



# SWITCHYARD FIXED TARGET BEAMLINES

## SECTION III CHAPTER 12 OF THE FERMILAB SAD

Revision 1 August 7, 2023

This Chapter of the Fermilab Safety Assessment Document (SAD) contains a summary of the results of the Safety Analysis for the Switchyard Fixed Target Beamlines 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 12 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *Switchyard Fixed Target Beamlines*, 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	1	August 7, 2023	<ul style="list-style-type: none"> <li>• Updated to align with updated SAD template</li> <li>• Included Risk Matrix tables and hazard discussion</li> <li>• Enclosure J listed as a separate enclosure.</li> <li>• Switchyard RSIS updated to include upstream Main Injector P150 Extraction RSIS usage for interlocked radiation detector input. See Change Request 272.</li> </ul>
John E. Anderson Jr. Craig Moore	0	October 15, 2013	Initial release of the Switchyard Fixed-Target Beam Lines 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 <i>Safety of Accelerators</i>
$^7\text{Be}$	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
<sup>3</sup> H	Tritium
HA	Hazard Analysis
HAR	Hazard Analysis Report
HCA	High Contamination Area
HCTT	Hazard Control Technology Team
HEP	High Energy Physics
HFD	Hold for Decay

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

MCR	Main Control Room
MEBT	Medium Energy Beam Transport
MEI	Maximally Exposed Individual
MeV	Mega-electron volt
MI	Main Injector
MINOS	Main Injector Neutrino Oscillation Search
MMR	Material Move Request
MOI	Maximally-Exposed Offsite Individual <i>(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.)</i>
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
<sup>22</sup> 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-12. Switchyard 120 Fixed Target Beamlines

### III-12.1. Introduction

This Section III, Chapter 12 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the Switchyard Fixed Target beamlines.

#### III-12.1.1 [Purpose/Function](#)

The Switchyard fixed target beamlines transport beams of accelerated particles to target stations located along the Fermilab fixed-target beam lines. 120 Giga-electron Volt (GeV) protons are extracted from the Main Injector toward the Switchyard. The beam is split in the Switchyard and redirected to fixed-target beam lines, which have been historically designated the Meson, Neutrino, and Proton beam lines.

#### III-12.1.2 [Current Status](#)

The Switchyard fixed target beamlines are currently **Operational**.

The P150 Beamline (P1 Beamline) is currently **Operational**.

The P2 Beamline is currently **Operational**.

The P3 Beamline is currently **Operational**.

The Switchyard Continental Beamline is currently **Operational**.

#### III-12.1.3 [Description](#)

The Switchyard fixed target beamlines start in the Tevatron F-Sector at E48 and continues to the upstream end of the Meson, Neutrino, and Proton enclosures M01, N01, and P01 respectively. The Switchyard fixed-target areas are comprised of the following enclosures:

- Tevatron F-Sector from E48 to F46
- Tevatron Transfer Hall from F47 to A24
- Switchyard Enclosure B
- Switchyard Enclosures C, D, & E
- Switchyard Enclosure J
- Meson Beam Line Enclosure F1-Manhole
- Meson Beam Line Enclosures F2-Manhole & F3-Manhole
- Neutrino Beam Line Enclosure G2

The Switchyard Fixed Target Beamlines may refer to the following beam lines:

- P150 Beamline (also known as P1 Beamline) in F-Sector
- P2 Beamline in F-Sector
- P3 Beamline in F-Sector & Transfer Hall
- M1 Beamline in F-Sector

- Switchyard Continental in Transfer Hall, Enclosure B, Enclosure C, D, & E, Enclosure G2, F1-Manhole, F2-Manhole, and F3-Manhole.
- G1 Stub beamline in Enclosure C, D, & E

The following Service Buildings are included in the Switchyard Fixed Target Beamlines:

- F0
- F1
- F17
- F23
- F2
- F27
- F3
- F4
- A0
- A1
- Switchyard Service Building (SSB)
- G2

III-12.1.4 [Location](#)

The Switchyard fixed target area is located on the Fermilab site in Batavia, IL.

