PIP-II Booster

Functional Requirements Specification

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**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 scope covers design, fabrication, installation, and testing of the new 800 MeV injection area in the Booster and the modifications required to run the Booster at 20 Hz. It also covers the design, installation and testing of 2 new Booster gradient magnets with wider aperture, new Booster longitudinal and transverse dampers and a new 2-stage collimation system. The PIP II Booster injection area includes a new injection girder with ORBUMP magnets, a stripping system with an injection absorber, two shorter Booster gradient magnets and painting magnets will accomplish multi-turn 800 MeV injection into the Booster from the SRF PIP II Linac at a 20 Hz cycle rate. The injection girder includes utilities, mechanical support hardware, beam line elements, diagnostics and all associated power supplies and controls.

This FRS addresses the functional requirements of WBS 121.05.04.

# Acronyms

|  |  |
| --- | --- |
| 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 |

# Reference

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| **#** | **Reference** | **Document #** |
| 1 | PIP-II Booster Engineering Process Document Management (EPDM) | ED0007865 |
| 2 | Accelerator Complex Upgrades L2 System Configuration Document (SCD) | TBD |
| 3 | [Fermilab Engineering Manual](http://directorate-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=34) (FEM) | - |
| 4 | [Fermilab Environmental Safety and Health Manual](http://eshq.fnal.gov/manuals/feshm/) (FESHM) | - |
| 5 | Fermilab Radiological Control Manual (FRCM) | - |

# Key Assumptions

The final installation of the injection girder can be done only during the tie-in construction and when occupancy is approved. Final testing can begin after Linac commissioning up to the girder is completed.

# Functional Requirements

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| **Requirement #** | **Requirement Statement** |
|  F-121.5.04-001 | The Booster injection girder shall accommodate the PIP II multi-turn injection and Booster lattice requirements including associated waste beam absorber and stripping system. |
|  F-121.5.04-002 | The Booster injection girder shall provide orbit and beam diagnostics. |
|  F-121.5.04-003 | The Booster injection girder shall provide all necessary vacuum hardware and associated diagnostics. |
|  F-121.5.04-004 | The Booster injection girder shall provide all necessary cooling hardware and associated diagnostics. |
|  F-121.5.04-005 | The Booster injection girder shall include a 20 Hz pulsed power system at the required power and regulation. |
|  F-121.5.04-006 | The Booster injection pulsed devices shall be capable of flattop lengths > 550 us. |
|  F-121.5.04-007 | The Booster injection girder shall have the necessary footprint and tunnel access. |
|  F-121.5.04-008 | The Booster injection girder shall be located in the long-11 region of the Booster. |
|  F-121.5.04-009 | The Booster injection girder shall operate within the constraints of the present Booster vacuum system operating parameters. |
|  F-121.5.04-010 | The Booster injection girder shall operate within the constraints of the present Booster low conductivity water system operating parameters. |
|  F-121.5.04-011 | The Booster injection girder shall have fiducials or other alignment features to allow for proper alignment by alignment services. |
|  F-121.5.04-012 |  The Booster Gradient magnets shall resonate at 20 Hz. |
|  F-121.5.04-013 | The Booster pulsed devices along with their Power Supplies shall operate at 20 Hz  |
|  F-121.5.04-014 | The Booster dipole field at injection shall be able to accommodate the 550 us beam injection time and provide for a smooth transition to acceleration.  |
|  F-121.5.04-015 | The new Booster “D” gradient magnets on either side of the injection girder shall match the nominal “D” gradient magnet bend angle and higher harmonics as a function of energy.  |
| F-121.5.04-016 | The new Booster injection system shall include a set of horizontal and vertical phase space painting magnets and supplies capable of the required closed orbit control at the foil during injection at 20 Hz. |
| F-121.5.04-017 | The Booster injection girder shall allow H- injections up to 1 GeV. |
| F-121.5.04-018 | The new Booster wide aperture magnets will reduce extraction losses. |
| F-121.5.04-019 | The new Booster longitudinal dampers shall allow us to damp all Rf cavities high order modes along with the mode 2. |
| F-121.5.04-020 | The new Booster transverse dampers shall provide head-tail damping allowing us to reduce the chromaticity and reduce losses. |
| F-121.5.04-021 | The new Booster 2-stage collimation system shall collimate and remove halo particles from the LINAC reducing injection losses. |
| F-121.5.04-022 | All Booster extraction devices and their associated Power Supplies shall operate at 20 Hz. |
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# 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
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| * 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
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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, if applicable, 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.