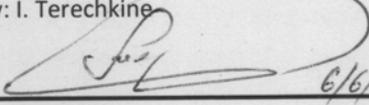
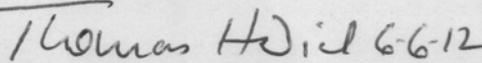
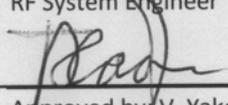
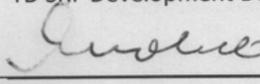
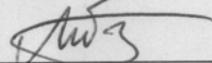


Fermilab

Focusing Lens for SSR1 Cryomodule
Project X Injector Experiment (PXIE)
Functional Requirements Specification

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Revision History

Revision	Date	Section No.	Revision Description
1	06/08/2012	All	First revision



Introduction and Scope

The SSR1 section of the PXIE linac contains eight 325 MHz superconducting single spoke cavities and four solenoid-based focusing lenses operating at 2 K. This specification addresses the features of the focusing lens design that are essential for reliable performance of lenses as part of the cryomodule and of the cryomodule as part of the linac. This specification is based on the FRS for the cryomodule (docdb #931), and for the PXIE test facility (docdb #980).

SSR1 CRYOMODULE LENS FUNCTIONAL REQUIREMENTS

The general design requirements for the lenses in the SSR1 cryomodule are summarized in the list below that consists of three sections:

- Requirements essential for the beam dynamics in the linac:
 - Integrated focusing strength of the lens must be not less than $4 \text{ T}^2\text{m}$;
 - Each lens must contain two dipole correctors; bending strength of each corrector must be not less than $0.0025 \text{ T}\cdot\text{m}$;
 - Clear aperture in the lens must be not less than 30 mm;
 - Uncertainty of the location of the effective magnetic axis in the focusing solenoid of the lens relative to reference points on the outer surface of the device must be better than 0.1 mm RMS.
- Requirements essential for proper functioning of the cryomodule:
 - Maximum current in the solenoid of the lens must be less than 100 A;
 - Maximum current in the dipole correctors must be less than 50 A;
 - LHe vessel must be used for cooling the windings down to 2 K;
 - The lenses must be quench-protected; the energy deposited in the lenses after quenching must be as low as reasonably achievable;
 - The LHe vessel must meet the requirements of the Fermilab's ES&H manual chapters for pressure vessel;
 - The design of the LHe vessel must ensure reliable and reproducible mechanical connection to the alignment fixture of the cryomodule;
 - Maximum magnetic field generated by lenses in the cryomodule in the area near the surface of the SSR1 superconducting cavities must not exceed the level that would result in more than two-fold reduction of the intrinsic quality factor after quench event at any point on the surface of the cavity.
- Requirements introduced to simplify the process of commissioning the PXIE:
 - The LHe vessel must be made with integrated beam pipe;
 - The LHe vessel must be designed to allow reliable and reproducible connection to the beam position monitor;
 - Location of the magnetic axis must be referred to fiducials installed on extension beams that made them visible through windows in the ends of the



cryomodule; the beams must be reliably and reproducibly attached to the LHe vessel of the lens.

INTERFACES

- Each focusing lens is to be installed on an individual alignment fixture and individual thermal insulating post.
- Each focusing lens is mechanically and vacuum-tight connected to the beam pipe and Beam Position Monitor.
- LHe vessel of each lens is connected to the filling LHe line and to the phase separating pipe.
- Current is delivered to the focusing solenoid and the correctors of the lens by three pairs of current leads connected to power supplies located outside the cryomodule.
- Each focusing lens will be equipped with extension beams where optical fiducials used for the lens alignment are fixed.
- Each focusing lens must be equipped with gauges and voltage taps required by a quench-protection system.
- Each Lens is thermally shielded by using an appropriate shielding scheme.

INSTRUMENTATION

Each lens must be equipped with the next set of gauges and voltage taps:

- Voltage taps in all coils of the lens to monitor quench during training.
- Voltage taps in all coils of the lens for the quench protection system.
- Calibrated temperature gauge at the top of each coil in the LHe vessel.
- Alignment fiducials on the LHe vessel or corresponding placeholders.

QUALITY ASSURANCE

All coils of each lens must be trained at 2 K before they are installed in the LHe vessel.

Each lens must be tested in LHe vessel at 2 K before installation in the cryomodule.

The tests will check the following:

- Maximum current in each coil.
- Orientation of the steering dipoles.
- Compliance with the required focusing and bending strength.
- Quench protection system performance.
- Leak tests and pressure tests for quality assurance and FESHM compliance.

Every step of the lens fabrication, including materials inspection, lens component fabrication, LHe vessel assembly, and testing must be documented.



REFERENCES

1. S. Nagatsev, “FRS for PXIE test stand”, docb #980
2. T. Nicol, “325 MHz SSR1 Cryomodule Functional Requirements Specification”, PX doc base, #931.
3. V. Lebedev, “Major requirements to PXIE Optics and Design”, PX docbase #930
4. T. Khabiboulline, et al, “Acceptable Level of Magnetic Field on the Surface of a Superconducting RF Cavity”, FNAL TD note TD-12-008, June 2012.