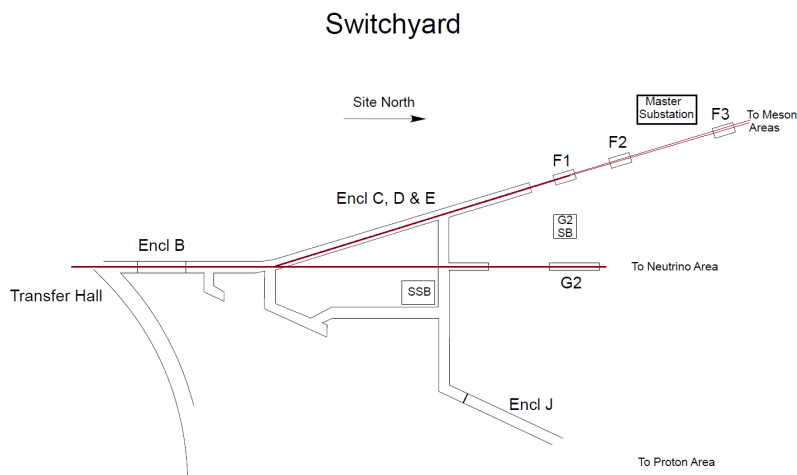


Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.

The Switchyard fixed target area is located to the east of Wilson Hall the on the Fermilab site.



Figure 2. Aerial view of the Fermilab site, indicating the location of the Switchyard fixed target area.



M02-31 Jan 2019  
Based on previous work by  
gjh 6 Sept 2019

Figure 3: Beam Delivery Path for Switchyard. Operational Area beam delivery in Red.

### III-12.1.5 [Management Organization](#)

The Switchyard fixed target beamlines are managed by Accelerator Directorate, Beams Division, External Beam Delivery Department.

### III-12.1.6 [Operating Modes](#)

The Switchyard fixed target beamlines transport a 120 GeV proton beam from the Main Injector, via the P150 Beamline (P1 Beamline), P2 Beamline, P3 Beamline, and Switchyard Continental beamline, to three possible destinations: the Switchyard Absorber, the Meson beamlines, and Neutrino beamline. The Switchyard absorber is used for commissioning and beam tune up. The Meson beam lines service two experimental areas, Meson Test and Meson Center, for use in test beam research and development. The Neutrino beam line services experiments installed in the NM4 experimental hall.

The Switchyard Fixed Target Beamlines were assessed with an Accelerator Safety Envelope limit of  $1.03 \times 10^{16}$  120 GeV protons per hour delivered from the Main Injector. The Operational beam intensity limit is set lower than the ASE limit. This upper limit on intensity is the outcome of detailed shielding assessments performed to address radiological concerns summarized in section.[4]

### III-12.1.7 [Inventory of Hazards](#)

The following table lists all the identified hazards found in the Switchyard Fixed Target Beamline enclosures and support buildings. Section III-12.10 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 III-12.2 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 Switchyard Fixed Target Beamlines. Accelerator specific controls are identified as purple/bold throughout this chapter.

All other hazards present in the Switchyard Fixed Target Beamlines 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 Switchyard Fixed Target Beamlines.

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

An additional hazards that was identified in the Switchyard area that is not included in the Hazard Identification table above is Working at Heights, which will be address in Section III-12.2.9.6.

### III-12.2. Safety Assessment

All hazards for the Switchyard Fixed Target Beamlines are summarized in this section, with additional details of the analyses for accelerator specific hazards.

#### III-12.2.1 Radiological Hazards

The Switchyard Fixed Target Beamlines present radiological hazards in the form of prompt ionizing radiation, residual activation, groundwater activation, surface water activation, radioactive water systems, air activation, soil interactions, radioactive waste, contamination, 7Be, and radioactive sources. Detailed shielding assessments[2][3][4] address 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 Switchyard Fixed Target Beamlines assess the areas described in Section III-12.1.3.

Based on hazard analysis hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from the Radiological Hazards within the Switchyard Fixed Target Beamlines is at an acceptable level.

#### III-12.2.1.1 Prompt Ionizing Radiation

Prompt ionizing radiation is the principle radiological hazard that arises when beam is transported through the Switchyard beam lines. To protect workers and the 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 Review Subcommittee reviewed the detailed shielding assessments to address ionizing radiation concerns. The assessments provide a detailed analysis of the beam line; 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 Switchyard Fixed Target Beamlines have included analyses of injection, extraction, and absorption areas. The shielding assessments require that:[4]

- All penetrations must be filled with shielding as specified.
- All movable shielding blocks must be installed as specified.
- The average beam intensity in Switchyard beam lines shall not exceed  $2.5 \times 10^{15}$  120 GeV protons per hour.
- The Radiation Safety Interlock System must be certified as working.
- Radiation Detectors around the Switchyard beam lines are installed and interlocked to the Radiation Safety Interlock System.

