PIP-II Quadrupole Magnet

Technical Requirements Specification

Document number: ED0011xxxx, Rev. -

**Document Approval**

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Revision History

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| Revision | Date of Release | Description of Change |
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# Purpose

There will be a total of 57 quadrupole magnets in the Linac to Booster transfer line for PIP-II. These quadrupole magnets will be divided up into three categories; 49 regular quads, 2 large aperture quads and 6 End of Line quads, This TRS will specify the magnet requirements.

# Scope

WBS Dictionary Definition for the BTL MagPS: Design, procurement, fabrication, and testing of all types (dipoles, quads, correctors, special) of magnets and power supplies in the beam transfer line. This specific TRS addresses the technical requirements of the quadrupole magnets

# Acronyms

|  |  |
| --- | --- |
| FESHM | Fermilab ES&H Manual |
| FRCM | Fermilab Radiological Control Manual |
| FRS | Functional Requirements Specification |
| TRS | Technical 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 |
| EPDM | Engineering Process Document Management |
| NPT | National Pipe Thread |

# Reference

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| **#** | **Reference** | **Document #** |
| 1 | EPDM | ED0005433 |
| 2 | [Fermilab Engineering Manual](http://directorate-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=34) | NA |
| 3 | BTL Dipole FRS | NA |
| 4 | BTL Dipole Magnet Preliminary Design | NA |
| 7 | Physics Driven Requirement | ED001026 |

# Key Assumptions

It is assumed that the quadrupole magnets will be delivered complete with water manifolds and will be capable of being split into two halves. It is also assumed that these magnets will be capable of DC operation at 1000 MeV .

# Technical Requirements

The requirements for the 49 regular quadrupole magnets are shown below in table 5-1. The design of the magnets must allow for the magnet to be split in two in order to facilitate the installation of a beam tube

Table ‑. Regular Magnet Requirements

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| **Requirement #** | **Requirement Statement** |
| T-Q-121.03.05-A001 | Effective length of the regular quads is 0.23 m with a yoke length of 0.2 m |
| T-Q-121.03.05-A002 | Physical length of the regular magnets (length including coils) shall not exceed 0.35 m |
| T-Q-121.03.05-A003 | The pole tip radius shall be 26 mm |
| T-Q-121.03.05-A004 | The regular quad gap shall be 52 mm |
| T-Q-121.03.05-A005 | The good field region shall not be less than 24 mm in diameter about the center |
| T-Q-121.03.05-A006 | The regular quad field uniformity shall be better than dB/B=.1% |
| T-Q-121.03.05-A007 | The regular quad integrated field shall be 2T at 100 amps |
| T-Q-121.03.05-A008 | The regular quads shall be capable of DC operation at 125 amps |
| T-Q-121.03.05-A009 | The regular quads shall be capable of ramping at a maximum rate of .02 T/sec Integrated field (10 Amps/sec) |
| T-Q-121.03.05-A010 | The regular quads shall not exceed transverse dimensions of 600 mm width and 600 mm height |
| T-Q-121.03.05-A011 | The regular quad coils shall be continuous (no splices) |
| T-Q-121.03.05-A012 | The regular quad coils shall provide for water cooling; the bus used shall have a hole for water of at least 5 mm diameter |
| T-Q-121.03.05-A013 | The regular quads shall have eight alignment fiducials welded to the steel; 2 on top of each end and 1 at each end on the sides of the magnet on the midline of the magnet |
| T-Q-121.03.05-A014 | The regular quads shall be able to be hipotted up to 1000 volts DC with less than 1 microamp of current |

Table ‑. Large Aperture Quad Magnet Requirements

The beam abort line will require two special quadrupole magnets with a large aperture to all for passage of both the beam going to the Booster as well as beam going to the abort. The nominal 800 MeV separation between these beams is 56.8 mm in the focusing quad ( where the 1 sigma beam size is 1.75 mm H and .76 mm V) and 14.6 mm in the defocusing quad (where the one sigma beam size is .75 mm H and 1.8 mmV). The requirements are shown below

