ACCELERATOR DIVISION ADMINISTRATIVE PROCEDURE

ADAP-11-0003

APPROVED ACCELERATOR BEAM INTENSITY OPERATING LIMITS

RESPONSIBLE DEPARTMENT: ESH&Q RPS

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1.0 PURPOSE AND SCOPE

In accordance with the DOE Accelerator Safety Order, DOE O 420.2C, and as flowed down through the Fermilab Director's Policies, the Fermilab Environment Safety and Health Manual (FESHM) including the Fermilab Radiological Control Manual (FRCM), this document defines the approved accelerator beam intensity operating limits derived from the various radiological shielding assessments or other safety documents such as the Fermilab Safety Assessment Document (SAD).

The table in Section 2.0 specifies the beam intensity limitations for each section of the Fermilab accelerator complex. The shielding assessments conducted for each beamline or experimental area with respect to the FRCM limits found that continuous operation at an intensity defined in the Operating Intensity Limits along with the stated beam energy is safe and defines the normal Beam Permit operating limits.

The Basis listed in the table identifies what limits the beam intensity for each area. The term "Overburden" is used in the table when the Operating Intensity is limited by the shielding surrounding the beamline enclosure. The term "Absorber" is used when the intensity is limited by the thermal and/or mechanical properties of a specified beam absorber. These intensity limits are specified in particles per hour since the concern here is prompt radiation exposures from beam operations. The terms "Groundwater", "Surface Water", and "Air Activation" are used when the intensity is limited by the number of particles that, due to activation of air or unprotected soil surrounding the enclosures, result in radioactivity in the air, groundwater, or surface water. Air, groundwater, and surface water limits are cumulative effects and are expressed in particles per year.

2.0 BEAM INTENSITY OPERATING LIMITS

Area	Operating Intensity Limit	Beam Energy	Basis
Linac	3.54E17 protons/hour	400 MeV	Overburden [1]
Linac to NIF	6.70E17 protons/hour	66 MeV	Overburden [2]
Linac Absorber #1	6.40E20 protons/year	400 MeV	Groundwater [3]
Linac Absorber #2	6.40E20 protons/year	400 MeV	Groundwater [3]
MuCool Test Area to Emittance Absorber (Emittance Mode)	9.60E15 protons/hour	400 MeV	Overburden [4]
MuCool Test Area to Final Beam Absorber (Experiment Mode)	9.60E14 protons/hour	400 MeV	Overburden [4]
MuCool Test Area Final Beam Absorber	2.35E18 protons/year	400 MeV	Air Activation [5]
Booster to MI-8 Line Cell 803	2.70E17 protons/hour	8 GeV	Overburden [6]
Booster 8 GeV Absorber	6.80E18 protons/year	8 GeV	Surface Water [7]
MI-8 Line from Cell 803 to Cell 850	2.84E17 protons/hour	8 GeV	Overburden [8]
Booster Neutrino Beamline from MI-8 Line Cell 850	1.62E17 protons/hour	8 GeV	Overburden [8]
Booster Neutrino Beam Target Station	7.50E20 protons/year	8 GeV	Air Activation [9]
Main Injector	2.93E17 protons/hour	8 GeV	Overburden [10]
Main Injector	2.93E17 protons/hour	120 GeV	Overburden [10]
Main Injector	2.34E17 protons/hour	150 GeV	Overburden [10]
MI-40 Abort	1.56E19 protons/year	8, 120 & 150 GeV	Surface Water [11]

