PIP-II BTL Specialty Magnet

Functional Requirements Specification

Document number: ED000XXXX, Rev. -

**Document Approval**

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Revision History

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# Purpose

An FRS describes the programmatic or project needs and/or requested behavior of a system or component. The document typically outlines what is needed by the end user as well as the requirements and requested properties of inputs and outputs. The FRS specifies the functions that a system or component must perform and establishes consensus among stakeholders on what the system is expected to provide.

# Scope

This FRS addresses the functional requirements of the BTL specialty magnets for the 800 MeV Linac to Booster transfer line. Specifically there will be a Septum magnet which will allow for beam to be transported to either the Booster or to a beam absorber, a fast switch magnet which will deflect beam to the field region of the Septum magnet, a C magnet for Booster injection and a sweep magnet that will move the beam in a circular pattern on the face of the beam absorber.

# Acronyms

|  |  |
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| FESHM | Fermilab ES&H Manual |
| FRCM | Fermilab Radiological Control Manual |
| FRS | Functional Requirements Specification |
| L2 | WBS Level 2 |
| L3 | WBS Level 3 |
| PIP-II | Proton Improvement Plan II Project |
| SCD | System Configuration Document |
| TC | Teamcenter |
| WBS | Work Breakdown Structure |
| BTL | Beam Transfer Line |

# Reference

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| **#** | **Reference** | **Document #** |
| 1 | *EPDM for given system shall be included here* | ED000xxxx |
| 2 | *L2 System Configuration Document (SCD) shall be included here* | ED000xxxx |
| 3 | [Fermilab Engineering Manual](http://directorate-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=34) | NA |
| 4 | [Fermilab Environmental Safety and Health Manual](http://eshq.fnal.gov/manuals/feshm/) | NA |
| 5 | Fermilab Radiological Control Manual | NA |

# Key Assumptions

This FRS will describe the specifications for 1) a fast switch magnet, 2) a septum magnet, 3) a Booster Injection C magnet and 4) A beam absorber sweep magnet. The septum magnet does not need to be one single magnet but can be several magnets. Other magnetic elements as well as power supplies, and interlocks are not included in this FRS.

# Functional Requirements

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| **Requirement #** | **Beam Abort Line Septum Magnet** |
| F-121.3.05-001 | The septum magnet will provide the necessary field to bend the 800 MeV particles with a current of less than 2000 amps (a total of 133 mm displacement) |
| F-121.3.05-002 | The septum magnet shall have a total magnetic length of 2.6 m and a flange to flange length not to exceed 3.1 m |
| F-121.3.05-003 | The field free region of the septum magnet will have a aperture of 52 mm |
| F-121.3.05-004 | The field region of the septum magnet will have a minimum aperture of 34 mm x 34 mm |
| F-121.3.05-005 | The septum thickness between the field and no field region shall be < 17 mm |
| F-121.3.05-006 | The field region of the septum magnet will have a good field region of 30 mm where dB/B<.2% |
| F-121.3.05-007 | The septum magnet shall be directly water cooled with a minimum cooling path diameter of .229 inches |
| F-121.3.05-008 | Coils with water flow shall be continuous, that is no splices |
| F-121.3.05-009 | All external water connections shall be appropriately sized female NPT fittings |
| F-121.3.05-010 | The maximum water pressure drop is 80 psid at the operating flow |
| F-121.3.05-011 | Water flow velocity in the magnet coils shall be between 5 and 8 feet per second |
| F-121.3.05-012 | Water temperature rise shall not exceed 10 degrees C |
| F-121.3.05-013 | Provisions shall be made to allow for rigging the magnet |
| F-121.3.05-014 | Feet for mounting the magnet on a stand shall be welded to the body of the magnet |
| F-121.3.05-015 | Provisions shall be made to allow for the installation of alignment fiducials. Fiducials shall accept standard 1.5”dia. SMR balls or SMR nests and shall be visible from the beam right side. |
| **Requirement** | **Booster Injection C- Magnet** |
| F-121.3.05-016 | The C- magnet will provide the necessary field to bend the 800 MeV particles with a current of less than 2000 amps |
| F-121.3.05-017 | The C- magnet shall have a total magnetic length of 1.8 m and a flange to flange length not to exceed 2.2 m |
| F-121.3.05-018 | The C-magnet shall have a vertical half size of less than 160 mm |
| F-121.3.05-019 | The C-magnet shall have a aperture of 52 mm |
| F-121.3.05-020 | The C-magnet shall have a good field region of 24 mm where dB/B<.05% |
| F-121.3.05-021 | The C- magnet shall be directly water cooled with a minimum cooling path diameter of .229 inches |
| F-121.3.05-022 | Coils with water flow shall be continuous, that is no splices |
| F-121.3.05-023 | All external water connections shall be appropriately sized female NPT fittings |
| F-121.3.05-024 | The maximum water pressure drop is 80 psid at the operating flow |
| F-121.3.05-025 | Water flow velocity in the magnet coils shall be between 5 and 8 feet per second |
| F-121.3.05-026 | Water temperature rise shall not exceed 10 degrees C |
| F-121.3.05-027 | Provisions shall be made to allow for rigging the magnet |
| F-121.3.05-028 | Feet for mounting the magnet on a stand shall be welded to the body of the magnet |
| F-121.3.05-029 | Provisions shall be made to allow for the installation of alignment fiducials. Fiducials shall accept standard 1.5”dia. SMR balls or SMR nests and shall be visible from the beam right side. |
| **Requirement #** | **Fast Switch Magnet** |
| F-121.3.05-030 | The fast switch magnet shall provide the proper deflection of 800 MeV beam within 20 usec |
| F-121.3.05-031 | The fast switch magnet will provide the necessary field to bend the 800 MeV particles with a current of less than 1000 amps |
| F-121.3.05-032 | The fast switch magnet shall have a total magnetic length of 2 m and a flange to flange length not to exceed 2.3 m |
| F-121.3.05-033 | The fast switch shall have a aperture of 45 mm |
| F-121.3.05-034 | The fast switch magnet shall have a good field region of 24 mm where dB/B<1% |
| F-121.3.05-035 | Provisions shall be made to allow for rigging the magnet |
| F-121.3.05-036 | Feet for mounting the magnet on a stand shall be welded to the body of the magnet |
| F-121.3.05-037 | Provisions shall be made to allow for the installation of alignment fiducials. Fiducials shall accept standard 1.5”dia. SMR balls or SMR nests and shall be visible from the beam right side. |
| **Requirement #** | **Beam Sweep Magnet** |
| F-121.3.05-038 | The beam sweep magnet shall deflect 800 MeV beam at a frequency of 11 Hz |
| F-121.3.05-039 | The beam sweep magnet will provide the necessary field to bend the 800 MeV particles with a current of less than 40 amps and a voltage of less than 100 volts |
| F-121.3.05-040 | The beam sweep magnet shall have a total magnetic length of 0.5 m and a flange to flange length not to exceed 1.2 m |
| F-121.3.05-041 | The sweep magnet shall have a aperture of 52 mm |
| F-121.3.05-042 | The sweep magnet shall have a good field region of 24 mm where dB/B<1% |
| F-121.3.05-043 | Provisions shall be made to allow for rigging the magnet |
| F-121.3.05-044 | Feet for mounting the magnet on a stand shall be welded to the body of the magnet |
| F-121.3.05-045 | Provisions shall be made to allow for the installation of alignment fiducials. Fiducials shall accept standard 1.5”dia. SMR balls or SMR nests and shall be visible from the beam right side. |