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

### III-12.2.1.2 Residual Activation

The Switchyard beam absorber will be highly activated, even when the Switchyard beam lines are not in operation or in a standby status. Access to beam absorber 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 an “as-low-as-reasonably-achievable” (ALARA) plan will be required for work on any highly activated equipment with a potential individual exposure greater than 200 mrem or potential job exposure greater than 1000 person-millirem (mrem). These tasks will be supervised by members of the ES&H Radiation Protection Group under the direction of the area Radiation Safety Officer (RSO).

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

### III-12.2.1.3 Groundwater Activation

Groundwater and surface water activation hazards are assessed in detailed shielding assessments. [2] [3] [4] Radioactivity is induced by the interaction of the high-energy particles with the soils that surrounds the beam line at the Switchyard beam absorber. 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 calculates the concentration buildup for continuous operations over a 10-year period. The release estimate for surface and groundwater after 10 years of operation at an integrated intensity of  $2.98 \times 10^{17}$  protons per year will produce combined  $^3\text{H}$  (tritium) and  $^{22}\text{Na}$  (sodium-22) concentrations that are 23.0% of the surface water limits and a negligible fraction of the groundwater limits respectively. The annual concentration estimates for  $^3\text{H}$  and  $^{22}\text{Na}$  surface water and groundwater from the Switchyard absorber are given in Table 2.

*Table 2: Switchyard Absorber Surface Water & Groundwater Tritium & Sodium-22 Release Concentrations*

Description	Annual Concentration Limits (picocurie per milliliter) [pCi/ml]		Annual Concentration Estimate (pCi/ml)	
	$^3\text{H}$	$^{22}\text{Na}$	$^3\text{H}$	$^{22}\text{Na}$
<b>Switchyard Absorber Surface Water</b>	1900	10	$6.0 \times 10^0$	$5.0 \times 10^{-1}$
<b>Switchyard Absorber Groundwater</b>	20	0.4	$7.05 \times 10^{-9}$	$6.27 \times 10^{-10}$

The 3H and 22Na surface and groundwater concentration estimates are a negligible fraction of FRCM limits. Groundwater is sampled as part of the Fermilab Environment, Safety, Health, and Quality Section Environmental Monitoring Program. Sump discharges and pond surface waters are sampled as part of the ES&H Procedure ADDP-SH-1003, Routine Monitoring Program.

#### III-12.2.1.4 Surface Water Activation

Surface water activation in the Switchyard fixed target beamlines is characterized in Section III Chapter 12.2.1.3, Table 2.

#### III-12.2.1.5 Radioactive Water (RAW) Systems

The Switchyard Absorber is the only Radioactive Water (RAW) system for the Switchyard Fixed Target Beamlines in use. The absorber is a beam dump, contained in a reservoir of water. Specifications and evaluation of hazards associated with the system are covered in Review of Environmental Vulnerabilities Associated with the Switchyard (March 17, 1999, updated June 9, 1999). Current Switchyard operation runs at lower energy, 120 GeV vs. 800 GeV, and less intensity than the 1999 Fixed Target run. Access to the Switchyard Absorber is controlled by ES&H and requires additional work planning controls before any access is made. Based on hazard analysis and implementation of indicated preventative and mitigated controls, risk of hazards from the Radioactive Water (RAW) System within the Switchyard Fixed Target Beamlines is at an acceptable level.

#### III-12.2.1.6 Air Activation

In the P1 Beamline and P2 Beamline, the beam traverses a continuous vacuum. There is no activation from known loss points. [2] In the P3 Beamline and Switchyard Continental, the beam traverses a continuous vacuum until it reaches the downstream Switchyard Absorber intensity monitor. This air gap is the only known air activation point in Enclosure C, D, & E. Analysis is detailed in the shielding assessments. [2][3] Based on hazard analysis and implementation of indicated preventative and mitigated controls, risk of hazards from Air Activation within the Switchyard Fixed Target Beamlines is at an acceptable level.

#### III-12.2.1.7 Closed Loop Air Cooling

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.1.8 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 Switchyard beam absorber. 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 (cm) and can only penetrate up to 200 meters (m) of earth equivalent shielding. The Switchyard beam absorber is 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 above grade. The soil surrounding the Switchyard area will be sampled during



decommissioning to document activation levels as required by the Fermilab Environment, Safety, and Health (ES&H) Manual (FESHM).