Area	Operating Intensity Limit	Beam Energy	Basis
Recycler	2.25E17 protons/hour	8 GeV	Overburden [12]
NuMI	2.25E17 protons/hour	120 GeV	Overburden [13]
NuMI Target Station	1.24E21 protons/year	120 GeV	Surface Water [14]
P1-P2 Lines Muon Campus Operations Only	6.50E16 protons/hour	8 GeV	Overburden [15]
P1-P2 Lines Muon Campus and Switchyard Operations	5.41E16 protons/hour	8 GeV	Overburden [16]
P1-P2 Lines Switchyard Operations	1.25E15 protons/hour	120 GeV	Overburden [16]
Muon Campus M1-M3 Lines to Delivery Ring	3.60E13 protons/hour	8 GeV	Overburden [17]
Muon Campus M1 Line to AP0 Target	4.32E16 protons/hour	8 GeV	Overburden [17]
AP0 Target Station	3.20E20 protons/year	120 GeV	Surface Water [18]
Delivery Ring Cleanup Absorber	9.49E18 protons/year	8 GeV	Surface Water [19]
P3 Line to Switchyard Absorber	6.00E14 protons/hour	120 GeV	Overburden [20]
P3 Line to M01 Target Train (Meson Primary)	1.68E14 protons/hour	120 GeV	Overburden [20]
P3 Line to Meson Test	1.20E13 protons/hour	120 GeV	Overburden [20, 21]
Switchyard Absorber	2.98E17 protons/year	120 GeV	Groundwater [22]
M01 Target Train Absorber	7.94E17 protons/year	120 GeV	Groundwater [22]
M02 Absorber	1.74E17 protons/year	120 GeV	Surface Water [22]
M03 Pinhole Collimator	1.74E17 protons/year	120 GeV	Surface Water [22]
P3 Line to Meson Center	6.00E12 protons/hour	120 GeV	Overburden [23]

Area	Operating Intensity Limit	Beam Energy	Basis
MC6 Target Pile	5.26E16 protons/year	120 GeV	Surface Water [24]
P3 Line to Neutrino Muon	6.00E14 protons/hour	120 GeV	Overburden [25]
NM3 Target Station	5.26E18 protons/year	120 GeV	Surface Water [26]
FAST Beam to Low Energy Absorber	1.96E17 electrons/hour	55 MeV	Absorber [27]
FAST Low Energy Absorber	1.16E21 electrons/year	55 MeV	Surface Water [28]
FAST Beam to High Energy Absorber	3.37E18 electrons/hour	300 MeV	Overburden [29]
FAST High Energy Absorber	3.40E21 electrons/year	300 MeV	Surface Water [30]
FAST Injection into IOTA Ring	3.60E13 electrons/hour	150 MeV	Overburden [31]
IOTA Ring Circulating Beam	2.00E10 electrons	150 MeV	Overburden [32]

3.0 DISTRIBUTION

An electronic controlled copy of this procedure is maintained on the AD ESH website at: https://ad-esh.fnal.gov/ad_adap.html.

An uncontrolled copy is provided to the Fermi Site Office.

4.0 REFERENCES

1. ***Completion of the Linac Shielding Assessment and Verification of Operation at Full Intensity***, memo from G. Dugan to D. Cossairt, June 28, 1991, on pages 5-6 of the ***Linac Shielding Assessment***, October 18, 1991. Operation at 400 MeV is documented in ***Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning***, C. Schmidt and T. Kroc, September 21, 1993.

2. ***Completion of the Linac Shielding Assessment and Verification of Operation at Full Intensity***, memo from G. Dugan to D. Cossairt, June 28, 1991, on pages 5-6 of the ***Linac Shielding Assessment***, October 18, 1991. Overall operation of NIF is documented in ***Neutron Therapy Facility 1992 Shielding Assessment***, A. J. Lennox, April 10, 1992. Note that the NIF operating limit has historically been set at about 10% of what is approved in the preceding documents.

3. ***Linac Momentum Beam Dump Vacuum***, L. Allen *et al.*, November 2011, Beams-doc-4095, page 27. The straight-ahead dump is structurally similar to the momentum dump, so the same intensity limit is used for both.

4. ***MuCOOL Facility Shielding Assessment***, C. Johnstone *et al.*, November 1, 2010, page 4.

5. ***MuCOOL Facility Shielding Assessment***, C. Johnstone *et al.*, November 1, 2010, page 23.

6. ***Booster Shielding Assessment***, January 17, 2017, page 5.

7. ***Booster Shielding Assessment***, January 17, 2017, page 9.

8. ***8 GeV Beam Line and MiniBooNE Beam Line Nova-Era Operational Limits***, M. Gerardi, March 10, 2010, post-assessment memo in ***Shielding Assessment Document for the 8 GeV Fixed Target Facility***, C. Moore, June 20, 2002.

9. ***Addendum to the MiniBooNE Target Station Shielding Assessment***, M. Gerardi *et al.*, June 18, 2004, page 3.

