Fermi National Accelerator Laboratory

Fermilab

PIP-II Booster
Functional Requirements Specification

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Document Approval

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Revision History

Revision	Date of Release	Description of Change
-	6-12-2019	Initial release
A	1-13-2020	Deleted Requirement F-121.5.05-A017 which states, The Booster injection girder shall allow H- injections up to 1 GeV. All other requirements were moved up numerically.
B	2-2-2021	Added the inclusion of a new current monitor, called CHG0, as A022
C	2-11-2021	Changed word should to shall in requirement A022
D	9-29-2021	Revised order of TRS requirements and concatenate 20 Hz requirements. Revised requirement A001

Table of Contents

1. Purpose

An FRS describes the 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.

2. 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.

3. 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
TC	Teamcenter
WBS	Work Breakdown Structure

4. Reference

#	Reference	Document #
1	PIP-II Booster Engineering Process Document Management (EPDM)	ED0007865
2	Fermilab Engineering Manual (FEM)	-
3	Fermilab Environmental Safety and Health Manual (FESHM)	-
4	Fermilab Radiological Control Manual (FRCM)	-

5. Key Assumptions

5.1. The term “Booster Upgrade” is defined to encompass all the new components, modifications, and upgrades to the Booster proper to allow the Booster to operate at 800 MeV injection energy, increased injection flux, increased rep rate, and hence beam power required for interfacing to the new PIP-II SC Linac and the BTL.

5.2. The term “Booster injection system” will encompass the injection girder, the injection absorber, the new reduced length CFM on either side of the injection girder and phase space painting magnets.

5.3. The term “injection girder” is defined as the structure that will hold a) the injection foil changer system, b) the (four) injection ORBUMP magnets and the interface to their dedicated power supply, Booster ring vacuum system, and cooling water supply, and c) the two vacuum spool pieces.

5.4. The installation for the 20 Hz modifications for components outside the BTL-Booster tie-in construction area and the relocation of components and modifications in the Long 11 straight must wait till the LBNF shutdown starts. These must be complete by the time construction starts for the final tie-in to Booster.

5.5. The installation of the injection girder, the injection absorber, the CFM injection girders either side of the injection straight, and the installation of the painting magnets can be done only when the Booster tie-in construction is complete, and we have beneficial occupancy.

5.6. Final testing can begin after Linac commissioning up to the girder is completed.

6. Functional Requirements

Requirement #	Requirement Statement
Booster Injection System	
F-121.5.04-A001	The Booster injection system shall provide a waste beam injection absorber.
F-121.5.04-A002	The Booster injection system shall provide a set of four horizontal and four vertical phase space painting magnets and supplies capable of the required closed orbit control at the foil during injection.
F-121.5.04-A003	The Booster injection system shall provide two reduced length CFM type D magnets match the nominal “D” CFM bend angle and higher harmonics as a function of energy.
F-121.5.04-A004	The Booster dipole field at injection shall be able to accommodate PIP-II beam injection time and provide for a smooth transition to acceleration.
F-121.5.04-A005	All components that participate in the injection process shall accommodate PIP-II injection time.
F-121.5.04-A006	The Booster injection system shall provide a Booster injection girder.
F-121.5.04-A007	The Booster injection girder shall be located in the long 11- region of the Booster.

F-121.5.04-A008	The Booster injection girder shall contain the following components: four 20 Hz ORBUMP magnets, injection foil system, 2 vacuum spool pieces, and beam diagnostic instrumentation.
F-121.5.04-A009	The Booster injection girder components shall interface to existing Booster tunnel vacuum system.
F-121.5.04-A010	The Booster injection girder components shall interface to existing Booster tunnel LCW system.
20 Hz	
F-121.5.04-A011	The Booster Gradient magnets shall resonate at 20 Hz.
F-121.5.04-A012	All Booster injection devices and their associated Power Supplies shall operate at 20 Hz.
F-121.5.04-A013	All Booster extraction devices and their associated Power Supplies shall operate at 20 Hz.
Other Booster Upgrades	
F-121.5.04-A014	The new Booster wide aperture magnets shall reduce extraction losses.
F-121.5.04-A015	The new Booster longitudinal dampers shall allow damping of all RF cavities high order modes along with the mode 2.
F-121.5.04-A016	The new Booster transverse dampers shall provide head-tail damping allowing a reduction in the chromaticity and losses.
F-121.5.04-A017	The Booster shall have a high-resolution beam current monitor capable of measuring beam current intensities found in PIP and PIP-II.
F-121.5.04-A018	The new Booster 2-stage collimation system shall collimate and remove halo particles into a well shielded absorber. The system should operate at both 400 MeV and 800 MeV.

7. 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:

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 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
• 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
• FESHM Chapter 5001 Structural Safety

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:

ASME B31.3 Process Piping
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.