Excessive beam loss coming from the transport of beam through buried pipe is also considered a source of soil interaction. These hazards are evaluated in detailed shielding assessments [2][3][4].

Based on hazard analysis and implementation of indicated preventative and mitigated controls, the risk of hazards from soil interactions within the Switchyard Fixed Target Beamlines is at an acceptable level.

#### III-12.2.1.9 Radioactive Waste

Radioactive waste produced during Switchyard 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 Switchyard, 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 hazards from Radioactive Waste within the Switchyard Fixed Target Beamlines is at an acceptable level.

#### III-12.2.1.10 Contamination

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

#### III-12.2.1.11 Beryllium-7

$^7\text{Be}$  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  $^7\text{Be}$  within the Switchyard Fixed Target Beamlines is at an acceptable level.

#### III-12.2.1.12 Radioactive Sources

Radioactive Sources may be used in shutdown and maintenance activities. These sources, when used in the Switchyard Fixed Target Beamlines, 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 Switchyard Fixed Target Beamlines is at an acceptable level.

#### III-12.2.1.13 Nuclear Material

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.1.14 Radiation Generating Devices (RGDs)

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.1.15 Non-Ionizing Radiation Hazards

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.2 Toxic Materials

N/A

##### III-12.2.2.1 Lead

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

##### III-12.2.2.2 Beryllium

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

##### III-12.2.2.3 Fluorinert & Its Byproducts

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

##### III-12.2.2.4 Liquid Scintillator Oil

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

##### III-12.2.2.5 Pseudocumene

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

##### III-12.2.2.6 Ammonia

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

##### III-12.2.2.7 Nanoparticle Exposures

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.3 Flammables and Combustibles

##### III-12.2.3.1 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use

### III-12.2.3.2 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

### III-12.2.4 Electrical Energy

N/A

#### III-12.2.4.1 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.4.2 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.4.3 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

### III-12.2.5 Thermal Energy

N/A

#### III-12.2.5.1 Bakeouts

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.5.2 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.5.3 Cryogenics

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

### III-12.2.6 Kinetic Energy

N/A

#### III-12.2.6.1 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.6.2 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.6.3 Motion Tables

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.6.4 Mobile Shielding

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.7 Potential Energy

*<copy/pasted from previous chapter, review and update as needed.>*

#### III-12.2.7.1 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.7.2 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.7.3 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.7.4 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.7.5 [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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.8 [Magnetic Fields](#)

N/A

#### III-12.2.8.1 [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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.9 [Other Hazards](#)

N/A

#### III-12.2.9.1 [Confined Spaces](#)

The Switchyard Fixed Target Beamlines contain areas defined as Confined Spaces. The F2-Manhole enclosure and F3-Manhole enclosure are confined spaces due to a single point of access and egress. Access to these enclosures 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 Switchyard Fixed Target Beamlines is at an acceptable level.

All other confined spaces in the Switchyard Fixed Target Beamlines, 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 Switchyard Fixed Target Beamlines implement the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.9.2 [Noise](#)

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-12.2.9.3 [Silica](#)

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.9.4 [Ergonomics](#)

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

#### III-12.2.9.5 Asbestos

This hazard is not applicable to the Switchyard Fixed Target Beamlines.

#### III-12.2.9.6 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.10 [Access & Egress](#)

N/A

#### III-12.2.10.1 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.11 [Environmental](#)

N/A

#### III-12.2.11.1 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.11.2 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

#### III-12.2.11.3 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 Switchyard Fixed Target Beamlines involving this hazard implements the controls specified in the Common Risk Matrix Table. No unique controls are in use.

### III-12.3. [Summary of Hazards to Members of the Public](#)

Under normal operating conditions, the Switchyard Fixed Target Beamlines are not hazardous to members of the public.

### III-12.4. [Summary of Credited Controls](#)

#### III-12.4.1 [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 Switchyard Fixed Target Beamlines were designed with a concrete and earth covered radiation shield to protect personnel from radiological exposure during beam operations.

##### III-12.4.1.1 [Shielding](#)

###### III-12.4.1.1.1 [Shielding Including Labyrinths](#)

The Switchyard Fixed Target Beamlines Shielding Assessments contain the transverse, longitudinal, and labyrinth shielding summaries. These summaries indicate that all transverse and longitudinal ranges provide adequate shielding and monitoring and are within FRCM requirements.