10. ***Main Injector 1500 kW Incremental Shielding Assessment***, W. S. Higgins *et al.*, May 23, 2018, page 3. Note that although the 8 GeV intensity limit could be substantially higher if it were scaled with beam energy, there is no operational need for a higher 8 GeV intensity; therefore, the 8 GeV intensity limit has been set equal to the 120 GeV intensity limit.

11. ***Main Injector 1500 kW Incremental Shielding Assessment***, W. S. Higgins *et al.*, May 23, 2018, page 6.

12. ***Recycler Ring Incremental Shielding Assessment 2.25x10^{17} Protons/Hour***, W. Schmitt *et al.*, October 3, 2012, page 2.

13. ***Addendum to the NuMI Beam Line Shielding Assessment for 1 MW Operation of NOvA Experiment***, K. Vaziri *et al.*, July 17, 2018, page 1.

14. ***Addendum to the NuMI Beam Line Shielding Assessment for 1 MW Operation of NOvA Experiment***, K. Vaziri *et al.*, July 17, 2018, Table 2, page 7.

15. ***P1 and P2 Beamline Incremental Shielding Assessment***, M. Geelhoed, February 9, 2016, page 4.

16. ***P1-P2 Beamline Operating Limits***, W. Schmitt, October 20, 2016, post-assessment memo in ***P1 and P2 Beamline Incremental Shielding Assessment***, M. Geelhoed, February 9, 2016.

17. ***Muon g-2 Shielding Assessment***, A. Leveling, February 7, 2017, page 5.

18. ***AP0 Target Station Review Committee Report***, C. Hojvat *et al.*, June 9, 1997, Section F, page 10.

19. ***Delivery Ring Cleanup Abort Design***, A. Leveling, November 3, 2015, Beams-doc-5178, Table 2, page 22.

20. ***Further Explanation of Assessed Beam Intensity for P3 to SY Absorber***, M. Vincent, November 14, 2017, post-assessment memo in ***P3 to Switchyard Absorber Incremental Shielding Assessment***, M. Geelhoed *et al.*, September 20, 2017.

21. ***Meson Test Operating Limits Based on Operational Experience***, G. Lauten, October 22, 2015, post-assessment memo in ***2003 Shielding Assessment for the Switchyard 120 Project***, C. Brown *et al.*, April 8, 2003.

22. ***2003 Shielding Assessment for the Switchyard 120 Project***, C. Brown *et al.*, April 8, 2003, pages 9-10.

23. ***Addendum to the SY 120 Shielding Assessment for the Continued Operation of the Meson Center Beam Line***, T. Kobilarcik and W. Schmitt, November 25, 2013, page 4.

24. ***Addendum to the SY 120 Shielding Assessment for the Continued Operation of the Meson Center Beam Line***, T. Kobilarcik and W. Schmitt, November 25, 2013, pages 8-9.

25. ***Neutrino Muon Beamline Shielding Assessment***, T. Kobilarcik and M. Geelhoed, February 24, 2012, page 4.

26. ***Neutrino Muon Beamline Shielding Assessment***, T. Kobilarcik and M. Geelhoed, February 24, 2012, page 9.

27. ***Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector***, M. Church *et al.*, December 12, 2014, page 5.

28. ***Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector***, M. Church *et al.*, December 12, 2014, pages 12-13.

29. ***Shielding Assessment for IOTA/FAST Electron Injector at 300 MeV***, D. Broemmelsiek and I. Rakhno, August 23, 2017, page 14.

30. ***Shielding Assessment for IOTA/FAST Electron Injector at 300 MeV***, D. Broemmelsiek and I. Rakhno, August 23, 2017, page 22.

31. ***Fermi National Accelerator Laboratory Safety Assessment Document, Revision 16, Section IV, Chapter IV-3: Fermilab Accelerator Science & Technology (IOTA/FAST) Electron Injector***, E. Harms *et al.*, April 23, 2018, ESHQ-doc-1066, page 7.

32. ***Addendum to Shielding Assessment for IOTA/FAST Electron Injector at 300 MeV to add the IOTA Ring with Electrons***, D. Broemmelsiek and I. Rakhno, March 27, 2018, page 6.