lines 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 primary beamline 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 modified B1 dipole 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.

II - 15.5.3 *Administrative 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, division, or department procedures. These procedures are the administrative controls that encompass the human interactions that define safe accelerator operations.

II - 15.5.3.1 Beam Permits and Running Conditions

In accordance with AD Administrative Procedure on *Beam Permits, Running Conditions, and Startup* (ADAP-11-0001), beam will not be transported to the Meson Primary, 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 AD Division Head in consultation with the ESH&Q Section, AD Operations Department Head, and AD External Beamlines Department Head. The Running Conditions list the operating modes, ASE and Operating beam intensity limits for the Meson primary, 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 AD Division Head.

In order to run beam in the Meson Primary areas, the F Line Manholes and enclosures M01-M05 must be secure. In order to run beam in the MTest areas, the MT6 Section 1 and MT6 Section 2 enclosures must be secure. In order to run beam in the MCenter areas, the MC6, MC7 Section 1, MC7 Section 2, and MB7 enclosures must be secure.

II - 15.5.3.2 Summary of Beam Operating and Safety Envelope Parameters

The Meson area beam lines have been assessed from the standpoint of beam operating and safety envelope parameters. The Meson Primary beam line can safely transport up to

1.68×10^{14} 120 GeV protons/hr. The MTest beam line can safety transport up to 1.2×10^{13} 120 GeV protons/hr. The MCenter beam line can safely transport up to 1.02×10^{12} 120 GeV protons/hr.

Accelerator operational approvals shall be obtained by following the AD Procedure ADAP-11-0001, administered by the ESH&Q Section and AD Division Head. 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 AD Division Head in consultation with the ESH&Q Section, assigned RSO, AD Operations Department Head, and AD External Beamlines Department Head. The Running Conditions for the Meson areas describe the operating configuration as reviewed by the assigned RSO, AD Operations Department Head, AD Systems Department Head, and as approved by the AD Division Head.

II - 15.6 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.

II - 15.7 Glossary, Acronyms

AD	Accelerator Division
ASE	Accelerator Safety Envelope
Ci	Curie
ESH&Q	Environment, Safety, Health, and Quality
Fermilab	Fermi National Accelerator Laboratory
FESHM	Fermilab Environment, Safety, and Health Manual
FRCM	Fermilab Radiological Control Manual
GeV	Giga-electron volt
^{3}H	tritium
hr	hour
MeV	Mega-electron volt
mrad	milli-radian
mrem	milli-rem
mrem/hr	milli-rem per hour
^{22}Na	sodium-22
pCi/ml	pico-Curie per milliliter
RRM	Repetition Rate Monitor
RSIS	Radiation Safety Interlock System
RSO	Radiation Safety Officer
RWP	Radiological Work Permit
SAD	Safety Assessment Document

II - 15.8 References

[1] **2003 Shielding Assessment for the Switchyard 120 Project**, C. Brown, T. Kobilarcik, G. Koizumi, E. Ramberg, and W. Higgins, April 8, 2003. **Post Assessment Document to the 2003 SY 120 Shielding Assessment to enable a low energy pion mode of operation in the MTest Beamline,** C. Brown, January 10, 2007.

[2] **Addendum to the SY 120 Shielding Assessment to add the MCenter Branch to the Beam Line**, C. Brown, D. Jensen, February 2004.

[3] **Addendum to the SY 120 Shielding Assessment for Continued Operation of the Meson Center Beam Line**, Thomas Kobilarcik, Wayne Schmitt, November 2013. **MC7 NOvA Tertiary Beamline Post Assessment Document**, W.S. Higgins and M. Vincent, October 29, 2018.

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

[5] **Fermilab Environment Safety & Health Manual**. - The web link is: http://esh.fnal.gov/xms/FESHM