###### III-12.4.1.1.2 [Movable Shielding](#)

The Switchyard area has moveable shielding placed in the equipment drop hatches adjacent to the SSB, at the downstream end of the G2 enclosure, and at the upstream end of the F1-Manhole enclosure. The shielding is administratively controlled by ES&H, using a procedure that outlines the conditions required to access the equipment drop hatch. The shielding is locked with two padlocks, one padlock cored to the enclosure entry key and one cored to configuration control series, utilized exclusively by members of ESH. The assigned RSO or designee will document the application and removal of the configuration control in a database established for this purpose.

###### III-12.4.1.1.3 [Penetration Shielding](#)

The details of the Switchyard penetration assessments have been documented. [2][3][4] The shielding summary details the mitigations necessary for each penetration to comply with the requirements of the FRCM.

##### III-12.4.1.2 [Fencing](#)

The use of fences, gates, and locks in addition to the controls provide necessary and sufficient protection for those working in the Switchyard 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.

#### *III-12.4.1.2.1 Radiation Area Fencing*

The Switchyard area has posted and locked radiological fences to prohibit access to outside berm areas. These include the fences at the South Booster Road, Gate AOPSA1, Gate inside ring at Transfer Hall, Gate AOPAA1, Gate B/CPA1, Fenced penetrations at Road D, Gate SSBVA1, Gate SSBVA2, Gate FNCLCPA1, F1-Manhole enclosure equipment hatch F1MPA1, F2-Manhole personnel hatch F2MPA1, Gate M01PAW, Gate G2PA1, Gate G2PA2, Gate G2VA1, Gate G2PA3, Gate M01 PAE, and Gate M01PAW.

#### *III-12.4.1.2.2 Controlled Area Fencing*

The Switchyard Fixed Target Beamlines do not have any areas with Controlled Area fencing.

### III-12.4.2 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 Switchyard area include Switchyard beam loss controls and a radiation safety interlock system.

#### *III-12.4.2.1 Radiation Safety Interlock System*

The Switchyard beam line employs a Radiation Safety Interlock System (RSIS). The characteristics of the system are described in Section I of the Fermilab SAD.

The Switchyard RSIS inhibits beam transport by controlling redundant critical devices, HP3US and HP3DS, which are dipole bend strings located in the Tevatron F-Sector beam line at the F3 Service Building and F4 Service Building. HP3US and HP3DS are a string of 104 twenty-foot magnets providing a bend angle of 450 milliradians and 360 milliradians respectively. Beam cannot traverse even the first two magnets in either 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 Main Injector P150 Extraction RSIS preventing beam extraction from the Main Injector. The Switchyard RSIS prevents personnel access to Tevatron Transfer Hall, Enclosure B, and Enclosure C, D, & E with beam enabled. Access is not allowed to these areas unless the critical devices are disabled.

The Main Injector P150 Extraction RSIS inhibits beam transport by controlling two sets of redundant critical devices, I:LAM52 & I:V701 and R:LAM52 & R:V703. I:LAM52 & I:V701 are the Main Injector Extraction Lambertsons and C-Magnets that direct 120 GeV beam to the P1 Beamline. R:LAM52 & R:V703 are the Recycler Extraction Lambertson and dipole magnet that direct 8 GeV beam to the P1 Beamline. Whereas Switchyard operation uses 120 GeV beam, the following discussion focuses on I:LAM52 and I:V701. The Lambertsons and C-magnets deflect the 120 GeV beam 24 milliradians upwards. Beam cannot be transported into the P1 Beamlines without both magnet strings being powered. In the event of a critical device failure, the system has a failure mode function that reaches back and disables the Main Injector RSIS, preventing beam from entering the Main Injector and Recycler.

The spill rate to the Switchyard beamlines is controlled by a Repetition Rate Monitor (RRM) interlocked to the Switchyard RSIS. This device inhibits beam extraction to the Switchyard enclosures if the monitored power supply is energized for more than four seconds in any forty-five second period. Beam cannot be



transported to any of the experimental areas at a frequency rate greater than once every forty-five second period.