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| **Requirement #** | **Requirement Statement** |
| T-Q-121.03.05-B001 | The large aperture quads shall have a minimum aperture of (y/x) 80x200 mm |
| T-Q-121.03.05-B002 | The large aperture quads shall have an effective length of .4 m |
| T-Q-121.03.05-B003 | The large aperture quads shall have a good field region of 10 x 150 mm |
| T-Q-121.03.05-B004 | The large aperture quads integrated field shall be 2T at 100 amps |
| T-Q-121.03.05-B005 | Physical length of the large aperture quads (length including coils) shall not exceed 0.55 m |
| T-Q-121.03.05-B006 | The large aperture quads field uniformity shall be better than dB/B=.1% |
| T-Q-121.03.05-B007 | The large aperture quads shall be capable of DC operation at 165 amps |
| T-Q-121.03.05-B008 | The large aperture quads shall be capable of ramping at a maximum rate of .02 T/sec Integrated field (10 Amps/sec) |
| T-Q-121.03.05-B009 | The large aperture quads shall not exceed transverse dimensions of 600 mm width and 600 mm height |
| T-Q-121.03.05-B010 | The large aperture quads coils shall be continuous (no splices) |
| T-Q-121.03.05-B011 | The large aperture quads coils shall provide for water cooling; the bus used shall have a hole for water of at least 5 mm diameter |
| T-Q-121.03.05-B012 | The large aperture quads shall have eight alignment fiducials welded to the steel; 2 on top of each end and 1 at each end on the sides of the magnet on the midline of the magnet |
| T-Q-121.03.05-B013 | The large aperture quads shall be able to be hipotted up to 1000 volts DC with less than 1 microamp of current |

Table ‑3. EOL Quadrupole Magnet Requirements

The End Of Line Quads will be used to focus the beam for injection into the Booster Accelerator. There are six such magnets required.)

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| **Requirement #** | **Requirement Statement** |
| T-Q-121.03.05-C001 | Effective length of the EOL quads is 0.23 m with a yoke length of 0.2 m |
| T-Q-121.03.05-C002 | Physical length of the EOL magnets (length including coils) shall not exceed 0.35 m |
| T-Q-121.03.05-C003 | The pole tip radius shall be 26 mm |
| T-Q-121.03.05-C004 | The EOL quad gap shall be 52 mm |
| T-Q-121.03.05-C005 | The good field region shall not be less than 24 mm in diameter about the center |
| T-Q-121.03.05-C006 | The EOL quad field uniformity shall be better than dB/B=.1% |
| T-Q-121.03.05-C007 | The EOL quad integrated field shall be 3T at less than 150 amps |
| T-Q-121.03.05-C008 | The EOL quads shall be capable of DC operation at 220 amps |
| T-Q-121.03.05-C009 | The EOL quads shall be capable of ramping at a maximum rate of .02 T/sec Integrated field (10 Amps/sec) |
| T-Q-121.03.05-C010 | The EOL quads shall not exceed transverse dimensions of 600 mm width and 600 mm height |
| T-Q-121.03.05-C011 | The EOL quad coils shall be continuous (no splices) |
| T-Q-121.03.05-C012 | The EOL quad coils shall provide for water cooling; the bus used shall have a hole for water of at least 5 mm diameter |
| T-Q-121.03.05-C013 | The EOL quads shall have eight alignment fiducials welded to the steel; 2 on top of each end and 1 at each end on the sides of the magnet on the midline of the magnet |
| T-Q-121.03.05-C014 | The EOL quads shall be able to be hipotted up to 1000 volts DC with less than 1 microamp of current |

Table ‑3. Magnet Water Requirements

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| **Requirement #** | **Requirement Statement** |
| T-Q-121.03.05-D001 | All external water connections shall be appropriately sized female NPT fittings |
| T-Q-121.03.05-D002 | The maximum water pressure drop is 80 psid at the operating flow |
| T-Q-121.03.05-D003 | Water flow velocity in the magnet coils shall be between 5 and 8 feet per second |
| T-Q-121.03.05-D004 | Water temperature rise shall not exceed 10 degrees C above the nominal 35 degrees C water temperature ( 5.5 degrees F) |
| T-Q-121.03.05-D005 | Nominal inlet water temperature is 95 degrees F (35 degrees C) |

Table ‑4. Magnet Support Structure Requirements

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| **Requirement #** | **Requirement Statement** |
| T-Q-121.03.05-F001 | All quads shall have three feet for mounting that are welded to the body of the magnet; these feet will be located 22% of the length from each end |
| T-Q-121.03.05-F002 | All magnets shall have provisions to allow for rigging the magnet; this could be tapped holes of an appropriate size to allow for swivel hoist rings that are appropriate for the magnet load with a safety margin |

# 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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| 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 |
| Pressure Piping safety |
| * FESHM Chapter 5031.1 Piping Systems |
| 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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| NFPA 70 – National Electrical Code |
| IEC Standards for Electrical Components |
| ASME BPVC Section IX Qualification Standard for Welding, Brazing and Fusing Procedures |

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.