# Safety Requirements

The system shall abide by all Fermilab ES&H (FESHM) and all Fermilab Radiological Control Manual (FRCM) requirements including but not limited to:

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| Pressure and Cryogenic Safety |
| * FESHM Chapter 5031 Pressure Vessels |
| * FESHM Chapter 5031.1 Piping Systems |
| * FESHM Chapter 5031.5 Low Pressure Vessels and Fluid Containment |
| * FESHM Chapter 5031.6 Dressed Niobium SRF Cavity Pressure Safety |
| * FESHM Chapter 5032 Cryogenic System Review |
| * FESHM Chapter 5033 Vacuum Vessel Safety |
| Electrical Safety |
| * FESHM Chapter 9110 Electrical Utilization Equipment Safety |
| * FESHM Chapter 9160 Low Voltage, High Current Power Distribution Systems |
| * FESHM Chapter 9190 Grounding Requirements for Electrical Distribution and Utilization Equipment |
| Radiation Safety ANSI ASC A14.3  -2000  Safety Requirements for Fixed Ladders |
| * FRCM Chapter 8 ALARA Management of Accelerator Radiation Shielding |
| * FRCM Chapter 10 Radiation Safety Interlock Systems |
| * FRCM Chapter 11 Environmental Radiation Monitoring and Control |
| General Safety |
| * FESHM Chapter 2000 Planning for Safe Operations |

Any changes in the applicability or adherence to these standards and requirements require the approval and authorization of the PIP-II Technical Director or designee.

In addition, the following codes and standards in their latest edition shall be applied to the engineering, design, fabrication, assembly and tests of the given system:

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| ASME B31.3 Process Piping ANSI ASC A14.3  -2000  Safety Requirements for Fixed Ladders |
| ASME Boiler and Pressure Vessel Code (BPVC) |
| CGA S-1.3 Pressure Relief Standards |
| NFPA 70 – National Electrical Code |
| IEC Standards for Electrical Components |

In cases where International Codes and Standards are used the system shall follow FESHM Chapter 2110 Ensuring Equivalent Safety Performance when Using International Codes and Standards and requires the approval and authorization of the PIP-II Technical Director or designee.

Additional Safety Requirements that are not listed in the general list above shall be included in the Requirements table in the Functional Requirements section.