Radiation detectors are placed around the Switchyard Fixed Target Beamlines. They are configured so that a beam loss producing a radiation flux that exceeds the allowable limit will inhibit the Main Injector P150 Extraction RSIS critical devices to provide radiation protection for those in the area. The alarm levels of radiation detectors are interlocked to the Main Injector P150 Extraction RSIS. Such detectors can disable beam within one second of exceeding a predetermined level. The radiation detectors limit the radiation flux from one-pulse accidents to less than the limit appropriate to each Switchyard area. The justification for this implementation is documented in Change Request 272.

Trained and qualified personnel from the Accelerator Directorate, Beams Division, 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 maintenance of interlock systems are maintained in conformance with the requirements stated in the FRCM.

#### III-12.4.2.2 [ODH Safety System](#)

Historically, the Tevatron F-Sector, Tevatron Transfer Hall, Enclosure B, and Enclosure C, D, & E were classified as Oxygen Deficient Hazard (ODH) Areas. Following the decommissioning of the Tevatron and the Switchyard Cryogenic dipole magnets, known as the Left and Right Bends, the areas have been evaluated as ODH 0 areas on 3/6/2012 as per ADDP-CR-2314, *Tevatron Configuration for ODH-0 Classification*. By reclassifying the area to ODH-0, the in place ODH monitoring system was decommissioned as per the Division Head note dated 3/6/2012. Documentation is on file with the AD DSS.

There is no requirement for an ODH system in the Switchyard Fixed Target Beamlines.

#### III-12.4.3 [Administrative Credited Controls](#)

All Switchyard 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.

##### III-12.4.3.1 [Operation Authorization Document](#)

In accordance with AD Administrative Procedure on *Beam Permits, Run Conditions, and Startup* (ADAP-11-0001), beam will not be transported to the Switchyard Fixed Target Beamlines without an approved Beam Permit and Run Condition. The Beam Permit specifies beam power limits as determined and approved by the Head of the Accelerator Directorate, in consultation with the Head of ES&H, assigned area RSO, Accelerator Directorate, Beams Division, Operations Department Head, and Beams Division External Beam Delivery Department Head. The Run Conditions list the operating modes and safety envelope for the Switchyard Fixed Target Beamlines. Run Conditions are issued by ES&H, and are signed

by the Accelerator Directorate, Beams Division, Operations Department Head, assigned area RSO, and the Head of Accelerator Directorate. To run beam in the Switchyard Fixed Target Beamlines, the following enclosures must be secured:

- MI/TeV Crossover
- Tevatron F-Sector
- Tevatron Transfer Hall
- Muon Pre-Target Enclosure
- Switchyard Enclosure B
- Switchyard Enclosures C, D, & E

In addition, the Switchyard Repetition Rate Monitor (RRM) must be active.

#### III-12.4.3.2 Staffing

The following staffing shall be in place during applicable beam operation:

- At least one member of the AD Operations Department who has achieved the rank of Operator II or higher shall be on shift.
- At least one member of the AD Operations Department shall be present in the Main Control Room (MCR).

#### III-12.4.3.3 Accelerator Operating Parameters

The Switchyard Fixed Target Beamlines have been assessed from the standpoint of beam operating and safety envelope parameters. The beam lines were assessed with an Accelerator Safety Envelope limit of  $1.03 \times 10^{16}$  120 GeV protons per hour delivered from the Main Injector. [2][3][4] In practice, the Operational Beam Intensity limit is set lower than the ASE limit and defined in the Run Conditions.

#### III-12.5. Defense-in-Depth Controls

There are no defense-in-depth controls.

#### III-12.6. 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 beam lines and the Switchyard Beam Absorber on an hourly basis.

#### III-12.7. Decommissioning

DOE Field Element Manager approval shall be obtained prior to the start of any decommissioning activities for the Switchyard Fixed Target Beamlines.

### III-12.8. Summary and Conclusion

Specific hazards associated with the operation of the Switchyard area enclosures are identified and assessed in this chapter of the Fermilab SAD. The designs, controls, and procedures to mitigate Switchyard specific hazards are identified and described. The Switchyard 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 Switchyard 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-12.9. References

- [1] Fermilab Radiological Control Manual
- [2] P1 and P2 Beamline Incremental Shielding Assessment
- [3] P3 to SY Absorber Incremental Shielding Assessment 09-20-17
- [4] 2003 Shielding Assessment for the Switchyard 120 Project
- [5] Review of Environmental Vulnerabilities Associated with the Switchyard (March 17, 1999, updated June 9, 1999)
- [6] Change Request 272

### III-12.10. 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*.